

ORIGINAL RESEARCH

SURGERY

Risk Factors for Heart Failure Readmission After Cardiac Surgery



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ABSTRACT

BACKGROUND Heart failure (HF) is a leading cause of readmission after cardiac surgery, yet risk factors for HF readmission after cardiac surgery remain poorly characterized.

OBJECTIVES This study aimed to identify risk factors associated with 30-day HF-specific readmissions after cardiac surgery using a national database.

METHODS We queried the 2016 to 2018 National Readmissions Database to identify U.S. patients who underwent coronary artery bypass grafting (CABG), mitral valve repair/replacement, and/or aortic valve repair/replacement. Exclusion criteria included history of ventricular assist device or heart transplant, dialysis-dependent renal insufficiency, and death during index admission. Clinical variables were defined using International Classification of Diseases-10th Revision codes. The primary outcome was a 30-day readmission for HF following discharge. Multivariable logistic regression was used to account for relevant clinical and demographic covariates and identify independent risk factors for HF readmissions following cardiac surgery.

RESULTS Our study included 394,050 patients who underwent cardiac surgery (mean age 66 ± 12 years, 63% isolated CABG, 27% isolated valve, 11% CABG + valve). Of these patients, 7,318 were readmitted within 30 days of discharge for a principal diagnosis of HF. Independent risk factors of HF-specific readmission included older age, female sex, prolonged length of stay, comorbid congestive HF, nondialysis dependent chronic kidney disease, chronic obstructive pulmonary disease, chronic liver disease, obesity, atrial fibrillation, and acute kidney injury. Prior CABG was marginally protective for HF-specific readmission.

CONCLUSIONS Using a national registry, we identified risk factors associated with HF readmission after cardiac surgery. Further analysis of these risk factors and their association with HF readmission is warranted.

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Unplanned readmission after cardiac surgery remains a significant problem, with rates ranging from about 10% to 20%.¹⁻¹⁰ Postoperative readmissions are associated with increased mortality and high cost burden, with readmissions following coronary artery bypass grafting (CABG) accounting for an estimated annual cost of >\$250 million.⁶ Notably, heart failure (HF) is consistently

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**ABBREVIATIONS
AND ACRONYMS****AKI** = acute kidney injury**CABG** = coronary artery bypass grafting**CKD** = chronic kidney disease**COPD** = chronic obstructive pulmonary disease**HF** = heart failure**ICD9** = International Classification of Diseases - 9th Edition**ICD10** = International Classification of Diseases - 10th Edition**LOS** = length of stay**MCS** = mechanical circulatory support**NRD** = National Readmissions Database

one of the top 3 causes of 30-day readmission after cardiac surgery.^{1-4,6-10} Patients undergoing cardiac surgery are particularly at risk for HF exacerbations due to intraoperative and perioperative factors that can compound on underlying ischemic cardiomyopathy in patients with coronary disease and/or left ventricular remodeling and dysfunction in patients with valvular disease.^{11,12} Therefore, understanding risk factors for HF readmissions is an important step in reducing a source of patient morbidity, mortality, and cost.

Several studies have investigated risk factors for all-cause readmission after cardiac surgery,^{1,6,8,13} but there are scant data regarding risk factors for readmission specifically due to HF, particularly at a national level. One single institution study of over 1,700 patients undergoing cardiac surgery and discharged alive over the span of 2 years found that postoperative length of stay (LOS), diabetes, preoperative HF, and bleeding were all independent risk factors for 30-day HF readmission after a variety of cardiac surgical procedures, including CABG and valvular surgery.⁴ Another study, which included all patients undergoing isolated CABG in New York State and discharged alive over the course of a year, found that age, previous open heart surgery, HF on admission, increased LOS, and renal insufficiency were risk factors for 30-day HF readmission after CABG.² The aforementioned studies were either institutional or state-based, and there is a lack of information regarding risk factors for HF readmission following cardiac surgery using a national database, which would be better powered and generalizable to the US patient population. Furthermore, previous studies on HF readmission following cardiac surgery were typically performed as secondary analyses from more general studies of all-cause readmission, and thus the model, covariates, and primary outcome were not designed with a specific emphasis on risk factors for HF readmission following cardiac surgery.

