Surgery 166 (2019) 778–784

Contents lists available at ScienceDirect

Surgery

journal homepage: www.elsevier.com/locate/surg

Presented at the Academic Surgical Congress 2019

# Impact of hospital safety-net status on failure to rescue after major cardiac surgery

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ARTICLE INFO

*Article history:*
Accepted 31 May 2019
Available online 12 July 2019

ABSTRACT

*Background:* Hospitals with safety-net status have been associated with inferior surgical outcomes and higher costs. The mechanism of this discrepancy, however, is not well understood. We hypothesized that discrepant rates of failure to rescue after complications of routine cardiac surgery would explain the observed inferior outcomes at safety-net hospitals.

*Methods:* The National Inpatient Sample was used to identify adult patients who underwent elective coronary artery bypass grafting and isolated or concomitant valve operations between January 2005 and December 2016. Hospitals were stratified into low-, medium-, or high-burden categories based on the proportion of uninsured or Medicaid patients to emulate safety-net status as defined by the Institute of Medicine. Failure to rescue was defined as mortality after occurrence of neurologic, cardiovascular, respiratory, renal, or infectious complications (major and minor complications). Multivariable regression was used to perform risk-adjusted comparisons of the rate of complications, failures to rescue, and resource use for high-burden hospitals versus low-burden and medium-burden hospitals.

*Results:* Of an estimated 2,012,104 patients undergoing elective major cardiac operations, 2% died, whereas 36% suffered major and minor complications. Safety-net hospitals had higher odds of failure to rescue after major comorbidity (adjusted odds ratio 1.12, 95% confidence interval 1.01–1.23). Occurrence of major and minor complications at safety-net hospitals was associated with increased costs ($2,480 [95% confidence interval $1,178–$3,935]) compared with low-burden hospitals.

*Conclusion:* Safety-net hospitals were associated with higher rates of failure to rescue after occurrence of tamponade, septicemia, and respiratory complications. Implementation of care bundles to tackle cardiovascular, respiratory, and renal complications may affect the discrepancy in incidence of and rescue from complications at safety-net institutions.



## Introduction

Postoperative mortality serves as a hard end point that is frequently used for benchmarking and quality-improvement purposes. For decades, high surgeon and hospital volumes have been associated with reduced mortality and complications attributable to the skill of the operating team.[1–3] Despite its simple definition, however, mortality after surgical procedures is influenced by many variables beyond the operating room itself. Prior studies of complex procedures, such as pancreatectomy and esophagectomy, have demonstrated minimal interhospital variation in complication rates despite marked disparities in mortality.[4–7] It is now recognized that hospitals vary in the ability to avoid mortality once a complication occurs, which is recognized as failure to rescue (FTR).[8–11]

Patients undergoing cardiac surgery represent a high-risk group for both complications and mortality. These patients often have several major comorbidities, are older, and require meticulous postoperative care in order to avoid devastating complications.

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https://doi.org/10.1016/j.surg.2019.05.034
0039-6060/

