Early readmission for congestive heart failure predicts late mortality after cardiac surgery

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Objective: Early readmission in patients hospitalized for medical congestive heart failure is common, expensive, and associated with a worse late survival. Our objective was to compare late survival in patients' readmission for congestive heart failure with readmission for other causes in patients undergoing cardiac surgery.

Methods: Of 3654 consecutive patients undergoing cardiac surgery at a single institution between April 2004 and June 2010, 3492 (96%) were discharged from the hospital before 30 days and analyzed. Survival curves by readmission reason were compared using the log-rank test. Multivariable analyses adjusted for patient demographics, known preoperative cardiac risk factors, and surgical characteristics.

Results: The readmission rate at 30 days was 13% (465/3492): 23% for arrhythmias/heart block, 12% for congestive heart failure, 40% for surgery related causes, 14% for infection, and 11% for noncardiac causes. Independent risk factors for readmission include age, gender, congestive heart failure, and cardiopulmonary bypass time. Eight percent (268/3492) of discharged patients died within the 6-year study: 14% in the readmission group versus 7% in the nonreadmission group ($P < .01$). Patients who had been readmitted for congestive heart failure had worse late survivals compared with all patients who had been readmitted for causes related to their surgery.

Conclusions: Readmission within 30 days after cardiac surgery for congestive heart failure predicts late mortality. Targeted postoperative management may be warranted in patients with surgical congestive heart failure. (J Thorac Cardiovasc Surg 2012;144:671-6)

Early readmission is common in patients hospitalized for medical congestive heart failure (CHF). Estimated 30-day readmission rates approach 25%^{1,2} among patients with previous heart failure hospitalization. In the elderly population, readmission rates may be as high as 45%.^{3,4} Frequent readmissions are associated with high personal and shared medical costs, and burden the already stressed health care system. In addition to its monetary consequence, readmission has long served as a predictor of worse patient outcomes. All-cause readmission after heart failure hospitalization has proven to be a predictor of both 1-year and total mortality in elderly outpatient populations.^{5,6}

Although early readmission has been widely studied in the population with medical heart failure, limited data availability precluded an accurate description of the relationship between early readmission and late outcomes after cardiac surgery. The Society of Thoracic Surgeons National Database reports 30-day readmission rates within this patient population to range from 9.0% to 14.5%, varying by

surgery type.⁷ As in medical heart failure readmission, readmission in the population who underwent cardiac surgery is expensive and believed to be associated with poorer outcomes. However, this patient population requires separate study because readmission causes and subsequent outcomes differ from those of patients with nonsurgical heart failure. Our objective was to define the impact of 30-day readmission on late survival after cardiac surgery, with specific focus on those patients' readmission for CHF.

PATIENTS AND METHODS

A total of 3654 patients underwent cardiac surgery at Northwestern Memorial Hospital between April 2004 and June 2010. This project was approved by the institutional review board at Northwestern University (institutional review board project STU000012288). Any subject refusing participation in the project was not included in this analysis. Included surgeries were aortic and mitral valve repairs and replacements, coronary artery bypass grafting (CABG), and combined procedures. All ventricular assist device and transplant recipients were excluded from study. The remaining 3492 patients (96%) discharged from the hospital before 30 days after surgery constitute our study population. Their institutional database records were retrospectively collected and analyzed. All readmissions to Northwestern Hospital were included from institutional records. In addition, readmissions from outside hospitals were determined by a mailed survey that inquired of any hospital admissions or procedures since discharge and included an information release form to allow our data collection from other institutions. Readmission occurrence and reason were determined and adjudicated by Northwestern University's Bluhm Cardiovascular Institute Clinical Trials Unit staff based on institutional progress notes and discharge summaries in accordance with the Society of Thoracic Surgeons database.⁷ Readmission reasons were grouped into 5 categories:

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Abbreviations and Acronyms

BMI	= body mass index
CABG	= coronary artery bypass grafting
CHF	= congestive heart failure
CI	= confidence interval
OR	= odds ratio

(1) arrhythmia, (2) CHF, (3) infection (deep sternum, conduit harvest site, or pneumonia), (4) surgery-related reason (acute vascular complication, anticoagulation complication, coronary artery dysfunction, myocardial infarction, pericardial effusion or tamponade, permanent cerebrovascular accident, renal failure or transient ischemic attack, or other surgery-related readmission, including surgical complications such as graft failure), and (5) nonrelated reason (including gastrointestinal complications and bleeds). Mortality was ascertained by Social Security Death Index and telephone follow-up.