Given the significant burden of HF readmissions following cardiac surgery and the ongoing lack of adequate studies investigating pertinent risk factors, we sought to better understand risk factors for these readmissions in order to identify at-risk patients who may require closer follow-up and/or alternative preoperative and postoperative management strategies. We utilized a national database to identify risk factors associated with 30-day HF-specific readmission after

cardiac surgery. To our knowledge, this is the first study primarily focused on risk factors for HF readmission after cardiac surgery using a national database.

METHODS

DATA SOURCE. The study population for this retrospective cohort study was collected from the National Readmissions Database (NRD), which is publicly available as part of the Healthcare Cost and Utilization Project by the Agency for Healthcare Research and Quality. The NRD is derived from the Healthcare Cost and Utilization Project State Inpatient Databases and includes discharge data from 2010 to 2018 from 28 states, accounting for up to 58.7% of all U.S. hospitalizations.¹⁴ Unique patient linkage numbers allow for tracking of patients across hospitals within a state, such that readmissions can be monitored.¹⁴ Index admission and readmission diagnoses are based on coding using the International Classification of Diseases-10th Edition (ICD10). The NRD data transitioned from ICD9 to ICD10 coding starting in the last 3 months of 2015,¹⁴ therefore, the cohort of patients in this study spanned from 2016 to 2018 for coding consistency. This protocol received exempt review by the Lifespan Institutional Review Board, IRB#006421.

STUDY POPULATION. The cohort included patients who underwent open cardiac surgical procedures including CABG, mitral valve replacement/repair, and aortic valve replacement/repair, and were discharged alive at the end of their index admission (admission that included cardiac surgical procedure) between January 2016 and December 2018. These procedures were included as they encompass the majority of cardiac surgical procedures in the United States.¹⁵ Exclusion criteria included patients with ventricular assist device implantation or heart transplant, patients with discharges in December due to lack of data on 30-day readmission across calendar years in the NRD, patients who died at the end of their index admission, and patients with dialysis-dependent renal insufficiency including those with dialysis-dependent chronic kidney disease (CKD) and end-stage renal disease, given unique volume management strategies among these patients.

VARIABLES AND OUTCOMES OF INTEREST. Most exposure variables were collected from the NRD database based on ICD10 codes, with the exception of age, sex, elective admission status, insurance status, median household income, hospital bed size, hospital

teaching status, LOS, and discharge disposition, all of which are available as part of the NRD dataset for each patient. (All ICD codes used in this study are listed in Supplemental Table 1)

Exposures for the primary aim of this study included several possible risk factors for HF readmission based on previous studies and clinical relevance. Exposures were considered in terms of baseline demographics, comorbidities, and in-hospital factors. Baseline demographics included age and sex. Comorbidities included preoperative history of smoking, hypertension, diabetes, nondialysis-dependent CKD, HF, chronic obstructive pulmonary disease (COPD), chronic liver disease, obesity, prior CABG, and atrial fibrillation. In-hospital factors included elective status of surgery, LOS, nonroutine discharge, as well as postoperative complications including acute kidney injury (AKI), pneumonia, sepsis, bleeding, and the use of temporary mechanical circulatory support (MCS).

The primary outcome of this study was defined as 30-day readmission for HF as the primary readmission diagnosis after cardiac surgery, measured as a binary variable, with the comparison group including patients who were not readmitted or admitted for a primary diagnosis other than HF. For the primary outcome, readmission HF diagnosis was defined by ICD codes (Supplemental Table 1), which was inclusive of both systolic and diastolic HF.

