Hospital characteristics associated with failure to rescue in cardiac surgery

Check for updates

Gabriela O. Escalante, BA,[a] Jocelyn Sun, MPH,[b] Susan Schnell, MSN, ACNP-BC,[c] Emily Guderian, BSN, RN,[c] Charles A. Mack, MD,[d] Michael Argenziano, MD,[b,c] and Paul Kurlansky, MD[b,c]

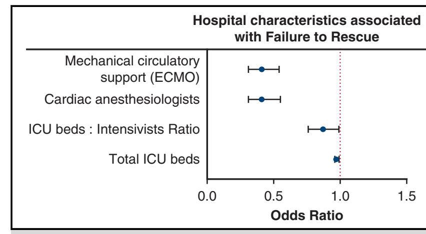
ABSTRACT

Objective: The study objective was to examine the association between hospital processes of care and failure to rescue in a diverse, multi-institutional cardiac surgery network.

Methods: Failure to rescue was defined as an operative mortality after 1 or more of 4 complications: prolonged ventilation, stroke, renal failure, and unplanned reoperation. Society of Thoracic Surgeons data from 20,950 consecutive patients in the Columbia HeartSource network who underwent 1 of 7 cardiac operations—coronary artery bypass grafting, aortic valve replacement ± coronary artery bypass grafting, mitral valve repair or replacement ± coronary artery bypass grafting—were analyzed to calculate failure to rescue rates. Hospital-specific characteristics were ascertained by survey method. Multivariable mixed-effects logistic models assessed the association of these hospital characteristics with failure to rescue while adjusting for patient-related factors known to be associated with mortality.

Results: Failure to rescue rates at affiliate hospitals ranged from 5.45% to 21.74% (median, 12.5%; interquartile range, 6.9%). When controlling for Society of Thoracic Surgeons–predicted risk of mortality with hospital as a random effect, 4 hospital characteristics were found to be associated with lower failure to rescue rates; the presence of cardiac-trained anesthesiologists (odds ratio, 0.41; CI, 0.31-0.55, $P < .001$), availability of extracorporeal membrane oxygenation mechanical circulatory support (odds ratio, 0.41; CI, 0.31-0.54, $P < .001$), ratio of intensive care unit beds to intensivists (odds ratio, 0.87; CI, 0.76-0.99, $P = .039$), and total number of intensive care unit beds (odds ratio, 0.97; CI, 0.96-0.99, $P = .002$)

Conclusions: In a diverse multi-institutional cardiac surgical network, we were able to identify specific hospital processes of care associated with failure to rescue, even when adjusting for patient-related predictors of operative mortality. (JTCVS Open 2023;16:509-21)



Hospital factors are associated with FTR on multivariable regression.

CENTRAL MESSAGE

Specific hospital characteristics can be identified that are associated with lower FTR rates in cardiac surgery.

PERSPECTIVE

This analysis suggests that the variation in FTR rates between hospitals can be partially explained by individual hospital characteristics, even when controlling for patient risk factors. Identifying hospital processes of care that are associated with FTR may help to guide future efforts to improve outcomes in cardiac surgery.

See Discussion on page 522.

To view the AATS Annual Meeting Webcast, see the URL next to the webcast thumbnail.

From the [a]Columbia University Vagelos College of Physicians and Surgeons, New York, NY; [b]Center for Innovation and Outcomes Research, Department of Surgery, Columbia University, New York, NY; [c]Division of Cardiac, Thoracic and Vascular Surgery, Columbia University, New York, NY; and [d]Department of Cardiothoracic Surgery, Weill Cornell Medicine, New York, NY.

This work was supported by the National Institutes of Health (5 T35 HL 7616-42; G.O.E.).

Read at the 103rd Annual Meeting of The American Association for Thoracic Surgery, Los Angeles, California, May 6-9, 2023.

Received for publication May 5, 2023; revisions received Sept 25, 2023; accepted for publication Oct 11, 2023; available ahead of print Nov 10, 2023.

Address for reprints: Gabriela O. Escalante, BA, Columbia University Vagelos College of Physicians and Surgeons, 100 Haven Ave Apt 29E, New York, NY 10032 (E-mail: goe2001@cumc.columbia.edu).

2666-2736

https://doi.org/10.1016/j.xjon.2023.10.014

Patients who experience complications after cardiac surgery have a higher risk of mortality than those who do not. Rescuing patients from complications requires effective processes of care that can promptly recognize and appropriately respond to patient needs. The rate of failure to rescue (FTR), or death after a surgical complication, varies between hospitals in part due to differences in patient population risk profiles and differences in hospital characteristics.[1] Although a hospital's patient population risk profile cannot be readily modified, its characteristics and processes of care are amenable to interventions.[2,3] FTR has been recognized as an important metric for quality

Abbreviations and Acronyms

CABG = coronary artery bypass grafting
ECMO = extracorporeal membrane oxygenation
FTR = failure to rescue
ICU = intensive care unit
IQR = interquartile range
MEM = mixed-effects logistic model
OR = odds ratio
PROM = predicted risk of mortality
STS = Society of Thoracic Surgeons

assessment (Agency for Healthcare Quality and Research. Failure to Rescue, available at: https://psnet.ahrq.gov/primer/failure-rescue, accessed April 19, 2023) and has received increasing attention in the cardiac surgical realm.[4-8]

Although previous studies have identified hospital characteristics that are associated with FTR rates broadly,[2,9,10] specific processes of care associated with reduced FTR rates in cardiac surgery remain to be better defined. We examined the relationship between hospital characteristics and FTR rates in cardiac surgery in a diverse multi-institutional network with the aim of identifying specific institutional features associated with lower FTR rates and thus better outcomes after complications in cardiac surgery. We hypothesized that FTR rates would vary significantly between hospitals, independent of the complication rates, and that this variation could be partially explained by individual hospital characteristics.

MATERIAL AND METHODS

Institutional Review Board

Institutional Review Board approval was obtained from the Columbia University Institutional Board, with waiver of consent. Institutional Review Board Protocols AAAT7723 (approved July 15, 2022) and AAAT7724 (approved July 20, 2022).

Data Source

This study was based on data from 11 cardiac surgery programs affiliated with the Columbia University HeartSource Network. Columbia HeartSource[11] is an outreach project arising from the Divisions of Cardiac Surgery and Cardiology of Columbia University Medical Center that assists affiliate programs with quality oversight and program development in cardiovascular care. HeartSource is a diverse network, including both large and small programs, each with a distinct surgical team, in academic and nonacademic environments as well as urban, suburban, and rural settings across the United States (Table E1). Data from all cardiac surgical procedures carried out in all HeartSource affiliate institutions are entered into the Society of Thoracic Surgeons (STS) Adult Cardiac Surgery Database, which was the source of data for this study. Additionally, all affiliate institutions were surveyed to assess hospital-specific factors: (1) the presence of an affiliated medical school; (2) the presence of a cardiothoracic surgery residency program; (3) the presence of a cardiology fellowship program; (4) the presence of cardiac-trained anesthesiologists; (5) whether cardiac or cardiac surgically trained intensivists are involved in the care of patients in the intensive care unit (ICU) where cardiac surgical patients are cared for; (6) the availability of these intensivists in the hospital (24 hours 7 days/week coverage vs daytime hours only); (7) the ratio of total ICU beds that intensivists cover to the number of intensivists; (8) the total number of beds in the ICU where cardiac surgical patients are cared for; (9) the nurse to patient ratio in the ICU where cardiac surgical patients are cared for at different time points postoperation (during the first 4-6 hours postoperatively, after stabilization, and if needing prolonged ICU stay); (10) the percentage of ICU nursing staff positions that are open; (11) the rate of nurse turnover in the ICU where cardiac surgical patients are cared for; and (12) the presence of an organized program of mechanical circulatory support for patients after cardiac surgery (Figure E1). Surveys were performed online using the Qualtrics tool and were completed by each program director. All survey questions from all sites were answered completely. Care pathways relevant to the survey questions remained relatively constant during the study period.