**Table I**
Patient and hospital demographics by HBH status

| | LBH (N = 542,785) | MBH (N = 1,007,957) | HBH (N = 461,362) | Total (N = 2,012,104) | *P* value |
|---|---|---|---|---|---|
| Age ≥ 65 years | 60.04 | 59.41 | 57.39 | 59.12 | .001 |
| Elixhauser >5* | 15.23 | 15.57 | 17.44 | 15.91 | .020 |
| Female | 30.89 | 31.01 | 32.13 | 31.23 | .001 |
| Heart failure | 24.96 | 23.91 | 27.22 | 24.95 | .001 |
| Coronary artery disease | 75.52 | 76.72 | 74.49 | 75.88 | .052 |
| CPD | 23.06 | 24.07 | 23.32 | 23.63 | .114 |
| Diabetes | 5.47 | 5.64 | 6.21 | 5.72 | .043 |
| Chronic kidney disease | 10.63 | 10.12 | 12.25 | 10.75 | .002 |
| Chronic liver disease | 1.77 | 1.70 | 2.28 | 1.85 | <.001 |
| Obesity | 13.72 | 15.28 | 15.32 | 14.87 | .007 |
| Race | | | | | |
| Caucasian | 68.53 | 69.49 | 67.14 | 68.69 | <.001 |
| Black | 3.60 | 4.01 | 6.34 | 4.43 | |
| Hispanic | 3.87 | 3.85 | 9.31 | 5.10 | |
| Asian | 2.36 | 1.42 | 2.37 | 1.89 | |
| Native American | 0.53 | 0.31 | 0.50 | 0.41 | |
| Other/unknown | 21.12 | 20.92 | 14.34 | 19.47 | |
| Hospital teaching status | | | | | |
| Rural | 1.10 | 4.60 | 2.45 | 3.17 | .001 |
| Urban/nonteaching | 38.67 | 33.39 | 24.22 | 32.72 | |
| Urban/teaching | 60.23 | 62.01 | 73.33 | 64.12 | |
| Hospital region | | | | | |
| Northeast | 16.49 | 17.00 | 15.85 | 16.60 | .004 |
| Midwest | 29.06 | 28.98 | 15.88 | 26.00 | |
| South | 33.48 | 38.37 | 44.22 | 38.39 | |
| West | 20.97 | 15.65 | 24.06 | 19.01 | |
| Operation | | | | | |
| Isolated CABG | 56.33 | 58.02 | 57.34 | 57.41 | .199 |
| Isolated valve | 27.12 | 25.73 | 27.34 | 26.48 | |
| CABG/valve | 14.01 | 13.77 | 12.68 | 13.59 | |
| Multiple valve | 2.53 | 2.47 | 2.64 | 2.53 | |
| Complications | | | | | |
| MMC | 36.19 | 35.99 | 37.13 | 36.31 | .594 |
| Cardiac | 2.57 | 2.52 | 2.66 | 2.56 | .360 |
| Respiratory | 25.43 | 25.99 | 26.23 | 25.89 | .801 |
| Renal failure | 0.76 | 0.69 | 0.74 | 0.72 | .484 |
| Septicemia | 0.88 | 0.89 | 1.21 | 0.96 | <.001 |
| Infection | 1.99 | 1.85 | 2.35 | 2.00 | <.001 |
| Neurologic | 2.79 | 2.62 | 2.74 | 2.69 | .146 |
| Tamponade | 0.52 | 0.58 | 0.62 | 0.57 | .101 |

Data are %, unless otherwise indicated.
*CPD*, chronic pulmonary parenchymal disease; *CABG*, coronary artery bypass grafting.
* Elixhauser Comorbidity Index.

Hospital performance with regard to cardiac surgical patients is likely multifactorial and reflects the agility of hospital resources in early recognition and treatment of life-threatening conditions, such as tamponade or cardiac arrest. Safety-net hospitals, which are hospitals that have a high burden of underinsured patients and have previously been demonstrated to perform worse than their non-safety-net peers in many quality metrics.[12–16] This is perhaps attributable to the relative lack of resources, saturation of these systems and the burden of undiagnosed disease in patients who are served by safety-net hospitals.[17–19] Nonetheless, measures of FTR for cardiac surgery, specifically in safety-net hospitals, have not been previously investigated.[20–22]

With the shifting health care landscape in the United States, safety-net hospitals are experiencing a variety of changes, often with conflicting end results. Although the Affordable Care Act has provided insurance to many, loss of disproportionate share payments from Medicare and penalties for areas of underperformance are thought to particularly affect safety-net hospitals. It is therefore important to evaluate potential disparities in FTRs and outcomes in safety-net hospitals performing complex operations. The present study used a national sample to evaluate the influence of hospital factors on the rates of major complications and death after cardiac surgery. We hypothesized that high-burden hospitals (HBHs) would have higher odds of complications, FTRs, and costs.