Subsequent analysis was performed using the same exposures and primary outcome but separated by type of cardiac surgery. Specific cardiac surgery categories included isolated valve surgery, defined as isolated mitral valve repair/replacement and/or aortic valve repair/replacement, isolated CABG, and combined CABG and valvular surgery.

STATISTICAL ANALYSIS. Continuous variables are reported as mean ± SD, with comparisons between outcome groups performed using a t-test. Categorical variables are reported as number and percent, and statistically compared using chi-squared analysis.

Hierarchical logistic regression models were used to determine and quantify independent risk factors of 30-day readmission for HF after cardiac surgery. This model included all variables considered as possible risk factors for HF readmission based on previous studies and clinical relevance, as well as potential confounding variables. All associations between the exposures and the primary outcome are expressed as odds ratio, with 95% confidence intervals and P values. A 2-tailed P value of <0.05 was considered statistically significant. Analysis was performed with SAS 9.4.

TABLE 1 Patient Demographics and Hospital Characteristics Based on 30-Day Readmission for Heart Failure After Cardiac Surgery

	HF Readmission (n = 6,872)	No HF Readmission (n = 387,178)	P Value
Age, y	69.2 ± 10.6	65.5 ± 11.5	<0.001
Female	2,714 (39.5%)	110,641 (28.6%)	<0.001
Nonelective	3,770 (54.9%)	172,748 (44.7%)	<0.001
Hospital bed size			0.125
Small	492 (7.2%)	30,167 (7.8%)	
Medium	1,652 (24.0%)	93,691 (24.2%)	
Large	4,728 (68.8%)	263,320 (68.0%)	
Teaching hospital	5,469 (79.6%)	313,141 (80.9%)	0.002
Comorbidities			
Smoker	2,462 (35.8%)	162,322 (41.9%)	<0.001
Hypertension	5,636 (82.0%)	311,008 (80.3%)	<0.001
Diabetes	3,174 (46.2%)	148,538 (38.4%)	<0.001
CKD	2,510 (36.5%)	68,856 (17.8%)	<0.001
Heart failure	4,611 (67.1%)	142,766 (36.9%)	<0.001
COPD	2,171 (31.6%)	80,346 (20.8%)	<0.001
Liver disease	190 (2.8%)	7,741 (2.0%)	<0.001
Obesity	2,078 (30.2%)	104,087 (26.9%)	<0.001
Prior CABG	398 (5.8%)	18,963 (4.9%)	<0.001
Atrial fibrillation	4,037 (58.7%)	150,898 (39.0%)	<0.001
Surgery type			
CABG	3,607 (52.5%)	242,722 (62.7%)	<0.001
Valve	2,009 (29.2%)	102,707 (26.5%)	<0.001
CABG + valve	1,256 (18.3%)	41,749 (10.8%)	<0.001
Postoperative complications			
AKI	2,859 (41.6%)	72,347 (18.7%)	<0.001
Pneumonia	655 (9.5%)	17,794 (4.6%)	<0.001
Sepsis	289 (4.2%)	9,400 (2.4%)	<0.001
Bleeding	4,409 (64.2%)	219,566 (56.7%)	<0.001
Temporary MCS	772 (11.2%)	25,623 (6.6%)	<0.001
Length of stay, days	14.1 ± 9.8	10.1 ± 8.3	<0.001
Disposition home	1,618 (23.5%)	147,466 (38.1%)	<0.001

Values are mean ± SD or n (%). P value calculated using student's t-test for continuous variables and chi-squared analysis for categorical variables.

AKI = acute kidney injury; CABG = coronary artery bypass graft surgery; CKD = chronic kidney disease; COPD = chronic obstructive pulmonary disease; HF = heart failure; MCS = mechanical circulatory support.