Study Population

The study population consisted of all patients in the HeartSource Network from January 3, 2012, to December 31, 2019, who underwent 1 of 7 cardiac operations for which the STS has risk prediction models—coronary artery bypass grafting (CABG), aortic valve replacement ± CABG, mitral valve repair or mitral valve replacement ± CABG—between January 3, 2012, and December 31, 2019. Two patients were excluded from the present analysis due to incomplete outcome data.

Primary Outcome

The primary outcome was FTR, defined as an operative mortality in any patient who had 1 or more of the following complications, as defined in the STS Adult Cardiac Surgery Database: (1) prolonged ventilation, (2) stroke, (3) unplanned reoperation, or (4) renal failure. Operative mortality was defined as all deaths, regardless of cause, occurring during hospitalization for the index operation or within 30 days of the operation. Consistent with the previous reports from the STS,[6,8] sternal wound infection incidence was too low to contribute meaningfully to the analysis.

Statistical Analyses

R statistical software (4.1.1, R Foundation) was used for all analyses and GraphPad Prism (version 9.5.0) was used to generate data visualization. Categorical variables are reported as count and frequency and compared using the chi-square test or Fisher exact test depending on size (<5). Continuous variables are reported as mean and SD or median and interquartile range, depending on normality assessed using the Kolmogorov–Smirnov test. A predetermined alpha of 0.05 was used to determine statistical significance. Because this analysis was viewed as exploratory and hypothesis generating rather than definitive, no adjustment was made for multiple testing.

Variable selection. The hospital-specific factors included in the survey were considered by the authors based on prior literature and clinical experience. During survey making, response options for hospital-specific factors were predetermined as continuous or categorical. Additional clinical variables were collected from the STS database, and collection was also guided by STS adult cardiac surgery mortality risk models (Table 1).

Failure to rescue and operative mortality. For comparison purposes, FTR was reported as a proportion, comparing the number of patients who died as the result of any postoperative complication(s) with the total number of patients experiencing that/those complication(s). FTR and operative mortality were calculated by hospital site and for the entire patient sample.

Correlation analysis. Correlation between FTR (%) and complication rate (%) among all hospital sites was assessed using Spearman correlation.

TABLE 1. Patient characteristics

Variables	Overall	No complications	Any complication	*P* value
n	20,950	18,411	2539	
Patient age (median [IQR])	68.00 [60.00-75.00]	68.00 [60.00-75.00]	70.00 [62.00-76.00]	<.001
Gender (%)				
Female	6265 (29.9)	5399 (29.3)	868 (34.2)	<.001
Race (%)				
White	18,159 (86.7)	16,038 (87.1)	2121 (83.5)	<.001
Black	1293 (6.2)	1059 (5.8)	234 (9.2)	<.001
Asian	638 (3.0)	561 (3.0)	77 (3.0)	1
American Indian/Alaskan Native	34 (0.2)	28 (0.2)	6 (0.2)	.468
Native Hawaiian/Pacific Islander	72 (0.3)	59 (0.3)	13 (0.5)	.172
Other	325 (1.6)	279 (1.5)	46 (1.8)	.295
Hispanic or Latino ethnicity (%)	2672 (12.8)	2320 (12.6)	352 (13.9)	.079
Risk factors				
Diabetes (%)	8205 (39.2)	7063 (38.4)	1142 (45.0)	<.001
Renal failure/dialysis (%)	565 (2.7)	399 (2.2)	166 (6.5)	<.001
Hypertension (%)	17,800 (85.0)	15,589 (84.7)	2211 (87.1)	.002
Chronic lung disease (%)				<.001
Mild	3257 (15.5)	2845 (15.5)	412 (16.2)	
Moderate	987 (4.7)	795 (4.3)	192 (7.6)	
Severe	851 (4.1)	665 (3.6)	186 (7.3)	
Severity unknown	268 (1.3)	223 (1.2)	45 (1.8)	
Alcohol consumption (%)				<.001
None	9124 (43.6)	7997 (43.4)	1127 (44.4)	
≤1 drink/wk	6581 (31.4)	5715 (31.0)	866 (34.1)	
2-7 drinks/wk	3581 (17.1)	3235 (17.6)	346 (13.6)	
≥8 drinks/wk	1664 (7.9)	1464 (8.0)	200 (7.9)	
Liver disease (%)	654 (3.1)	530 (2.9)	124 (4.9)	<.001
Immunocompromised (%)	920 (4.4)	756 (4.1)	164 (6.5)	<.001
Peripheral arterial disease (%)	2591 (12.4)	2172 (11.8)	419 (16.5)	<.001
Cerebrovascular disease (%)	3845 (18.4)	3240 (17.6)	605 (23.8)	<.001
Prior cerebrovascular accident (%)	1645 (7.9)	1344 (7.3)	301 (11.9)	<.001
Body mass index (median [IQR])	28.23 [25.09-32.10]	28.20 [25.10-32.00]	28.49 [24.97-33.16]	.006
Body surface area (median [IQR])	2.87 [2.73-2.97]	2.87 [2.75-2.97]	2.83 [2.71-2.96]	<.001
Last creatinine level (median [IQR])	1.00 [0.83-1.20]	1.00 [0.82-1.20]	1.10 [0.90-1.42]	<.001
Previous interventions (%)				
Cardiovascular intervention	3520 (16.8)	2989 (16.2)	531 (20.9)	<.001
Coronary artery bypass	733 (3.5)	588 (3.2)	145 (5.7)	<.001
Valve repair or replacement	906 (4.3)	694 (3.8)	212 (8.3)	<.001
Preoperative cardiac status				
Previous myocardial infarction (%)	7537 (36.0)	6383 (34.7)	1154 (45.5)	<.001
Time between myocardial infarction and surgery (%)				<.001
≤6 h	147 (0.7)	96 (0.5)	51 (2.0)	
<24 h	253 (1.2)	175 (1.0)	78 (3.1)	
>24 h	3728 (17.8)	3128 (17.0)	600 (23.6)	
>21 d	3408 (16.3)	2983 (16.2)	425 (16.7)	
No myocardial infarction	13,414 (64.0)	12,029 (65.3)	1385 (54.5)	
Heart failure (%)	7308 (34.9)	6062 (32.9)	1246 (49.1)	<.001
NYHA-Class I	818 (3.9)	741 (4.0)	77 (3.0)	
NYHA-Class II	1743 (8.3)	1508 (8.2)	235 (9.3)	
NYHA-Class III	2782 (13.3)	2323 (12.6)	459 (18.1)	
NYHA-Class IV	1077 (5.1)	759 (4.1)	318 (12.5)	
NYHA classification not documented	888 (4.2)	731 (4.0)	157 (6.2)	
Ejection fraction (median [IQR])	55.00 [46.00-60.00]	55.00 [48.00-61.00]	53.00 [38.00-60.00]	<.001