## Methods

We performed a retrospective cohort study of all adult patients (aged ≥18 years) in the National Inpatient Sample (NIS) who underwent elective coronary artery bypass grafting, and isolated or concomitaant valve operations between January 2005 and December 2016. Those with nonelective admissions, endocarditis, left-ventricular assist device placement, or heart transplantation at the index encounter were excluded. The NIS is the largest all-payer, inpatient database developed for the Healthcare Cost and Utilization Project, maintained by the Agency for Healthcare Research and Quality.[23] NIS data are generated from state inpatient database discharge abstracts, extracting diagnosis and procedure codes and data on hospital bed size, metropolitan versus rural location, teaching status, and region. Starting in 2012, NIS methodology changed from including 100% of discharges to sampling 20% of discharges from participating institutions. Sampling probabilities for each stratum are used to obtain survey estimates representative of nearly 97% of the US population.[23]

Patient identification and comorbidity assessment were performed using all available International Classification of Diseases-9 and -10 administrative diagnosis and procedure fields available (Supplemental Table I). The Elixhauser Comorbidity Index, a previously validated composite score of 30 common comorbidities,

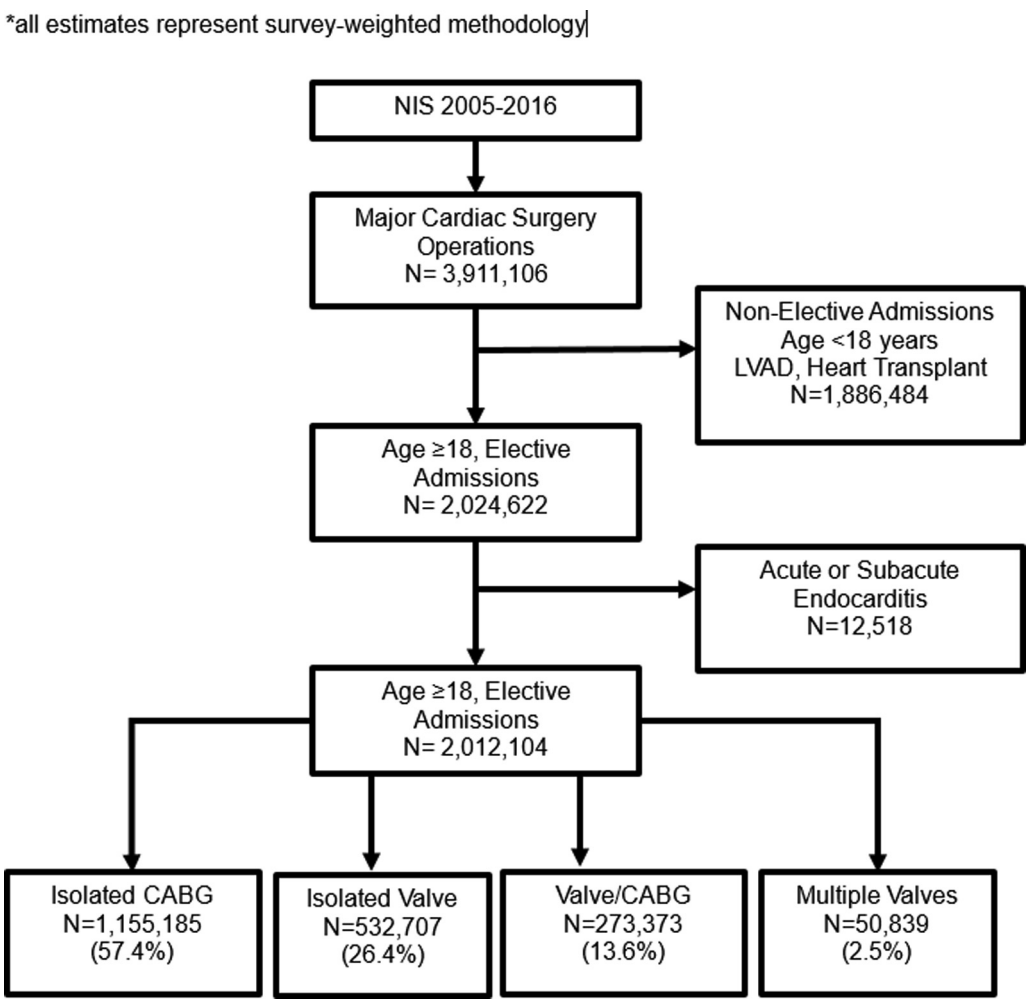


**Fig 1.** Study consort diagram of survey-weighted estimates.

was utilized as an additional measure of patient comorbidity.[24,25] Hospital burden of under- or uninsured patients of all NIS admissions was calculated, with hospitals at the highest quartile of under- or uninsured patient burden designated as safety-net hospitals (HBHs). Hospitals with the lowest quartile of underinsured patients (low-burden hospitals [LBHs]) were used as a reference in comparisons with HBHs. Remaining institutions were designated as medium-burden hospitals (MBHs).[12,14]