RESULTS

CHARACTERISTICS OF READMITTED PATIENTS. After consideration of inclusion and exclusion criteria, the study included 394,050 patients who underwent cardiac surgery (63% isolated CABG, 27% isolated valve surgery, and 11% combined CABG and valve surgery). The mean age of the study population was 65.5 ± 11.5 years, and 29% were female. Major comorbidities included hypertension (80%), smoking (42%), diabetes (39%), HF (37%), and obesity (27%). Postoperative complications included bleeding (57%), AKI (19%), pneumonia (4.7%), and sepsis (2.5%). Among all patients included in the study, 11% (43,160 patients) were nonelectively readmitted within 30 days for any cause. Complete demographic

TABLE 2 Independent Risk Factors of 30-Day Heart Failure Readmission After Cardiac Surgery

	OR (95% CI)	P Value
Preoperative variables		
Age (by 10 y)	1.19 (1.16-1.22)	<0.001
Female	1.5 (1.42-1.57)	<0.001
Diabetes	1.22 (1.16-1.28)	<0.001
CKD	1.39 (1.31-1.47)	<0.001
Heart failure	2.29 (2.17-2.41)	<0.001
COPD	1.45 (1.37-1.52)	<0.001
Chronic liver disease	1.21 (1.05-1.41)	0.011
Obesity	1.08 (1.03-1.14)	0.004
Prior CABG	0.88 (0.79-0.97)	0.014
Atrial fibrillation	1.67 (1.58-1.75)	<0.001
In-hospital variables		
AKI	1.67 (1.58-1.78)	<0.001
Temporary MCS	1.16 (1.08-1.26)	<0.001
LOS \geq 12 d	1.45 (1.37-1.54)	<0.001
Nonelective surgery	1.08 (1.02-1.13)	0.008
Nonroutine discharge	1.25 (1.17-1.32)	<0.001

Multivariable logistic regression model including the listed covariates, in addition to smoking, hypertension, pneumonia, sepsis, and bleeding, was used to determine independent risk factors of 30-day readmission for heart failure following an index admission involving major cardiac surgery.

AKI = acute kidney injury; CABG = coronary artery bypass graft surgery; CKD = chronic kidney disease; COPD = chronic obstructive pulmonary disease; LOS = length of stay; MCS = mechanical circulatory support.

information on all readmitted patients is listed in [Supplemental Table 2](#).

The top 3 causes for nonelective 30-day readmission were infection (19%), HF (16%), and arrhythmia (11%). HF readmission accounted for 16.2% of all readmissions in patients receiving isolated valvular surgery, 14.5% of all readmissions in patients receiving isolated CABG, and 20.8% of readmissions in patients receiving combined CABG and valvular surgery.

RISK FACTORS FOR HEART FAILURE READMISSIONS.

On univariate analysis, compared to nonreadmitted patients or patients admitted for other causes, those readmitted for HF were older, more likely to be female, and had more preoperative comorbidities and postoperative complications ([Table 1](#)). Multivariable analysis (c-statistic 0.755) assessing risk factors for HF readmissions identified several co-comorbidities as risk factors, including older age, female sex, diabetes, CKD, prior HF, COPD, chronic liver disease, obesity, and atrial fibrillation. In-hospital and postoperative factors associated with HF readmissions included AKI, temporary MCS, LOS \geq 12 days, nonelective surgery, and nonroutine discharge. Prior CABG was marginally protective for HF readmissions ([Table 2](#), [Central Illustration](#)). Frequencies of ICD10 diagnosis codes used to identify patients with history of HF are listed in [Supplemental Table 1](#).