Statistical Analyses

The association between every baseline variable (patient demographics, preoperative variables, and surgical characteristics) and 30-day readmission status was measured using a series of univariate logistic regression models. Variables significant at a 2-sided 5% alpha level are shown in Table 1. Variables in Table 1 were used as the initial pool of factors to create a multivariate logistic regression model. A stepwise variable selection procedure with 10% entry/exit significance levels was performed. The resulting multivariate logistic regression model was subsequently adjusted for surgical procedure type (isolated CABG, isolated valve, and CABG + valve). All significant variables in the final model are presented in Table 2. A similar approach was used to construct a multivariate model for 30-day CHF readmission. As such, variables significantly associated with 30-day CHF readmission in univariate and multivariate fashion are shown in Tables 3 and 4, respectively. All-cause long-term mortality was summarized using Kaplan–Meier survival curves. Overall survivorship comparisons between the readmission and nonreadmission groups were based on the log-rank test. A Cox regression model that adjusts for surgical procedure and all the univariate 30-day readmission predictors listed in SAS 9.2 software (SAS Inc, Cary, NC) was used to perform all statistical analyses. Statistical significance was established at the 2-sided 5% alpha level, and no multiplicity adjustments were made.

RESULTS

Some 66% of our patient population was male (2321/3492) with a mean body mass index (BMI) of 28.0 (± 5.8). Mean age was 63.2 ± 13.7 years, and 81% of surgeries were elective.

Risk Factors for 30-Day All-Cause Readmission After Cardiac Surgery

Of the 3492 patients discharged within 30 days of cardiac surgery, 465 (13%) required hospital readmission within 30 days of surgery. Of these patients, 23% were readmitted for arrhythmia or heart block, 12% were readmitted for CHF, 14% were readmitted for infection, 40% were readmitted for surgery-related reasons, and 11% were readmitted for nonrelated reasons (Table 5).

Significant univariate 30-day readmission risk factors are shown in Table 1. They include age, gender, history of CHF,

and New York Heart Association class III or IV. Initial length of hospital stay was also a significant predictor for early readmission: mean 7.67 ± 4.17 days for readmission versus 7 ± 3.88 days for nonreadmission (odds ratio [OR], 1.04; 95% confidence interval [CI], 1.02–1.06; $P < .001$). Independent multivariate predictors for 30-day readmission presented in Table 2 are age (OR, 1.13 per decade), female gender (OR, 1.29), history of CHF (OR, 1.29), cardiopulmonary bypass time (OR, 1.30 per hour), and readmission to the intensive care unit (OR, 1.53).

Risk Factors for 30-Day Congestive Heart Failure Readmission After Cardiac Surgery

Significant univariate 30-day CHF readmission risk factors are shown in Table 3 and include age, gender, history of CHF, history of atrial fibrillation, and initial length of hospital stay: median 8 (interquartile range, 6–12) days in CHF readmission versus 6 (interquartile range, 5–8) days in CHF nonreadmission (OR, 1.11; 95% CI, 1.06–1.16; $P < .001$). Independent multivariate predictors for 30-day readmission presented in Table 2 are history of CHF

TABLE 1. Univariate risk factors for 30-day readmission

Variable	OR	95% CI	P value
Age by decade	1.13	1.05–1.22	.002
Gender, female	1.32	1.07–1.62	.009
Diabetes	1.31	1.03–1.67	.027
Renal failure requiring dialysis	1.79	1.00–3.21	.049
Hypertension	1.28	1.03–1.59	.026
Prior cardiac intervention	1.28	1.04–1.57	.019
Prior valve surgery	1.46	1.02–2.08	.041
CHF	1.52	1.22–1.90	<.001
NYHA class III/IV	1.34	1.09–1.64	.005
History of atrial fibrillation	1.41	1.12–1.77	.003
Preoperative anticoagulant use	1.33	1.01–1.75	.041
Preoperative aspirin use	1.30	1.05–1.62	.018
Preoperative beta-blocker use	1.33	1.08–1.64	.007
Preoperative antiarrhythmic use	1.48	1.02–2.13	.037
LVEF by 10%	0.92	0.85–0.99	.026
Coronary artery disease	1.40	1.03–1.91	.030
Tricuspid insufficiency $\geq 2+$	1.52	1.15–2.02	.004
CABG procedure	1.09	0.90–1.33	.385
Aortic valve surgery	1.13	0.92–1.38	.236
Mitral valve surgery	1.01	0.82–1.25	.921
Tricuspid valve surgery	1.75	1.26–2.44	<.001
Other cardiac surgery	1.33	1.09–1.61	.005
Atrial fibrillation ablation surgery	1.40	1.09–1.79	.008
Cardiopulmonary bypass time (h)	1.29	1.16–1.44	<.001
Crossclamp time (h)	1.30	1.13–1.50	<.001
Intraoperative blood products used	1.46	1.19–1.79	<.001
Postoperative blood products used	1.32	1.08–1.61	.006
Readmission to the ICU	1.92	1.29–2.85	.001
Length of stay (d)	1.04	1.02–1.06	<.001