(Continued)

TABLE 1. Continued

Variables	Overall	No complications	Any complication	*P* value
Resuscitation ≤ 1 h before operation (%)	166 (0.8)	85 (0.5)	81 (3.2)	<.001
Cardiogenic shock (%)	397 (1.9)	207 (1.1)	190 (7.5)	<.001
Arrhythmia (%)	890 (4.2)	709 (3.9)	181 (7.1)	<.001
IV inotropic agents ≤ 48 h before operation (%)	275 (1.3)	144 (0.8)	131 (5.2)	<.001
Hemodynamic status (%)				
No. of diseased vessels				.03
None	5207 (24.9)	4626 (25.1)	581 (22.9)	
1	1781 (8.5)	1571 (8.5)	210 (8.3)	
2	3265 (15.6)	2880 (15.6)	385 (15.2)	
3	10,697 (51.1)	9334 (50.7)	1363 (53.7)	
Valvular stenosis				
Aortic	5072 (24.2)	4472 (24.3)	600 (23.6)	.483
Mitral	665 (3.2)	540 (2.9)	125 (4.9)	<.001
Tricuspid	24 (0.1)	21 (0.1)	3 (0.1)	1
Valvular insufficiency				
Aortic	2020 (9.6)	1747 (9.5)	273 (10.8)	.002
Mitral	5302 (25.3)	4383 (23.8)	919 (36.2)	<.001
Tricuspid	1972 (9.4)	1574 (8.6)	398 (15.6)	<.001
Operative factors				
Status (%)				<.001
Elective	11,484 (54.8)	10,390 (56.4)	1094 (43.1)	
Emergency	549 (2.6)	358 (1.9)	191 (7.5)	
Emergency salvage	32 (0.2)	11 (0.1)	21 (0.8)	
Urgent	8885 (42.4)	7652 (41.6)	1233 (48.6)	
Crossclamp time (median [IQR])	68.00 [54.00-88.00]	67.00 [53.00-86.00]	77.00 [59.00-103.00]	<.001
Reoperation (%)	1445 (6.9)	1145 (6.2)	300 (11.8)	<.001
Procedure type (%)				<.001
Coronary artery bypass	11,800 (56.3)	10,551 (57.3)	1249 (49.2)	
Aortic valve replacement	3600 (17.2)	3244 (17.6)	356 (14.0)	
Mitral valve repair	1810 (8.6)	1641 (8.9)	169 (6.7)	
Aortic valve replacement + coronary artery bypass	1587 (7.6)	1339 (7.3)	248 (9.8)	
Mitral valve replacement	1327 (6.3)	1037 (5.6)	290 (11.4)	
Mitral valve repair + coronary artery bypass	517 (2.5)	388 (2.1)	129 (5.1)	
Mitral valve replacement + coronary artery bypass	309 (1.5)	211 (1.1)	98 (3.9)	
Predicted risk of mortality (median [IQR])	0.02 [0.01-0.03]	0.01 [0.01-0.03]	0.03 [0.01-0.07]	<.001
Predicted morbidity or mortality (median [IQR])	0.13 [0.08-0.21]	0.12 [0.08-0.19]	0.24 [0.13-0.39]	<.001

Baseline comparisons by complication status. Valvular insufficiency was considered present if degree of insufficiency was moderate or severe. *IQR*, Interquartile range; *NYHA*, New York Heart Association; *IV*, intravenous.

Regression analysis. Univariable logistic regression was performed with all clinical variables and hospital-specific factors as the predictors of FTR as the dependent variable. Variables used for the multivariable mixed-effects logistic models (MEMs) were determined by univariable logistic regression results and clinical acumen.[8]

All models were checked for collinearity (variable inflation factor < 5 considered acceptable). Because of a high degree of collinearity among hospital factors, a MEM was built for each hospital-specific factor found to be statistically significant in univariable logistic regression analysis—7 in total. Each MEM was adjusted with hospital site added as a random effect and the same fixed effects: crossclamp time, cardiopulmonary bypass time, intraoperative blood transfusion of at least 6 units of red blood cells, and the logit-transformed STS predicted risk of mortality (PROM). Including PROM in this manner was an appropriate substitution for several candidate parameters for the model. Additionally, the quality of the model as assessed by the c-statistic was similar using either the candidate parameter or PROM.

Missing data were imputed using STS recommended guidelines.[12] The percentage of data missing from each baseline comparison variable is shown in Table E2.

RESULTS

A total of 20,950 patients were entered into the study. Baseline characteristics of patients included in the present study are listed in Table 1, with specific comparisons between patients with and without complications. Across all institutions, patients who experienced complications differed from those who did not on a number of factors, including age, gender, risk factors, previous interventions, preoperative cardiac status, operative factors, procedure type, mortality, predicted risk of mortality, and predicted risk of morbidity or mortality.

The mortality rate was significantly higher among patients with complications than patients without complications. Patients with complications had a mortality rate of 13.5% (343/2539), whereas patients without complications had a mortality rate of 0.8% (143/18,411). A higher number of complications was associated with higher mortality. The mortality rate was 6.3% (120/1907) for patients with 1 complication, 31.3% (167/533) for patients with 2 complications, 53.8% (50/93) for patients with 3 complications, and 100% (6/6) for patients with 4 complications.

FTR rates at affiliate hospitals ranged from 5.45% to 21.74% (Figure 1), with a median of 12.5% (interquartile range [IQR], 6.9%; STS average = 14.7%).[8] Seven institutions reported FTR rates lower than the STS national average. The complication rates, or percentage of operations in which any complication(s) occurred, at affiliate hospitals ranged from 7.1% to 17.4% (Figure 2), with a median of 12.7% (IQR, 3.4%). The complication rates, mortality rates, and FTR rates for each institution are displayed in Figure 3, *A*, with accompanying median and IQR values for each rate. Although the IQR for mortality was 0.7%, the IQR for FTR was 6.9% (Figure 3, *A*), demonstrating that institutions had greater variability in FTR despite having similar mortality rates. The IQR for FTR (6.9%) was also greater than the IQR for complication rates (3.4%) (Figure 3, *A*), indicating that institutions differed more in their ability to rescue patients from complications than in the rate of complications. A graphical representation of the spread of the mortality, complication, and FTR rates is displayed in Figure 3, *B*.