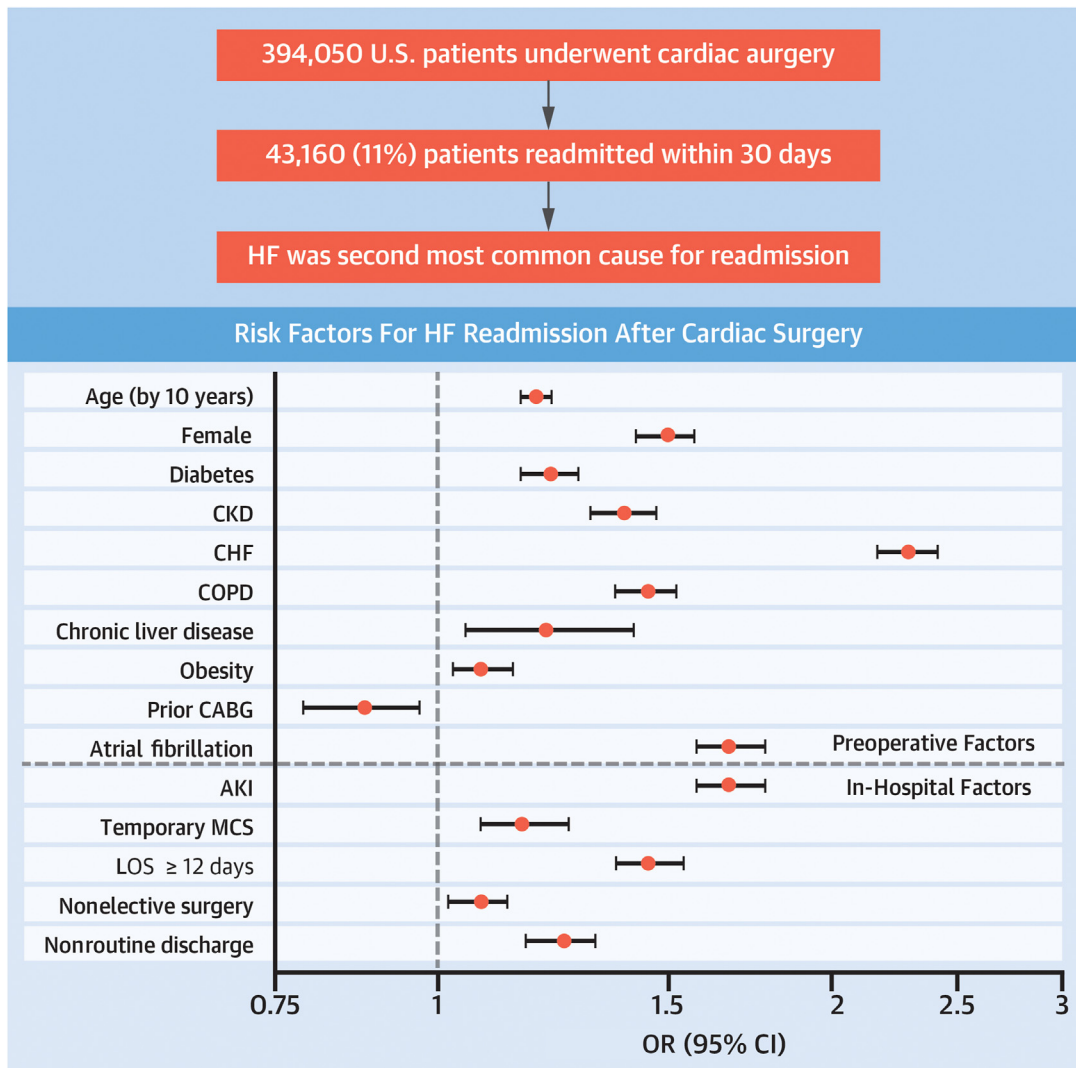
Multivariable analysis assessing risk factors for HF readmission following isolated valve, isolated CABG, or combined CABG and valvular surgery was subsequently performed. Several risk factors for HF readmission were shared among all 3 groups, including older age, female sex, diabetes, CKD, prior HF, COPD, atrial fibrillation, AKI, LOS \geq 12 days, nonelective surgery, and nonroutine discharge. Other risk factors were identified in one or 2 groups but not all 3, including chronic liver disease, obesity, pneumonia, and temporary MCS. Prior CABG was a risk factor for HF readmission in the isolated valve group but was associated with decreased risk of HF readmission in the isolated CABG and combined CABG and valve groups ([Table 3](#)).

