Predictors of Readmission for Complications of Coronary Artery Bypass Graft Surgery

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Context  Risk factors for perioperative mortality after coronary artery bypass graft (CABG) surgery have been extensively studied. However, which factors are associated with early readmissions following CABG surgery are less clear.

Objective  To identify significant predictors of readmission within 30 days following CABG surgery.

Design, Setting, and Patients  Causes for readmission within 30 days were investigated for all patients discharged after CABG surgery in the state of New York from January 1, 1999, through December 31, 1999. A variety of patient demographics, preoperative risk factors, complications, operative and postoperative factors, and provider characteristics were considered as potential predictors of readmissions.

Main Outcome Measure  Hospital readmissions within 30 days of discharge following CABG surgery.

Results  Of 16,325 total patients, 2,111 (12.9%) were readmitted within 30 days for reasons related to CABG surgery. The most common causes of readmission were postsurgical infection (n=598 [28%]) and heart failure (n=331 [16%]). Eleven risk factors were found to be independently associated with higher readmission rates: older age, female sex, African American race, greater body surface area, previous myocardial infarction within 1 week, and 6 comorbidities. After controlling for these preoperative patient-level risk factors, 2 provider characteristics (annual surgeon CABG volume <100, hospital risk-adjusted mortality rate in the highest decile) and 2 postoperative factors (discharge to nursing home or rehabilitation/acute care facility, length of stay during index CABG admission of ≥5 days) were also related to higher readmission rates.

Conclusions  Readmission within 30 days following discharge is an important adverse outcome of CABG surgery. Continued attempts should be made to explore the potential of readmission as a supplement to mortality in assessing provider quality.

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METHODS
Patient Population
Study patients were derived from the group of all patients who underwent isolated CABG surgery in New York State and were discharged alive between January 1, 1999, and December 31, 1999. Later data were unavailable because of the time required to audit and confirm the accuracy of the data. Because we were unable to capture readmissions to hospitals in other states, residents of other states were excluded. Of the remaining patients, we were interested in identifying those who were readmitted within 30 days after discharge for a variety of reasons related to complications of CABG surgery and contrasting them with patients who were not readmitted within 30 days of discharge. Patients discharged to home, rehabilitation facilities, and nursing homes were all included in the analyses.

Readmissions were classified into types that were likely to be complications of CABG surgery by using International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes identified for this purpose in a manner similar to that used in a recent study released by the Pennsylvania Health Care Cost Containment Council. Examples of complications that were used included infections, heart failure, myocardial ischemia/acute myocardial infarction, arrhythmias, and pulmonary thromboembolism/deep venous thrombosis.

Databases
We used New York State’s Cardiac Surgery Reporting System (CSRS), which consists of detailed clinical information about every patient undergoing CABG surgery in New York State since January 1, 1989. The CSRS contains numerous demographic variables; patients’ clinical risk factors and complications; dates of admission, surgery, and discharge; and discharge status. All 34 New York hospitals with cardiac surgery programs are responsible for coding the CSRS forms and have been trained to capture relevant information. When data fields are empty, hospitals are contacted and asked to complete the missing information. Also, comprehensive audits of approximately half of the hospitals in the CSRS are conducted each year, and several hospitals have been asked to recode all or part of their data as a result of the audits. The CSRS has been the basis of many studies of hospital and surgeon mortality rates and quality of care.

Because subsequent hospitalizations that do not involve coronary revascularizations (CABG surgery or coronary angioplasty) are part of the study as well as revascularizations, it was necessary to link CSRS with New York State’s administrative acute care discharge reporting system, the Statewide Planning and Research Cooperative System (SPARCS). This system contains patient demographics (age, sex, race); the principal and up to 14 secondary diagnoses; the primary and up to 14 secondary procedures; admission, discharge, and procedure dates; and discharge disposition (dead, home, another acute care facility, a nursing home) for all patients discharged from nonfederal acute care hospitals in New York.

The CSRS and SPARCS records were matched by using unique hospital identifiers along with patient identifiers and admission, surgery, and discharge dates. The patient identifiers used were the medical record number, the patient’s date of birth, and a portion of the patient’s Social Security number (SPARCS contains a personal identifier that includes the last 4 digits of the patient’s Social Security number and CSRS contains the entire Social Security number).

Data Analysis
The number and percentage of readmissions within 30 days for complications following surgery were calculated for the reasons for readmission. The percentages of patients undergoing CABG who were readmitted within 30 days of discharge were calculated for various factors related to readmission, including patient demographic and clinical characteristics, procedure-related factors, and hospital characteristics. \( \chi^2 \) and Fisher exact tests were used to test for the bivariate relationship between each of the factors and the readmission rate with and without the factor.

Patient preoperative risk factors that were bivariately related to higher readmission rates \((P<.10)\) were then used in a stepwise logistic regression model \((P<.05)\) to determine which of them were independently associated with readmission within 30 days related to one of the identified complications of CABG surgery. The binary dependent variable was readmission within 30 days for one of the specified reasons. Independent risk factors that were used in the model included demographic characteristics (age, sex, race), cardiac-related preoperative risk factors (myocardial infarction before CABG surgery, previous open heart surgery), and a variety of preoperative comorbidities listed in CSRS.

Age and body surface area were represented as continuous variables in the model because that form was most strongly related to readmissions. Female sex was treated as a binary variable and African American race and other race were defined as indicator variables with white race serving as the reference category. Each of the comorbidities was treated as a binary variable, as was previous open heart surgery. Myocardial infarction before CABG surgery was stratified into 3 time frames \((0-7, 8-20, \text{and none or } \geq 21\text{ days prior})\) with the latter treated as the reference category.