OR, Odds ratio; CI, confidence interval; CHF, congestive heart failure; NYHA, New York Heart Association; LVEF, left ventricular ejection fraction; CABG, coronary artery bypass grafting; ICU, intensive care unit.

TABLE 2. Multivariate risk factors for 30-day readmission

Characteristics	OR	95% CI	P value
Age by decade	1.13	1.04-1.23	.006
Gender, female	1.30	1.04-1.63	.019
CHF	1.31	1.03-1.66	.028
Cardiopulmonary bypass time	1.31	1.17-1.47	<.001
Readmission to the ICU	1.52	0.98-2.36	.059

Variables entered into the model include age; gender; diabetes; dialysis; hypertension; previous cardiac intervention or valve surgery; CHF; New York Heart Association class III/IV; history of atrial fibrillation; anticoagulant, aspirin, beta-blocker, and antiarrhythmic use; ejection fraction; coronary artery disease; tricuspid regurgitation 2+; tricuspid valve surgery; atrial fibrillation ablation surgery; cardiopulmonary bypass time; crossclamp time; intraoperative and postoperative blood products; readmission to the intensive care unit; and length of stay. *OR*, Odds ratio; *CI*, confidence interval; *CHF*, congestive heart failure; *ICU*, intensive care unit.

(OR, 3.36), history of atrial fibrillation (OR, 3.16), preoperative aspirin use (OR, 2.24), and postoperative blood products (OR, 2.80).

Overall 30-Day Readmission Predicts Late Mortality

Eight percent (268/3492) of patients discharged within 30 days after cardiac surgery died during the 6-year study period: 14% of the readmission group and 7% of the non-readmission group ($P < .001$) (Figure 1).

TABLE 3. Risk factors for readmission in those readmitted for congestive heart failure, univariate analysis

Characteristics	OR	95% CI	P value
Age by decade	1.33	1.04-1.69	.022
Dyslipidemia	2.08	1.09-3.95	.026
Chronic lung disease	2.10	1.06-4.15	.034
Peripheral vascular disease	2.60	1.08-6.26	.033
Prior cardiac intervention	3.22	1.80-5.77	<.001
Prior CABG	3.69	1.79-7.58	<.001
Prior PCI	2.15	1.06-4.35	.033
Prior MI	2.88	1.47-5.65	.002
CHF	3.51	1.92-6.44	<.001
NYHA class III/IV	2.69	1.50-4.82	<.001
History of atrial fibrillation	3.29	1.74-6.24	<.001
Preoperative warfarin (Coumadin; Bristol-Myers Squibb, New York, NY) use	3.09	1.31-7.27	.010
Preoperative aspirin use	2.33	1.28-4.25	.006
LVEF by 10%	0.69	0.56-0.84	<.001
Coronary artery disease	2.27	1.02-5.07	.045
Left main disease	2.94	1.22-7.10	.017
Tricuspid insufficiency $\geq 2+$	2.66	1.34-5.26	.005
Repeat sternotomy	2.95	1.56-5.58	<.001
Intraoperative blood products used	3.17	1.53-6.53	.002
Postoperative blood products used	3.23	1.69-6.17	<.001
Total hours in the ICU	1.01	1.00-1.01	.003
Length of stay (d)	1.09	1.03-1.16	.002

All models are adjusted for type of surgery: isolated CABG, isolated valve, and CABG + valve. *OR*, Odds ratio; *CI*, confidence interval; *CABG*, coronary artery bypass grafting; *PCI*, percutaneous coronary intervention; *MI*, myocardial infarction; *CHF*, congestive heart failure; *NYHA*, New York Heart Association; *LVEF*, left ventricular ejection fraction; *ICU*, intensive care unit.