DISCUSSION

Utilizing the NRD, we found that independent risk factors for 30-day HF readmissions after cardiac surgery included several preoperative factors including older age, female sex, diabetes, nondialysis dependent CKD, prior HF, COPD, chronic liver disease, obesity, and atrial fibrillation, as well as several in-hospital factors including AKI, temporary MCS, prolonged LOS, nonelective surgery, and nonroutine discharge. Interestingly, prior CABG was marginally protective for HF-specific readmissions. This study is the first to our knowledge to investigate risk factors for HF readmissions following cardiac surgery using a national database. The findings of this study may have important implications for postoperative management and surveillance strategies in patients at risk for HF exacerbation following cardiac surgery.

Several factors likely contribute to HF decompensation following cardiac surgery, including intraoperative and postoperative volume shifts, perioperative fluid resuscitation, myocardial microvascular dysfunction with cardiopulmonary bypass, ischemia/reperfusion injury, and postoperative renal impairment.^{11,12,16} Additionally, many patients who undergo CABG or valve replacement/repair have a pre-existing cardiomyopathy, whether it be due to systolic, diastolic, or combined systolic and diastolic dysfunction. This can be especially true in patients undergoing isolated valvular surgery, given that valvular disease can cause systolic and diastolic ventricular dysfunction and that guideline-based surgical indications are often influenced by the presence of left ventricular dysfunction.¹⁷ Furthermore, in patients undergoing CABG, exacerbations of coronary artery disease in combination with cardiopulmonary bypass and ischemia/reperfusion injury can contribute to myocardial stunning and

CENTRAL ILLUSTRATION Independent Risk Factors for Heart Failure Readmission After Cardiac Surgery



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Forest plot showing odds ratio and 95% CI for 30-day readmission for heart failure after cardiac surgery. Multivariable logistic regression model included above parameters as well as history of smoking and hypertension, as well as in-hospital complications of pneumonia, sepsis, and bleeding/transfusion requirement. Nonroutine discharge defined as any discharge disposition other than home or self-care. AKI = acute kidney injury; CABG = coronary artery bypass grafting; CHF = congestive heart failure; CKD = chronic kidney disease; COPD = chronic obstructive pulmonary disease; LOS = length of stay; MCS = mechanical circulatory support.

cardiomyopathy.¹⁸ It is therefore not surprising that HF is consistently among the top 3 causes of readmissions after cardiac surgery across studies,^{1-4,8} including in our analysis.

Identification of factors specifically related to HF readmissions after cardiac surgery has not been adequately investigated, though a few institution- and state-based studies have explored this topic.

In a state-based study out of New Jersey, Moreyra and others found that over a 10 year period (from 1998 to 2007), HF hospitalizations following CABG surgery increased among patients with ejection fraction <35%.¹⁹ Independent risk factors for HF admissions in this cohort included ejection fraction, older age, female sex, Black race, smoking, diabetes, renal disease, hypertension, and cerebrovascular

TABLE 3 Independent Risk Factors of 30-Day Heart Failure Readmission After Cardiac Surgery by Procedure Type