The primary outcomes of interest were in-hospital mortality and mortality after the occurrence of major and minor complications (MMCs), a composite variable generated to recognize the occurrence of neurologic, cardiovascular, respiratory, gastrointestinal, renal, and infectious complications. Death associated with any MMC was considered as FTR. Patient and hospital characteristics were compared between several cohorts using univariable and multivariable models, adjusting for patient characteristics. Hospital-level metrics available in the NIS, such as teaching status, bed size, and region, were also considered. $\chi^2$ analysis of survey-weighted data and adjusted Wald two-tailed t-test were utilized to compare patient and hospital characteristics among HBHs and hospitals at the lowest quartile of under- or uninsured patient burden.

Multivariable multilevel regression models were generated to assess predictors of mortality, composite complications, and individual complication categories, using patient and hospital characteristics along with final model selection based on optimized receiver-operating curve and Akaike's and Bayesian information criteria.[26,27] Age was treated in a curvilinear fashion. Adjusted incremental cost-analysis was performed using log transformation and exponentiation. Trends of inpatient all-cause mortality and complications were analyzed over the study period using survey-weighted estimates and a modified Cochran-Armitage test for significance.[28,29] In adherence with NIS guidelines, mediastinitis was included in the composite adverse event variable, but annual rate was not reported owing to its limited incidence.[23] This study was deemed exempt by the institutional review board at the University of California, Los Angeles. Stata software (version 15.1; Stata Corporation, College Station, TX) was used to perform all statistical analyses.

## Results

Of 3,911,106 patients who underwent major cardiac surgery, 2,012,104 met inclusion criteria (Fig 1). Isolated coronary artery bypass grafting was the predominant operation subtype across all institutions (Table I). Hospitals performing cardiac surgery comprised 30.2% of HBHs and 45.8% of LBHs. HBH institutions were more commonly large, metropolitan teaching hospitals compared with LBHs and MBHs (Table I). Patients at HBHs were younger, more likely to be female, more likely to be non-Caucasian, and had higher rates of heart failure, chronic kidney disease, and obesity (Table I).