The frequency of each type of complication is depicted in Figure 4, *A*. Across the institutions, the mean percentage of patients with any complication was 12.1%. The most common complication type was prolonged ventilation (9.4%), followed by unplanned reoperation (2.9%), renal failure (2.3%), and stroke (1.1%). Complications could co-occur in the same patient and were therefore not mutually exclusive. Each complication type resulted in a different FTR rate (Figure 4, *B*), with the most lethal complication being renal failure (36.3%), followed by stroke (17.7%), prolonged ventilation (16.4%), and unplanned reoperation (15.2%). There was no association between the FTR rate and complication rate across the institutions (Figure 5). Hospitals with higher FTR rates did not have significantly higher or lower complication rates than hospitals with lower FTR rates.

When controlling for STS-predicted risk of mortality with hospital as a random effect, 4 of the 12 hospital characteristics in the survey were found to be significantly associated with FTR rates (Figure 6 and Table E3). The presence of cardiac-trained anesthesiologists (odds ratio [OR], 0.41; CI, 0.31-0.55, $P < .001$), availability of extracorporeal membrane oxygenation (ECMO) mechanical circulatory support (OR, 0.41; CI 0.31-0.54, $P < .001$), ratio of ICU beds to intensivists (OR, 0.87; CI, 0.76-0.99, $P = .039$), and total number of ICU beds (OR, 0.97; CI, 0.96-0.99, $P = .002$) were identified to be significantly associated with FTR. All 4 variables were associated with lower FTR rates and therefore may be considered protective.

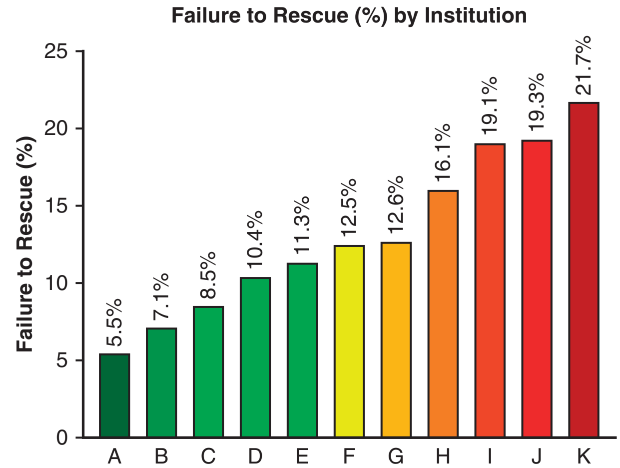


FIGURE 1. FTR rate by institution. Institutions are coded A-K in order of increasing FTR rate. FTR rates of each institution are listed as percentages above each bar. Bars are color coded by favorability of FTR (*green* = low FTR; *red* = high FTR).

DISCUSSION

Key findings of this study are (1) within a diverse cardiac surgical network there is considerable variation in FTR rates among institutions; (2) this variation is not related to the incidence of complications; and (3) several hospital process of care-related factors can be identified as significantly associated with reduced FTR rates after adjusting for patient-related factors (Figure 7). Specifically, the presence

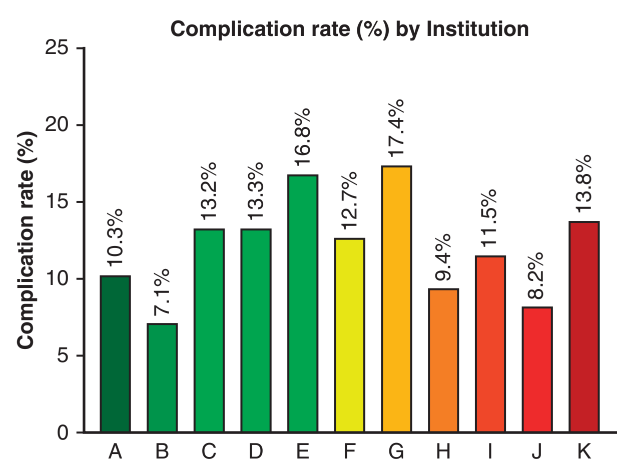
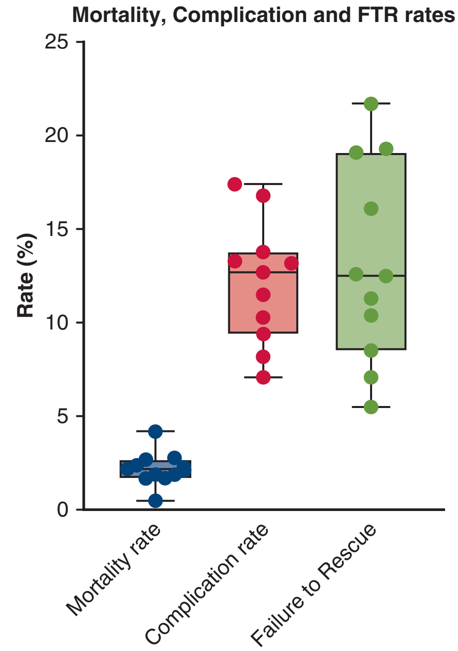


FIGURE 2. Complication rate by institution. Institutions are coded A-K in order of increasing FTR rate with bars color coded as in Figure 1. The complication rate is the percentage of operations in which any complication(s) occurred. Complication rates of each institution are listed as percentages above each bar.

Institution	A	B	C	D	E	F	G	H	I	J	K	Median [Q1 - Q3]	IQR
Complication rate	10.3	7.1	13.2	13.3	16.8	12.7	17.4	9.4	11.5	8.2	13.8	12.7 [10.0 - 13.4]	3.4
Mortality rate	1.9	0.5	1.7	1.7	2.4	1.9	2.8	2.2	2.2	2.7	4.2	2.2 [1.8 - 2.5]	0.7
Failure to Rescue	5.5	7.1	8.5	10.4	11.3	12.5	12.6	16.1	19.1	19.3	21.7	12.5 [9.9 - 16.8]	6.9

A



B

FIGURE 3. Complication, mortality, and FTR rates. A, Rates by institution. Institutions are coded A-K in order of increasing FTR rate as in Figures 1 and 2. Median and IQR were calculated for each rate. Values are percentages. *Q1,* First quartile; *Q3,* third quartile. B, Median, IQR, and range plotted as box-and-whisker plots for complication, mortality, and FTR rates. *Horizontal line* in each box represents median. *Lower* and *upper* borders of each box represent the *lower* and *upper* quartiles (25th percentile and 75th percentile). The *lower* and *upper* whiskers represent the minimum and maximum values of the data set. The individual values are plotted overlying each box-and-whisker plot.

of cardiac-trained anesthesiologists, ECMO mechanical circulatory support, a high ratio of ICU beds to intensivists, and a high total number of ICU beds were associated with lower FTR rates in the cardiac surgical setting. Although these hospital characteristics may themselves be protective against FTR in cardiac surgery, they may also be indicators of unmeasured factors present in higher-quality hospital systems that have a greater capacity to rescue patients after complications. It has been previously shown that hospital quality determines outcomes in cardiac surgery,[13] so higher-quality hospital systems may be more equipped to respond to complications. Notably, hospital complication rates were not well correlated with institutional rates of FTR, consistent with previous studies.[6,8] Although complication rate is a well-accepted metric of surgical quality, it appears that FTR provides additional information regarding surgical performance. Therefore, it is important to measure FTR in addition to complication rates in overall assessment of healthcare quality. Clarifying which hospital characteristics are associated with lower FTR rates will help us better understand processes of care that aid clinicians in rescuing patients after complications.