	Isolated Valve		Isolated CABG		CABG + Valve	
	OR (95% CI)	P Value	OR (95% CI)	P Value	OR (95% CI)	P Value
Preoperative						
Age (by 10 y)	1.20 (1.14-1.25)	<0.001	1.18 (1.14-1.23)	<0.001	1.14 (1.06-1.22)	<0.001
Female	1.48 (1.35-1.62)	<0.001	1.47 (1.37-1.58)	<0.001	1.48 (1.32-1.67)	<0.001
Diabetes	1.22 (1.10-1.35)	<0.001	1.30 (1.21-1.39)	<0.001	1.18 (1.05-1.33)	0.007
CKD	1.45 (1.30-1.62)	<0.001	1.44 (1.33-1.56)	<0.001	1.20 (1.05-1.37)	0.009
Heart failure	1.98 (1.78-2.20)	<0.001	2.39 (2.22-2.57)	<0.001	1.88 (1.64-2.14)	<0.001
COPD	1.50 (1.36-1.66)	<0.001	1.44 (1.33-1.55)	<0.001	1.40 (1.23-1.58)	<0.001
Chronic liver disease	1.35 (1.06-1.72)	0.016	1.13 (0.91-1.41)	0.28	1.11 (0.77-1.61)	0.57
Obesity	1.11 (1.00-1.23)	0.0599	1.07 (0.99-1.15)	0.079	1.17 (1.02-1.33)	0.020
Prior CABG	1.58 (1.32-1.90)	<0.001	0.70 (0.60-0.82)	<0.001	0.74 (0.59-0.94)	0.015
Atrial fibrillation	1.69 (1.53-1.88)	<0.001	1.62 (1.51-1.73)	<0.001	1.49 (1.32-1.68)	<0.001
In-hospital						
Pneumonia	0.99 (0.83-1.17)	0.8908	1.13 (1.00-1.28)	0.049	1.03 (0.85-1.26)	0.75
AKI	1.71 (1.53-1.91)	<0.001	1.64 (1.51-1.78)	<0.001	1.67 (1.46-1.90)	<0.001
Temporary MCS	1.10 (0.88-1.36)	0.4118	1.2 (1.08-1.32)	<0.001	1.26 (1.05-1.51)	0.014
LOS \geq 12 d	1.40 (1.25-1.57)	<0.001	1.55 (1.43-1.68)	<0.001	1.18 (1.02-1.36)	0.027
Nonelective surgery	1.20 (1.08-1.34)	<0.001	1.13 (1.05-1.22)	0.001	1.14 (1.00-1.3)	0.043
Nonroutine discharge	1.27 (1.14-1.41)	<0.001	1.22 (1.12-1.32)	<0.001	1.22 (1.05-1.41)	0.010

Bold values indicate $P < 0.05$. Separate multivariable logistic regression models run for each surgical group. All regression models included the same variables, including the listed covariates, in addition to smoking, hypertension, sepsis, and bleeding, to determine independent risk factors of 30-day readmission for heart failure following an index admission involving major cardiac surgery.

AKI = acute kidney injury; CABG = coronary artery bypass graft surgery; CKD = chronic kidney disease; COPD = chronic obstructive pulmonary disease; LOS = length of stay; MCS = mechanical circulatory support.

disease.¹⁹ Another state-based study out of New York by Hannan et al² found that older age, prior open heart surgery, stroke, previous congestive heart failure diagnosis, prolonged LOS, and severe renal dysfunction including need for dialysis were associated with HF-specific readmissions. These findings are largely consistent with our analysis using a national database. Interestingly, in the current study, we found that prior CABG in patients who underwent another CABG procedure was slightly protective for HF readmissions, a relationship that could possibly be secondary to differences in preoperative and postoperative follow-up in patients likely already known to cardiology and cardiac surgical teams. In a single hospital-based study, D'Agostino and others investigated risk factors for readmission following cardiac surgery, with an additional analysis assessing independent risk factors for HF-related readmission.⁴ Risk factors for HF readmission identified in that study included preoperative HF diagnosis, prolonged LOS, diabetes, plasma or platelet transfusion, postoperative inotrope use, and reoperation for bleeding.⁴ Compared to the current study, these state-based and single-institution studies have an advantage of increased granularity in covariates compared to ICD coding. However, several of the aforementioned studies

investigated risk factors for HF readmission as ancillary analyses to studies aimed primarily at determining general characteristics of overall readmission after cardiac surgery. Further, the current national database study has the advantage of increased power using data representative of admissions across the United States.