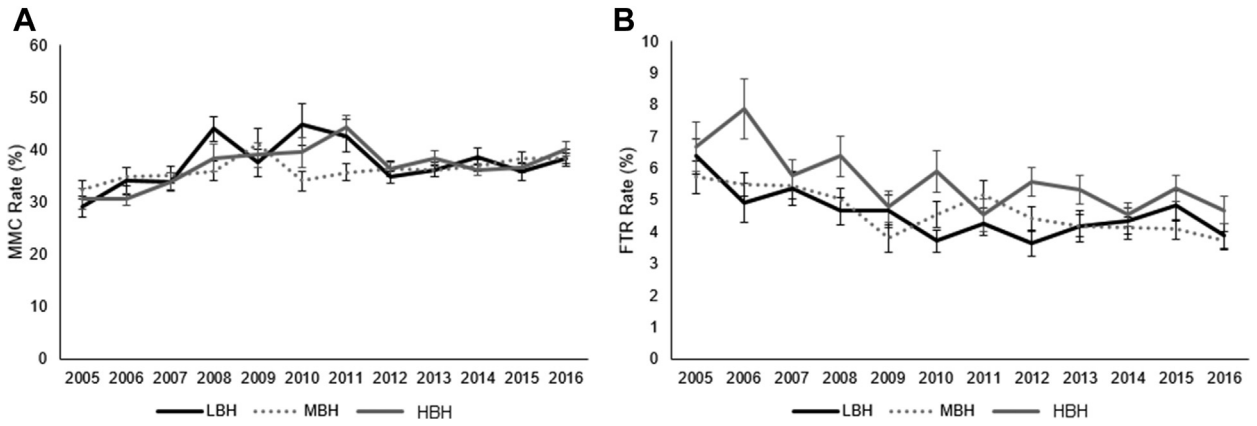


**Fig 2.** Trends in composite complication rate (MMC) (*A*) and FTR (*B*) after elective major cardiac surgery. *For all institutions, the rate of MMCs increased significantly ($P < 0.001$), whereas the rate of FTRs decreased significantly ($P < 0.001$). Error bars represent standard error.

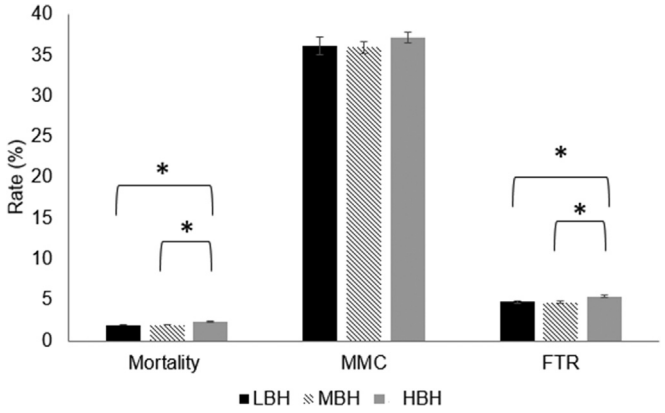


**Fig 3.** Univariate mortality, complications (MMC), and FTRs after MMC rate, stratified by hospital safety-net status. *$P < 0.01$.

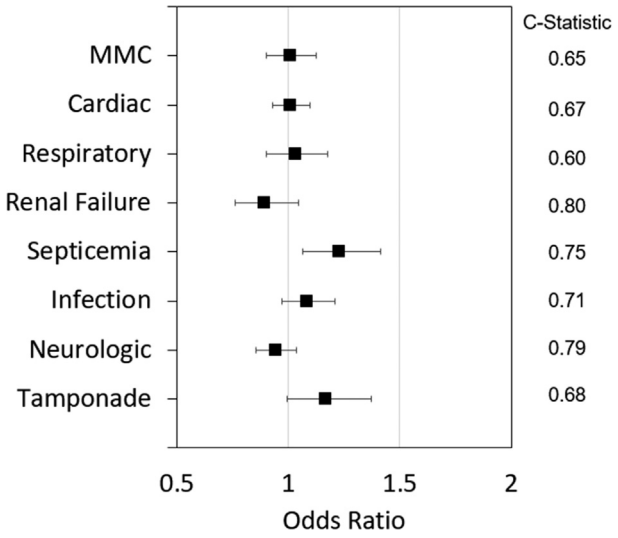


**Fig 4.** Adjusted odds of major complication categories by HBH. *Reference: LBHs, error bars represent 95% confidence intervals. The C-statistic of each model is represented to the right. †Models were adjusted for patient age (curvilinear treatment), sex, history of heart failure, coronary artery disease, cardiac arrhythmia, diabetes, chronic parenchymal pulmonary disease, peripheral vascular disease, history of neurologic disorders, chronic kidney disease, hospital teaching status, hospital region, operative type, and institutional cardiac surgery volume tertiles.