Notably, the presence of cardiac-trained anesthesiologists was associated with significantly lower FTR rates in cardiac surgery. Anesthesiologists play a critical role in preventing morbidity and mortality in patients, ensuring smooth operations. For example, operations in which anesthesia care is performed or directed by nonanesthesiologists (eg, nurse anesthetist or nonanesthesiologist physician) have higher FTR rates than operations with anesthesia care directed by anesthesiologist physicians.[14] Anesthesiologists' responsibility in rescuing patients from complications is especially apparent to patients and families, considering that 20% of anesthesia malpractice claims are for FTR.[15] Prior literature on the role of cardiac specific anesthesia training on mortality have been mixed,[16,17] yet there is compelling evidence that intraoperative transesophageal echocardiography—a surrogate for advanced cardiac anesthesia expertise—is associated with improved outcomes, which certainly corroborates our findings.[18,19]

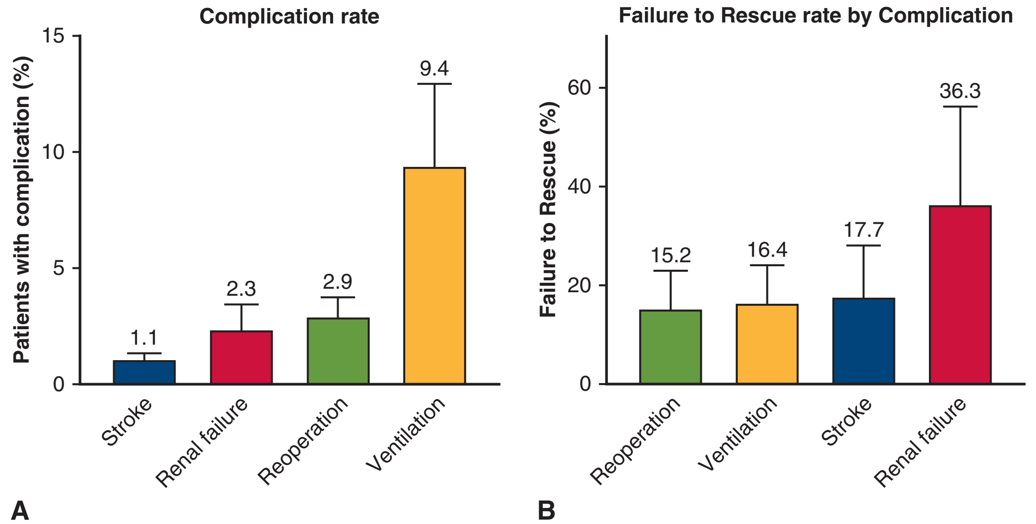


FIGURE 4. Complication rate and FTR by complication type. A, Frequency of each type of complication, depicted as mean ± SD. The percentage of patients with each complication is listed above each bar. Values are percentages. The complications can co-occur and are not mutually exclusive. Any complication refers to patients who had 1 or more complication. B, FTR rate by each type of complication, depicted as mean ± SD. Average FTR rate for each complication type is listed above each bar. Values are percentages.

Another hospital factor significantly associated with decreased FTR rates was the availability of ECMO mechanical circulatory support. The availability of ECMO also could signal a well-resourced hospital, which may contribute to lower FTR rates; however, availability of clinical resources alone does not determine FTR rates.[20] Despite improving survival with earlier institution of venoarterial ECMO in cardiac surgical patients,[21] patients with postpericardiotomy shock remain some of the most challenging of all ECMO-supported patients.[22] The extent to which availability of ECMO had a direct impact on improving the survival of patients with the complications delineated in this study (none of which are directly cardiac in nature) versus merely serving as a surrogate for hospitals with more extensive commitment to advanced care of cardiac patients cannot be determined by the available data.

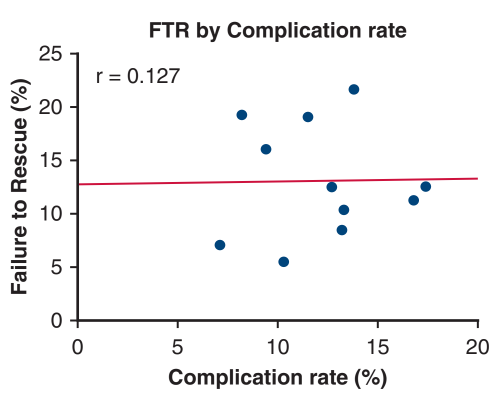


FIGURE 5. No correlation between FTR and complication rate. The rate of complication was not significantly associated with the rate of FTR among the hospitals in the present study. Spearman correlation coefficient r = 0.127.

ICU volume was also associated with more favorable FTR rates. Hospitals with a greater total number of ICU beds had lower FTR. These findings contribute to the ongoing discussion about the relationship between hospital volume and patient outcomes. High-volume hospitals tend to have more favorable FTR rates than low-volume hospitals both in the cardiac surgical setting[23] and in broader settings[24]; however, there is a lack of consensus about the actual relationship between hospital volume and patient outcomes. Studies have found that processes of care, not volume itself, determine patient outcomes.[13,25] Therefore, the number of ICU beds devoted to cardiac surgical patients may reflect not only merely hospital surgical volume but also institutional commitment to providing higher level of care of cardiac surgical patients. Interestingly, we found that a greater ratio of ICU beds to intensivists was associated with lower FTR rates. Although this finding may seem somewhat counterintuitive, it may in fact merely reflect the presence of more available ICU beds in larger volume programs. Other factors, the effective use of advanced practice practitioners—a vital and increasingly important element in advanced cardiac care,[26] as well as residents and fellows, which were not directly assessed in this study—may help to account for this finding.

Although the factors identified to be associated with FTR are informative, they should not be viewed as exclusionary in any way. Certainly, nursing turnover may have a dramatic impact on surgical outcomes. The absence of association in this study may well reflect the fact that these surveys were taken at the tail end of the COVID pandemic, when all