Our analysis of risk factors for HF readmission after cardiac surgery based on type of surgery underscored the significance of most of the aforementioned risk factors, which were shared among the 3 major categories of surgical procedures. Interestingly, prior CABG was found to be a risk factor for HF readmission only in the isolated valve surgery group but was cardioprotective in the isolated CABG and combined CABG and valve groups. These differences may reflect differences in pre-existing cardiomyopathy between groups, as indications for asymptomatic isolated valvular surgery are often based on the presence of left ventricular dysfunction, whereas criteria for valve replacement are less stringent in patients undergoing CABG.¹⁷

An interesting finding in the current study is the relationship between nondialysis-dependent renal insufficiency and HF-specific readmission following cardiac surgery. This relationship may be in part due to major volume shifts that occur after cardiac

surgery, and patients with renal dysfunction may not tolerate these volume shifts as well as others.¹³ Dialysis dependence is an established risk factor for all-cause readmission after cardiac surgery,^{1,2,5-8} and most studies that consider renal sufficiency in the analysis model focus only on dialysis-dependent renal insufficiency.^{2,5-8} However, nondialysis dependent CKD may be a subtle but valuable risk factor for postoperative HF readmissions. Patients with CKD may require higher doses of loop diuretics to achieve an adequate response,^{20,21} and clinicians are often hesitant to aggressively diuretic patients with elevated creatinine levels.²² It is therefore particularly notable that nondialysis-dependent CKD was an independent risk factor for postcardiac surgery HF readmissions, as these patients may benefit from more careful volume management strategies and/or closer follow-up care.

One possible strategy for reducing HF-specific readmissions following cardiac surgery is early involvement of cardiology and/or HF specialists in the perioperative setting in patients with known risk factors for HF readmission. Preoperative and postoperative care with guideline-directed medical therapy and volume management strategies in patients with reduced ejection fraction, diastolic dysfunction, and other risk factors for HF readmission as identified in this study and others may help mitigate readmission burden. However, additional studies in this area are warranted to determine whether these interventions affect outcomes.

STUDY LIMITATIONS. There are several limitations in this study, many of which are inherent to the use of an administrative database. One limitation is that of competing risks, as the NRD does not capture patients who died outside of the hospital or patients readmitted to a hospital in a different state from that of the index admission. Additionally, we lack mortality data in this study, as mortality data is not available in the NRD unless death occurs during an inpatient admission within 1 calendar year of the initial admission. Furthermore, patients who are admitted with a primary diagnosis other than HF but with HF exacerbation as a major component of their readmission may be missed in the analysis. Another limitation of this study, also related to a limitation of the administrative database, is that of unmeasured confounding. Because diagnoses are limited to ICD10 coding, the data lacks important clinical information such as volume status, preoperative ejection fraction, lab data, detailed operative information, diuretic and other medication use, number of transfusions, and

other factors that may have important effects on the analysis but are not able to be measured and accounted for. There may also be issues with misclassification, such as patients with a particular diagnosis who lack a formal ICD diagnosis listed in the patient record.

CONCLUSIONS

Using a national registry, we were able to identify risk factors associated with 30-day HF readmissions after cardiac surgery, including several preoperative factors such as older age, female sex, diabetes, nondialysis-dependent CKD, prior HF diagnosis, COPD, chronic liver disease, obesity, atrial fibrillation, as well as several in-hospital factors including AKI, temporary MCS, prolonged LOS, nonelective surgery, and nonroutine discharge. Further analysis of these risk factors and their association with HF readmission is warranted.

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PERSPECTIVES

COMPETENCY IN PATIENT CARE: HF is an ongoing leading cause of readmission after cardiac surgery, and clinicians should be able to identify patients at higher risk of these readmissions. This study demonstrates that preoperative risk factors include older age, female sex, diabetes, nondialysis-dependent CKD, prior HF diagnosis, COPD, chronic liver disease, obesity, and atrial fibrillation. In-hospital factors associated with HF readmission following cardiac surgery include AKI, temporary MCS, prolonged LOS, nonelective surgery, and nonroutine discharge.

TRANSLATIONAL OUTLOOK: These findings may help identify patients at risk for HF exacerbation following cardiac surgery and who may benefit from preoperative and postoperative optimization, management, and surveillance strategies.

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APPENDIX For supplemental tables, please see the online version of this paper.