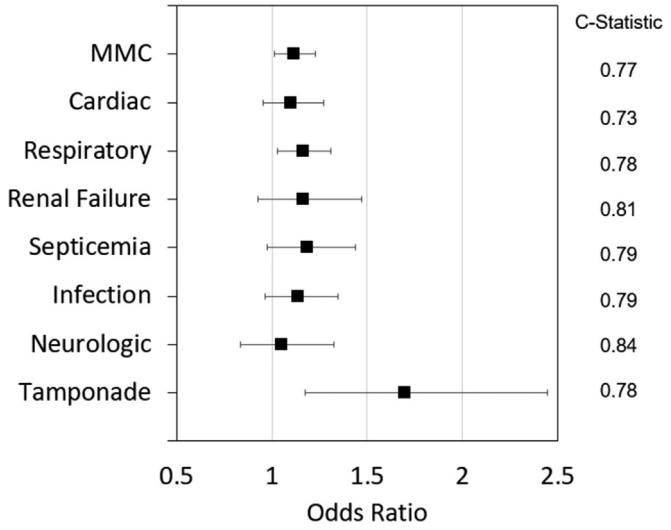


**Fig 5.** Adjusted odds of FTR after major complication categories by HBH. *Reference: LBHs, error bars represent 95% confidence intervals. The C-statistic of each model is represented to the right. †Models were adjusted for patient age (curvilinear treatment), sex, history of heart failure, coronary artery disease, cardiac arrhythmia, diabetes, chronic parenchymal pulmonary disease, peripheral vascular disease, history of neurologic disorders, chronic kidney disease, hospital teaching status, hospital region, operative type, and institutional cardiac surgery volume tertiles.

The overall in-hospital mortality and MMC rates were 2.0% and 36.0%, respectively, for all institutions. All-cause mortality for patients with MMCs was nearly 10-fold higher than in patients with an uncomplicated perioperative course (4.9% vs 0.4%, $P < 0.0001$). Over the study period, rates of MMCs increased, whereas FTR decreased at all institutions (Fig 2). FTR after occurrence of an MMC was significantly higher at HBHs (5.2% vs 4.0%, $P < 0.001$) compared with hospitals with the lowest burden of underinsured patients (Fig 3).

After adjusting for patient and hospital characteristics, HBH status was not associated with increased odds of MMCs (Fig 4). Among all complications that comprised MMCs, infectious adverse events, including septicemia, were more likely for patients treated at HBHs. There were no other significant associations with HBH status and complication categories that comprised MMCs (Fig 4).

HBH status was a significant predictor of FTR after tamponade and septicemia compared with LBHs after risk adjustment (Fig 5). Although the occurrence of MMCs and respiratory complications

**Table II**
Risk-adjusted analysis of predictors of FTR after MMCs

| Variable | Adjusted odds ratio | 95% confidence interval |
|---|---|---|
| Age | 1.06 | 1.05–1.06 |
| Female | 1.40 | 1.33–1.48 |
| Heart failure | 1.91 | 1.80–2.03 |
| Chronic pulmonary parenchymal disease | 0.92 | 0.87–0.98 |
| Peripheral vascular disease | 1.06 | 0.99–1.14 |
| Chronic kidney disease | 1.71 | 1.60–1.83 |
| Hospital teaching status | | |
| Rural | Reference | |
| Urban/nonteaching | 0.92 | 0.75–1.12 |
| Urban/teaching | 0.89 | 0.73–1.08 |
| Hospital region | | |
| Northeast | Reference | |
| Midwest | 1.14 | 1.01–1.29 |
| South | 1.40 | 1.24–1.57 |
| West | 1.21 | 1.06–1.37 |
| Operation | | |
| Isolated CABG | Reference | |
| Isolated valve | 0.58 | 0.52–0.65 |
| CABG/valve | 2.03 | 1.89–2.18 |
| Multiple valve | 1.44 | 1.24–1.67 |
| Institutional operative volume | | |
| LVH | Reference | |
| MVH | 0.93 | 0.86–1.00 |
| HVH | 0.79 | 0.73–0.86 |
| Safety-net status | | |
| LBH | Reference | |
| MBH | 0.98 | 0.90–1.06 |
| HBH | 1.12 | 1.01–1.23 |
| C-statistic | 0.77 | |

*CABG*, coronary artery bypass grafting.