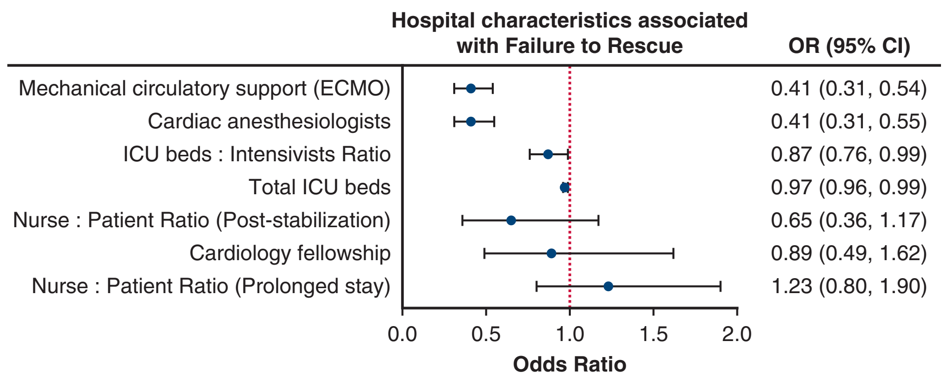


FIGURE 6. Hospital factors associated with FTR rate on mixed-effect multivariable regression. When adjusting for STS-predicted risk of mortality with hospital as a random effect, 4 of the 7 hospital factors that were associated with FTR on univariable analysis were found to be associated with FTR on mixed-effect multivariable regression. The presence of cardiac anesthesiologists, mechanical circulatory support in the form of ECMO, the ratio of ICU beds to cardiac intensivists, and the total number of ICU beds were each associated with decreased FTR and therefore may be considered protective against FTR. The ORs of all variables found to be significant on univariable analysis are illustrated on a forest plot with ORs and CIs listed adjacently. *OR,* Odds ratio.

hospitals were facing severe staffing challenges.[27] Therefore, the metric, although potentially extremely related to FTR, may not have had sufficient variance among institutions to serve as a distinguishing characteristic in this study. Likewise, nurse to patient ratio did not vary among sites and therefore was not identified as a distinguishing characteristic.

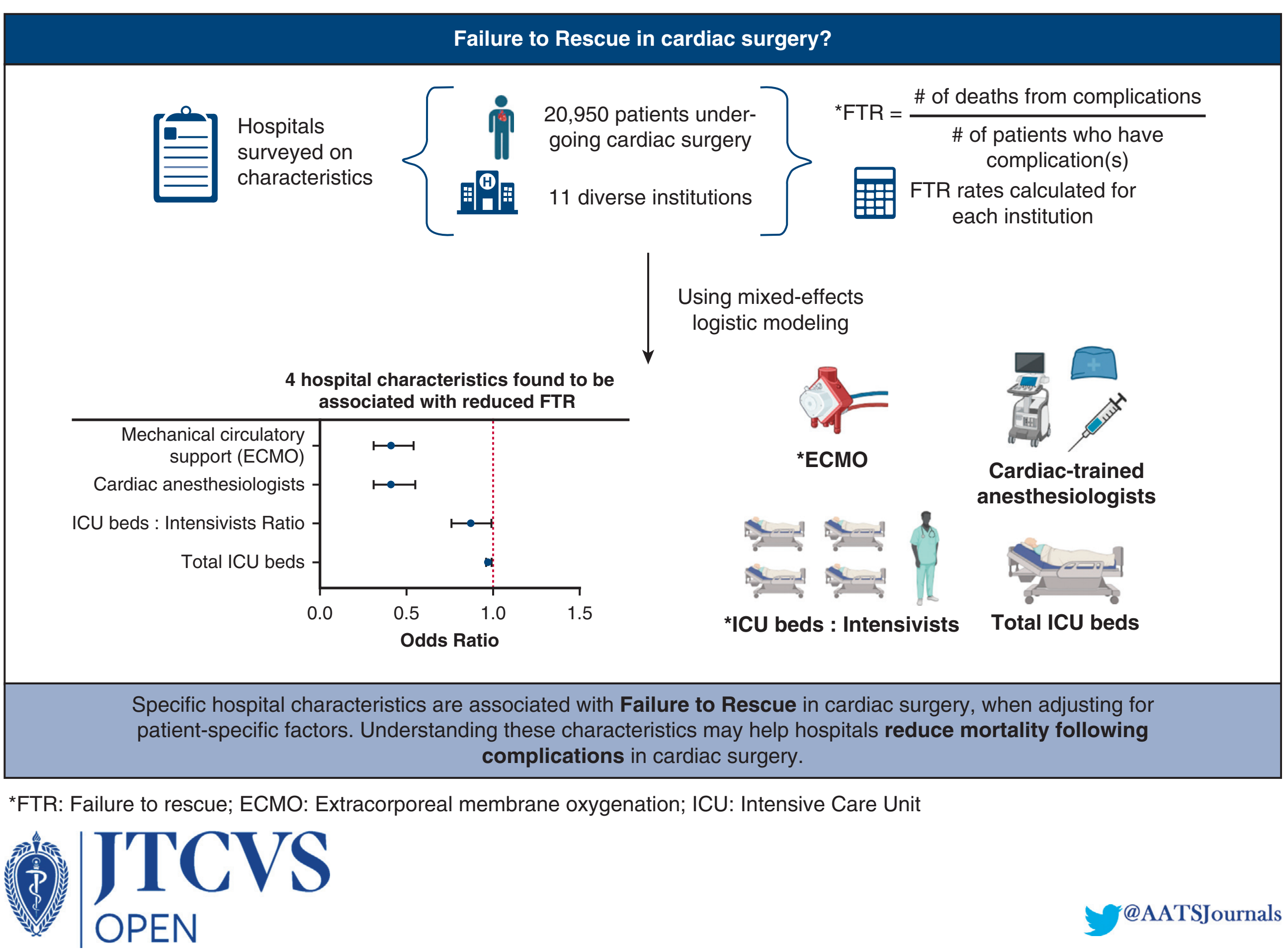


FIGURE 7. Methods, findings, and implications. The study's methods, key findings, and implications are illustrated. Created using BioRender.com.

Study Limitations

Although these results provide new insights into the hospital characteristics that may impact FTR rates in cardiac surgery, this study has several limitations. First, the observational analysis of retrospective data certainly limits causal inferences. The association of the factors we identified with FTR does not necessarily imply that these factors cause or prevent FTR. For example, an ECMO program initiated in a hospital without adequate infrastructure or surgical expertise to support it would be highly unlikely to reduce rates of FTR. The goal of this limited investigation was to inform future investigation from larger surgical networks—or regional or national data sources—as well as to suggest possible future cluster randomization trials of specific care pathways.

Second, the hospital characteristics included in this study do not include all possible characteristics that impact FTR in cardiac surgery. The survey was designed based on literature review and the authors' clinical experience, yet may exclude other factors of potential significance. For example, this study did not examine the relationship between FTR and socioeconomic factors such as payment models, revenue, safety net burden, or other potentially important social determinants of health. It has been previously shown that hospitals with a high safety net burden have higher FTR rates even when controlling for clinical resources,[20] suggesting that clinical resources alone do not account for difference in outcome. Examining the interaction among such resources, safety net burden, and the hospital characteristics examined in this study in relation to FTR would be a fruitful area of future investigation.

Third, it should be noted that those survey elements that were not found to have a significant association with FTR in this study may still bear an important relationship with FTR; however, the responses among institutions may not have been sufficiently different to distinguish those elements as driving factors in the difference in FTR that was noted among the sites in the study. Therefore, exploration of these elements on a national level may help to better identify their role in driving FTR rates.