TABLE 4. Multivariable analyses: Risk factors for 30-day readmission for congestive heart failure

Characteristics	OR	95% CI	P value
CHF	2.89	1.42-5.86	.003
History of atrial fibrillation	4.94	2.33-10.46	<.001
Preoperative aspirin use	2.31	1.14-4.66	.020
LVEF by 10%	0.78	0.62-0.98	.034
Postoperative blood products used	2.81	1.42-5.57	.003

Variables entered into the model include age, dyslipidemia, chronic lung disease, peripheral vascular disease, previous cardiac intervention, previous CABG, previous percutaneous coronary intervention, myocardial infarction, CHF, New York Heart Association class III/IV, history of atrial fibrillation, warfarin (Coumadin) and aspirin use, ejection fraction, coronary artery disease, left main disease, tricuspid regurgitation 2+, repeat sternotomy, intraoperative and postoperative blood products, total hours in the intensive care unit, and length of stay. *OR*, Odds ratio; *CI*, confidence interval; *CHF*, congestive heart failure; *LVEF*, left ventricular ejection fraction.

After adjusting for surgical procedure type (isolated CABG, isolated valve, and CABG + valve) and all other univariate predictors in Table 1, 30-day readmission remained a statistically significant predictor of late mortality (hazard ratio, 1.45; 95% CI, 1.04-2.02; $P = .028$).

Late Mortality Rates by Readmission Reason

Patients readmitted for CHF and noncardiac-related reasons had the highest long-term mortality rates (Table 6). Kaplan–Meier survival curves were created for the nonreadmission group and 5 readmission groups (Figure 2), and were compared using the log-rank test. Readmission for CHF was found to be associated with significantly worse late survival than nonreadmission and all other readmission causes related to surgery (log-rank, 7.60; $P = .006$). Patients readmitted for noncardiac-related causes had similar late survival as those readmitted for CHF (log-rank, 0.71; $P = .397$).

TABLE 5. Thirty-day readmission patient classification (N = 465)

Readmission reason	N	%
Arrhythmia/heart block	105	22.6
CHF	56	12.0
Infection	67	14.4
Deep sternum	13	2.8
Conduit harvest site	15	3.2
Pneumonia	39	8.4
Surgery-related reason	184	39.6
Acute vascular complication	3	0.7
Anticoagulation complication	8	1.7
Coronary artery dysfunction	1	0.2
Myocardial infarction	8	1.7
Pericardial effusion or tamponade	17	3.7
Permanent CVA	8	1.7
Renal failure	3	0.7
TIA	7	1.5
Other surgery-related readmission	129	27.7
Nonrelated reason	53	11.4
Total readmissions	465	

CHF, Congestive heart failure; *CVA*, cerebrovascular accident; *TIA*, transient ischemic attack.

FIGURE 1. Kaplan-Meier survival curves by 30-day readmission status (log-rank, 28.9; $P < .001$).

Readmission for surgery-related reasons was associated with a significantly lower rate of survival compared with nonreadmission (log-rank, 11.83; $P < .001$). Readmission for infection was not associated with worse late survivals compared with nonreadmission (log-rank, 2.25; $P = .134$). Readmission for arrhythmia was associated with significantly lower late mortality when compared with readmission for all other causes (log-rank, 11.70; $P < .001$).

DISCUSSION

Readmission after cardiac surgery is common and associated with worse outcomes.¹⁻⁴ Although the correlation between readmission and late mortality has been established in a patient population with medical CHF, limited data exist on the effect of early readmission on outcomes after cardiac surgery.

This study found older age, female gender, CHF, and increased cardiopulmonary bypass time to be significantly associated with 30-day readmission. Kumbhani and colleagues⁸ reported intraoperative myocardial acidosis to also predict readmission after cardiac surgery. This variable was not analyzed in this study, but this and other surgical complications are also potential risk factors for

readmission. Rockx and colleagues⁹ found that a BMI greater than 30 is predictive of early readmission. However, BMI was not found to be associated with higher readmission rates in this study. Because elevated BMI is linked to an increased risk of sternal wound and leg infections, of which this study had few, high BMI-related complications did not lead to a significant increase in readmissions. This study also analyzed BMI on a continuous numeric spectrum instead of grouping patients by designated BMI range as in the study by Rockx and colleagues.