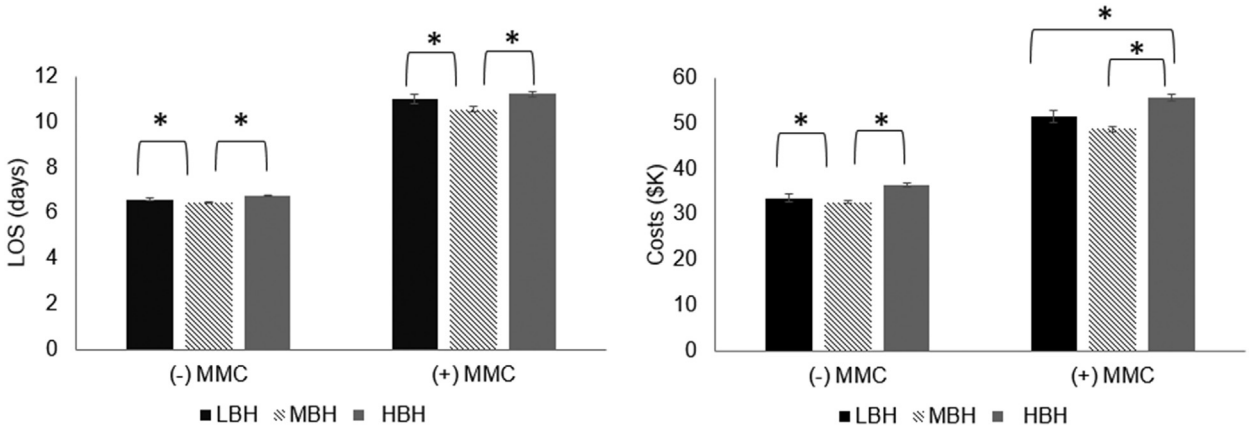


**Fig 6.** Univariate index resource utilization. *$P < 0.01$. (-)MMC represents patients who did not experience any one of the complications examined. (+)MMC represents patients who did experience at least one perioperative complication.

were not associated with HBH status, higher odds of FTR were observed after these adverse events at HBHs compared with LBHs. Additional predictors of FTR after MMCs are listed in Table II, demonstrating variations between regional and teaching hospitals.

Resource utilization at HBHs was also significantly higher than LBHs, with or without occurrence of MMCs (Fig 6). Adjusted cost-analysis further demonstrated an additional $2,480 (95% confidence interval $1,178–3935) in expenditures at safety-net hospitals compared with LBHs after occurrence of an MMC.

## Discussion

Disparities in FTRs have been demonstrated to account for much of the variation in postoperative mortality among different institutions. Access to financial resources, nurse-to-patient ratios, and overcrowding have all been reported to adversely affect FTR rates in safety-net hospitals performing general, vascular, and thoracic operations.[18,19,30] To our knowledge, the present study is the largest, nationwide study to compare outcomes after cardiac surgeries performed at safety-net institutions and to compare their FTR rates with other facilities. We found that over one-third of cardiac surgical patients experienced major complications resulting in a 5% complication-related mortality rate. This death rate is twice the overall value and 10-fold higher than the mortality rate of patients without major complications. After adjusting for patient and hospital characteristics, safety-net classification was independently associated with increased odds of FTR. Several of our findings warrant further discussion.