Fourth, the study did not explore the impact of microsystem factors such as attitudes, behaviors, teamwork, and safety culture on FTR. Microsystem factors encompass that *je ne sais quoi* of a medical workplace environment. They are important determinants of processes of care that affect patient outcomes[28]; however, microsystem factors are notoriously difficult to quantify and study. Indeed, institutional quality may be more a function of hospital culture than specific programs.[29] Future research aimed at quantifying these microsystem factors and examining their relationship with FTR would be of considerable interest.

Last, it should be noted that only raw FTR rates were evaluated. The model generated by the STS is designed to account for all of the potential combinations of complications and their interactions with operations performed. Unfortunately, the details of that model were not available and data from this study were not sufficient to support that complexity of modeling; however, limitation of this study to the complications and operations for which the STS does have readily available risk models did permit appropriate adjustment for patient characteristics.

CONCLUSIONS

We have validated the concept that FTR can be used to distinguish outcomes among hospitals, that FTR rates provide information not obtainable from complication rates alone, and that specific hospital processes of care can be identified that are significantly associated with FTR after cardiac surgery, even when adjusting for patient-related predictors of operative mortality. These findings are meant to be hypothesis-generating and are intended to lay the foundation for future investigations, as well as to help guide future efforts to reduce FTR and postoperative mortality in cardiac surgery.

Webcast

You can watch a Webcast of this AATS meeting presentation by going to: https://www.aats.org/resources/failure-to-rescue-how-can-hospitals-improve-cardiac-care.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

References

1. Silber JH, Williams SV, Krakauer H, Schwartz JS. Hospital and patient characteristics associated with death after surgery. A study of adverse occurrence and failure to rescue. *Med Care*. 1992;30:615-29.
2. Sheetz KH, Dimick JB, Ghaferi AA. Impact of hospital characteristics on failure to rescue following major surgery. *Ann Surg*. 2016;263:692-7.
3. Pucher PH, Aggarwal R, Singh P, Darzi A. Enhancing surgical performance outcomes through process-driven care: a systematic review. *World J Surg*. 2014;38:1362-73.
4. Pasquali SK, He X, Jacobs JP, Jacobs ML, O'Brien SM, Gaynor JW. Evaluation of failure to rescue as a quality metric in pediatric heart surgery: an analysis of the STS Congenital Heart Surgery Database. *Ann Thorac Surg*. 2012;94:573-9; discussion 579-80.

5. Reddy HG, Shih T, Englesbe MJ, Shannon FL, Theurer PF, Herbert MA, et al. Analyzing "failure to rescue": is this an opportunity for outcome improvement in cardiac surgery? *Ann Thorac Surg*. 2013;95:1976-81; discussion 1981.
6. Edwards FH, Ferraris VA, Kurlansky PA, Lobdell KW, He X, O'Brien SM, et al. Failure to rescue rates after coronary artery bypass grafting: an analysis from the Society of Thoracic Surgeons adult cardiac surgery database. *Ann Thorac Surg*. 2016;102:458-64.
7. Likosky DS, Strobel RJ, Wu X, Kramer RS, Hamman BL, Brevig JK, et al. Interhospital failure to rescue after coronary artery bypass grafting. *J Thorac Cardiovasc Surg*. 2023;165:134-43.e3.
8. Kurlansky PA, O'Brien SM, Vassileva CM, Lobdell KW, Edwards FH, Jacobs JP, et al. Failure to rescue: a new Society of Thoracic Surgeons quality metric for cardiac surgery. *Ann Thorac Surg*. 2022;113:1935-42.
9. Ghaferi AA, Osborne NH, Birkmeyer JD, Dimick JB. Hospital characteristics associated with failure to rescue from complications after pancreatectomy. *J Am Coll Surg*. 2010;211:325-30.
10. Lillo-Felipe M, Ahl Hulme R, Sjolin G, Cao Y, Bass GA, Matthiessen P, et al. Hospital academic status is associated with failure-to-rescue after colorectal cancer surgery. *Surgery*. 2021;170:863-9.
11. Columbia University Department of Medicine: Seymour PaGMDoC. Columbia HeartSource. Accessed November 7, 2023. https://www.columbiacardiology.org/about-us/columbia-heartsource
12. O'Brien SM, Feng L, He X, Xian Y, Jacobs JP, Badhwar V, et al. The Society of Thoracic Surgeons 2018 adult cardiac surgery risk models: part 2-statistical methods and results. *Ann Thorac Surg*. 2018;105:1419-28.
13. Kurlansky PA, Argenziano M, Dunton R, Lancey R, Nast E, Stewart A, et al. Quality, not volume, determines outcome of coronary artery bypass surgery in a university-based community hospital network. *J Thorac Cardiovasc Surg*. 2012;143:287-93.
14. Silber JH, Kennedy SK, Even-Shoshan O, Chen W, Koziol LF, Showan AM, et al. Anesthesiologist direction and patient outcomes. *Anesthesiology*. 2000;93:152-63.
15. Domino KZ, Mincer S, Posner K. Failure-to-rescue as a contributor to high severity outcomes in anesthesia malpractice claims. *Eur J Anaesthesiol*. 2020; 37:384-5.
16. Papachristofi O, Sharples LD, Mackay JH, Nashef SA, Fletcher SN, Klein AA, et al. The contribution of the anaesthetist to risk-adjusted mortality after cardiac surgery. *Anaesthesia*. 2016;71:138-46.
17. Glance LG, Hannan EL, Fleisher LA, Eaton MP, Dutton RP, Lustik SJ, et al. Feasibility of report cards for measuring anesthesiologist quality for cardiac surgery. *Anesth Analg*. 2016;122:1603-13.
18. Metkus TS, Thibault D, Grant MC, Badhwar V, Jacobs JP, Lawton J, et al. Transesophageal echocardiography in patients undergoing coronary artery bypass graft surgery. *J Am Coll Cardiol*. 2021;78:112-22.
19. MacKay EJ, Zhang B, Augoustides JG, Groeneveld PW, Desai ND. Association of intraoperative transesophageal echocardiography and clinical outcomes after open cardiac valve or proximal aortic surgery. *JAMA Netw Open*. 2022; 5:e2147820.
20. Wakeam E, Hevelone ND, Maine R, Swain J, Lipsitz SA, Finlayson SR, et al. Failure to rescue in safety-net hospitals: availability of hospital resources and differences in performance. *JAMA Surg*. 2014;149:229-35.
21. Saha A, Kurlansky P, Ning Y, Sanchez J, Fried J, Witer LJ, et al. Early venoarterial extracorporeal membrane oxygenation improves outcomes in postcardiotomy shock. *J Artif Organs*. 2021;24:7-14.
22. Fukuhara S, Takeda K, Garan AR, Kurlansky P, Hastie J, Naka Y, et al. Contemporary mechanical circulatory support therapy for postcardiotomy shock. *Gen Thorac Cardiovasc Surg*. 2016;64:183-91.
23. Scali ST, Giles KA, Kubilis P, Beck AW, Crippen CJ, Hughes SJ, et al. Impact of hospital volume on patient safety indicators and failure to rescue following open aortic aneurysm repair. *J Vasc Surg*. 2020;71:1135-46.e4.
24. Ghaferi AA, Birkmeyer JD, Dimick JB. Hospital volume and failure to rescue with high-risk surgery. *Med Care*. 2011;49:1076-81.
25. Kumbhani DJ, Fonarow GC, Heidenreich PA, Schulte PJ, Lu D, Hernandez A, et al. Association between hospital volume, processes of care, and outcomes in patients admitted with heart failure: insights from get with the Guidelines-Heart Failure. *Circulation*. 2018;137:1661-70.
26. Woo BFY, Lee JXY, Tam WWS. The impact of the advanced practice nursing role on quality of care, clinical outcomes, patient satisfaction, and cost in the emergency and critical care settings: a systematic review. *Hum Resour Health*. 2017;15:63.
27. Chan GK, Bitton JR, Allgeyer RL, Eliott D, Hudson LR, Burwell PM. The impact of COVID-19 on the nursing workforce: a national overview. *Online J Issues Nurs*. 2021;26.
28. Likosky DS. Clinical microsystems: a critical framework for crossing the quality chasm. *J Extra Corpor Technol*. 2014;46:33-7.
29. Curry LA, Spatz E, Cherlin E, Thompson JW, Berg D, Ting HH, et al. What distinguishes top-performing hospitals in acute myocardial infarction mortality rates? A qualitative study. *Ann Intern Med*. 2011;154:384-90.