Lahey and colleagues¹⁰ found that patients postoperatively discharged after 7 or more days were twice as likely to be readmitted as those discharged sooner. We also found initial length of hospital stay was significantly associated with early readmission in univariate models, but not in multivariate analysis. However, we did not isolate and further analyze the subgroup of patients with extremely long lengths of stay.

Our data suggest that not all readmissions, but specifically CHF and nonsurgery-related readmissions, are associated with reduced survival. Readmission for CHF was associated with higher mortality than all other surgery-specific readmission and nonreadmission groups. This study identifies CHF as a risk factor for both all-cause and CHF-related early readmission. In addition, it is associated with increased all-cause long-term mortality. Thus, patients with CHF are a high-risk group for elevated hospital costs and worse outcomes. It is not surprising that the preoperative presence of CHF and a lower ejection fraction are associated with readmission in this group. However, these data further support the role of atrial fibrillation as a marker or cause of a sicker population within the CHF group. After further validation of these findings, to reduce both readmission and subsequent mortality, targeted

TABLE 6. Readmission reasons by all-cause long-term mortality

Readmission reason	No. deceased/no. readmitted	% Deceased
Arrhythmia	4/105	3.8
CHF	16/56	28.6
Infection	8/67	11.9
Nonrelated reason	13/53	24.5
Surgery-related reason	25/184	13.6
Total	66/465	14.2

CHF, Congestive heart failure.

FIGURE 2. Kaplan–Meier overall survival curves by 30-day readmission status and reason. Kaplan–Meier survival curves for all readmitted types and nonreadmitted patients. CHF, Congestive heart failure.

strategies could be developed to identify and treat high-risk patients with CHF undergoing cardiac surgery. Patients readmitted for noncardiac-related reasons, such as gastrointestinal complications, had late survival similar to those in the CHF readmission group. These patients may also benefit from targeted preventative therapies.

Patients readmitted for infection did not have different survival from those not readmitted. Filsoofi and colleagues¹¹ alternatively found deep sternal wound infections after cardiac surgery to be associated with increased mortality. The small number of sternal wound infections in this study limited the analysis in our population. Certainly, if there were more sternal infections, there may be a different result. However, prevention remains the best method to address this problem.

Of note, readmission for arrhythmias was associated with better survival than nonreadmission. This is likely due to the group's overall healthier patient population. The presence of comorbidities also tended to be less in this group compared with other readmission and nonreadmission groups, including preoperative hypertension, diabetes, chronic obstructive pulmonary disease, and prior myocardial infarction or stroke.

This study has several limitations. It was performed at a single institution, which may reduce its widespread applicability because of differences in patient populations and care practices among treatment centers. Although extensive effort was made to identify all the readmissions in the study, some outside readmissions may not be reported. However, patient characteristics, overall readmission rate, and proportion of patients within readmission reason groups were similar to those reported in the Society of Thoracic Surgeons national database. The Society of Thoracic Surgeons national average readmission rate for all valve heart surgery, CABG, and combined procedures is

11.8%: 13.8% for arrhythmias, 15.8% for CHF, 20% for all infections, 15.1% for surgery-related reasons (including 2.1% myocardial infarction and 2.2% stroke), and 35.3% for nonrelated reasons,⁷ which is comparable to our experience.

Further, study duration is limited to 6 years and a relatively small population. To perform statistical analyses, readmission types were grouped into 5 categories. The readmission groups for infection, surgery-related reasons, and nonrelated reasons were particularly heterogeneous, with the possibility that certain subgroups directionally shifted associated trends. If a larger patient population was available for study, additional readmission groups could be analyzed to more specifically pinpoint high-risk patients.

Finally, unknown confounders are always a concern in retrospective studies. Determination of unknown causes for readmission and worse late survival are of importance because readmission is not itself a cause but a predictor of late mortality.

CONCLUSIONS

Despite the study's limitations, to the best of our knowledge, this is the first systematic study of the relationship between early readmission and late mortality in a patient population undergoing cardiac surgery. Our data suggest that not all readmission reasons incur increased mortality, but similar to the population with medical CHF, patients with surgical CHF who are readmitted postoperatively fare worse. Early identification of patients at risk for readmission and targeted postoperative management strategies may lead to improved survival.

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