Compared with an analysis of the Society of Thoracic Surgery (STS) registry, which examined the utility of FTR as a metric of

hospital quality after isolated coronary artery bypass grafting, the present report has a composite complication rate that is nearly 3-fold higher.[22] Surveillance for complications, including cardiac arrest, tamponade, pneumonia, among others, expands beyond those examined in the STS study (prolonged ventilation, renal failure, stroke, and reoperation). In addition, inclusion of more complex operations likely contributed to this discrepancy in reported rates. Conversely, the rate of FTR in the present study is nearly half of that reported by Edwards and colleagues.[22] This discordance between our study and that of the STS registry underscores the importance of standardized metrics for comparison and monitoring of hospital performance.

Furthermore, the present analysis of patients who received elective cardiac surgery, excluding endocarditis, demonstrated increased complication rates at HBHs only for rare events, such as tamponade and septicemia. The impact of safety-net designation on hospitals remains controversial. A comprehensive systematic review using definitions of quality by the Institute of Medicine found safety-net hospitals to be worse performers only in certain areas, such as patient centeredness and efficiency.[18] Although several studies have found that safety-net hospitals are associated with higher complication rates, other studies have refuted these findings.[31–34] With only 30% of safety-net hospitals performing cardiac surgery, the absence of association with increased incidence of all complications with HBHs may be influenced by the inherent availability of resources at HBHs that are capable of performing complex cardiac operations. One might assume that such centers have superior availability of intensivist and perioperative staff, reducing the rate of postoperative complications. Our findings support the general safety of performing cardiac operations in safety-net hospitals, which are crucial for providing specialized care to socioeconomically disadvantaged groups.

Although the overall incidence of complications was not different at safety-net hospitals, odds of mortality after these complications was nearly 17% higher compared with other facilities. With its increasing use as a quality metric, variations in FTR might serve as a finer discrimination tool to assess excellence of care and affect change. Systems-based interventions, such as the implementation of programs targeting high-risk clinical scenarios, have improved adherence to safety metrics but have shown mixed results on quality of care.[35] The observed association between hospital region and teaching facility designation with lower odds of FTR further underscores the potential relationship of institutional factors beyond safety-net designation in prompt recognition of complications. Furthermore, lower adherence to surgical recommendations, such as Surgical Care Improvement Project and STS quality measures,[33] may explain the increase in FTRs after respiratory complications at HBHs.[36,37] Studies examining STS measures of performance at safety-net institutions are not available, and adherence to quality-of-care measures after acute myocardial infarction are over a decade old. Enhanced resources aimed at early recognition and treatment of postoperative complications may serve as an important area for quality improvement at HBHs.

We acknowledge that the present study has several limitations. Given the administrative nature of the NIS, the true cause of inpatient mortality cannot be delineated. Furthermore, we do not have granular patient or hospital-level information regarding nursing specialization, intensivist availability, or compliance with various quality measures at individual centers. Operative information, such as bypass time and occurence of any intraoperative complications, are unavailable to further risk adjust the incidence of and mortality rates associated with the perioperative complications we have selected to study. Given the sampling change of the NIS in 2012, hospital-level designations may be biased. Sensitivity analysis of safety-net status designation from before and after the 2012 sampling change revealed comparable cut-off points for LBHs, MBHs, and HBHs. Institutional cardiac surgery volume was also calculated based on relative case volume within each year, decreasing the likelihood of incorrectly categorizing a high-volume institution as a low-volume institution merely owing to sampling strategy. Despite these limitations, we used a large validated national dataset and robust statistical methods to reduce the risk of bias.

In summary, this is the largest analysis comparing FTR rates after elective cardiac surgical procedures at HBHs with non-HBH counterparts. We found regional and hospital-level disparities in FTR after the occurrence of septicemia, cardiac tamponade, and respiratory complications. With the reform of medical coverage in the United States and its unpredictable impact on patient distribution, safety-net hospitals might be adversely affected. Critical analysis of FTR and efforts toward its improvement might serve as valuable targets for quality improvement among safety-net institutions.

## Funding/Support

None.

## Conflict of interest/Disclosure

The authors report no proprietary or commercial interest in any product mentioned or concept discussed in this manuscript.

## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.1016/j.surg.2019.05.034.

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