Key Words: adult cardiac surgery, complications, failure to rescue, hospital factors, mortality, processes of care

1. **Does this institution have an affiliated medical school?**
    - Yes
    - No
2. **Does this institution have a cardiothoracic surgery residency program?**
    - Yes
    - No
3. **Does this institution have a cardiology fellowship program?**
    - Yes
    - No
4. **Does this institution have cardiac-trained anesthesiologists?**
    - Yes
    - No
5. **Are cardiac and/or cardiac surgically trained intensivists involved in the care of patients in the intensive care unit where cardiac surgical patients are cared for?**
    - Yes
    - No
6. **If the answer to #5 is Yes, are these intensivists available in the hospital:**
    - 24 hours/day × 7 days/week
    - During daytime hours only
    - N/A: answer to #5 was **No**
7. **If the answer to #5 is Yes, during the hours when intensivists are involved in care of cardiac surgical patients, what is the ratio of total ICU beds that intensivists cover to the number of intensivists?** (# ICU beds covered by intensivists / # of intensivists)
8. **How many total beds are in the ICU where cardiac surgical patients are cared for?**
9. **In the ICU in which cardiac surgical patients are cared for, what is the nurse:patient ratio:**
    - During the first 4-6 hours postoperatively?
    - After stabilization?
    - If needing prolonged ICU stay (e.g. ventilation, mechanical circulatory support)?
10. **What percentage (%) of ICU nursing staff positions are open?**
11. **What is the rate (or approximate rate) of nurse turnover in the ICU where cardiac surgical patients are cared for? Please represent answer as a percentage (%)**. Nursing turnover rate = number of voluntary uncontrolled separations during the month for unit Registered Nurses (RNs) and Advanced Practice Nurses (APNs) + number of unit employees (full-time plus part-time) on the last day of the month for RNs and APNs. Multiply by 100 to get a percentage (%).
12. **Is mechanical circulatory support available for patients following cardiac surgery?**
    - ECMO
        - Yes
        - No
    - Impella
        - Yes
        - No

FIGURE E1. Survey assessing hospital-specific characteristics. All affiliate institutions were surveyed to assess hospital-specific factors. Survey response rate was 100%.

TABLE E1. Location and volume of participating hospitals

Hospital	Major/minor urban/rural*	Approximate annual volume†	State
A	Minor Urban	90	Connecticut
B	Major Urban	175	New York
C	Major Urban	500	New York
D	Major Urban	350	Florida
E	Major Urban	900	New York
F	Rural	110	New York
G	Major Urban	200	New York
H	Minor Urban	700	Florida
I	Minor Urban	330	South Carolina
J	Major Urban	175	New York
K	Major Urban	300	Tennessee

*"Minor Urban" population of city where hospital located < 150,000; "Major Urban" population of city where hospital located > 150,000; "Rural" located in rural setting and services rural population (some of the smaller "minor urban" centers also serve a rural community but nonetheless primarily serve a suburban and small urban community). †Approximate volume of combined CABG and valve operations (excludes percutaneous procedures, aortic surgery, transplant, left ventricular assist device, and isolated extracorporeal membrane oxygenation, ie, volumes based on the operations harvested for this study).

TABLE E2. Percentage of data missing from each baseline comparison variable

Variable	Missing (%)
Crossclamp time	4.1
Cardiopulmonary bypass time	2.6
Left ventricular ejection fraction	1.3
Myocardial infarction timing	0.5
Intraoperative blood products	0.3
Previous cerebrovascular accident	0.2
Creatinine	0.1
NYHA class	<0.1
Presentation on admission	<0.1
No. of diseased vessels	<0.1
Previous cardiac interventions	<0.1
Previous CABG	<0.1
Previous valve repair	<0.1
Previous myocardial infarction	<0.1
Heart failure	<0.1
Inotropes within 48 h	<0.1
Aortic occlusion	<0.1
Intraoperative RBC units	<0.1

Values are represented as a percentage (%): number of patients with missing data divided by total number of patients (n = 20,950). *NYHA,* New York Heart Association; *CABG,* coronary artery bypass grafting; *RBC,* red blood cell.

TABLE E3. Individual hospital responses to survey

Hospital	Medical school	CT residency	Cardiology fellowship	Cardiac anesthesia	Cardiac intensivists	Availability	Bed/intensivist ratio	ICU beds	% Open nursing	Nurse turnover	ECMO
A	Yes	No	No	Yes	Yes	Daytime	28:1	28	20%	1%	Yes
B	No	No	Yes	Yes	Yes	24/7	8:1	8	25%	25%	Yes
C	Yes	Yes	Yes	Yes	Yes	24/7	10:1	20	70%	11%	Yes
D	No	No	Yes	Yes	Yes	24/7	25:1	40	20%	5%	Yes
E	Yes	Yes	Yes	Yes	Yes	24/7	15:1	31	10%	20%	Yes
F	Yes	No	Yes	Yes	No	N/A	N/A	13	10%	10%	Yes
G	Yes	No	Yes	Yes	No	N/A	N/A	14	60%	85%	Yes
H	Yes	No	No	Yes	Yes	24/7	25:1	10	14%	16%	Yes
I	No	No	No	No	No	N/A	N/A	6	8%	10%	No
J	Yes	No	Yes	Yes	No	N/A	N/A	8	10%	8%	Yes
K	Yes	No	Yes	No	Yes	Daytime	8:1	8	40%	3%	No
Total*	73%	18%	73%	82%	64%	N/A		13† (8, 28)	20%† (10%, 40%)	10%† (5%, 20%)	82%

Open Nursing is nursing positions open. *CT*, Cardiothoracic; *ICU*, intensive care unit; *ECMO*, extracorporeal membrane oxygenation; *N/A*, not applicable; *24/7*, 24 hours/day, 7 days/week. *Percentages represent the percentage of programs for which the answer was "Yes." †Median (IQR).