After identifying the patient-related preoperative risk factors that were significantly related to readmissions, a variety of perioperative complications contained in CSRS, operative and postoperative factors (length of stay during the admission for CABG surgery, the type of graft used, type of surgery), and some provider characteristics (hospital and surgeon volume of CABG surgery in 1999, risk-adjusted mortality rate for CABG surgery in 1999, discharge location) were tested as independent variables in a stepwise logistic regression model \((P<.05)\). Readmis-
entire database. The discrimination of that was significant was then refit to the remaining half of the data. The subset half of the data, and then determining dependent variables using a random models. Models were cross-added little to the predictive ability of cause they were rarely significant and variables, but they were discarded be-

defined as other potential independent all independent variables were exam-

ditions related to their surgery. As indicated, the most frequent 4 reasons for readmission were responsible for 60% of all readmissions for complications within 30 days. The most fre-

quent reason for readmission was in-

fection (28.3%), followed by heart failure (15.7%), myocardial ischemia/acute myocardial infarction (7.9%), and arrhythmias (7.7%) (72% of which were atrial fibrillation). A total of 11 complications accounted for 89% of all readmissions related to CABG surgery.

Table 2 presents factors potentially related to readmission following CABG surgery. As indicated, elderly, female, and African American individuals were more likely to be readmitted than their counterparts. Several preoperative co-

morbidities (stroke, carotid artery dis-

ease, femoral/popliteal disease, hem-
dynamic instability, congestive heart failure [defined as paroxysmal noctur-

nal dyspnea, dyspnea on exertion due to heart failure, or chest radiograph showing pulmonary congestion], chronic obstructive pulmonary dis-

ease, calcified aorta, diabetes, renal fail-

ure, and hepatic failure) were also sig-

significant predictors of readmissions for the remaining half of the data. The subset that was significant was then refit to the entire database. The discrimination of each of the models was measured by using the c statistic, and calibration was measured using the Hosmer-Lemeshow goodness-of-fit statistic. All analyses were performed using SAS version 8.2 (SAS Institute, Cary, NC).

RESULTS

A total of 2497 (15.3%) of 16325 pa-

tients were readmitted within 30 days after discharge following CABG sur-

gery. Of these patients, 2111 (84.5% of the readmissions and 12.9% of all live discharges) were readmitted for purposes that were identified as complications directly related to CABG. A total of 58 (2.7%) of the 2111 readmitted pa-

ients died during their readmission, 1661 (78.7%) were discharged home af-

ther their readmission, and 247 (11.7%) were discharged to a rehabilitation/ acute care facility. The 386 patients who were readmitted for reasons other than complications of CABG surgery had 117 different principal diagnoses. The only 3-digit level ICD-9-CM codes with more than 20 cases were rehabilitation (44 cases), diabetes (25 cases), and chronic bronchitis (21 cases).

Table 1 presents the most frequent reasons for readmission within 30 days among patients who underwent CABG surgery who were readmitted for com-

lications related to their surgery. As indicated, the most frequent 4 reasons for readmission were responsible for 60% of all readmissions for complications within 30 days. The most frequent reason for readmission was infec-

tion (28.3%), followed by heart failure (15.7%), myocardial ischemia/acute myocardial infarction (7.9%), and arrhythmias (7.7%) (72% of which were atrial fibrillation). A total of 11 complications accounted for 89% of all readmissions related to CABG surgery.

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significant associated with higher readmission rates.

Also, several complications of CABG surgery were associated with higher re-

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admission rates, including sepsis, renal failure, and respiratory failure. Other factors that were significantly related bivariately to higher readmission rates were having had a myocardial infarction within a short time before surgery, previous open heart surgery, type of grafts used in surgery, lower hospital and surgeon volumes, and discharges to facilities other than home.

Table 3 presents the patient risk factors, operative and postoperative factors, and surgeon/hospital characteristics that were found to be significant independent predictors of readmission within 30 days. Older patients and women were significantly more likely to be readmitted within 30 days, as were patients with larger body surface areas. Having a myocardial infarction in the week preceding the operation was also a significant independent predictor of readmission, as were several comorbidities (femoral/popliteal disease, congestive heart failure, chronic obstructive pulmonary disease, diabetes, hepatic failure, and dialysis). The comorbidities with the highest relative odds of readmission were hepatic failure and dialysis.

Patients undergoing surgery performed by surgeons with annual CABG surgery volumes of less than 100 had higher odds of being readmitted than other patients. Also, patients discharged from hospitals with high risk-adjusted mortality rates, patients who were discharged to skilled nursing facilities or rehabilitation/acute care hospitals, and patients with higher postoperative lengths of stay had higher readmission rates. However, the hospital-level correlation between risk-adjusted mortality rate and risk-adjusted readmissions rate was only 0.09 ($P = .64$). The $c$ statistic for the entire logistic regression model including patient-provider characteristics was 0.62.

Table 4 presents significant predictors of one type of readmission: infections related to surgery. For this model, the $c$ statistic was slightly better (0.66). Older age, female sex, higher body surface areas, and 3-vessel coronary disease were associated with higher readmission rates. The set of comorbidities significantly related to higher readmission rates included hemodynamic instability, diabetes, and dialysis.
Sepsis occurring as a complication during the index admission was also a significant predictor of readmission related to infection, with an odds ratio for readmission of 3.80 (95% confidence interval, 2.12-6.83) relative to patients without sepsis. Also, patients in lower-volume hospitals had higher readmission risks, as did patients with longer postoperative lengths of stay in the index admission.

TABLE 5 presents the significant independent predictors of readmission for heart failure. Patient risk factors included previous open heart surgery, stroke, aortoiliac disease, renal failure, and congestive heart failure in the current or in a previous admission (these 2 were combined in the models in Tables 3 and 4 because their odds ratios were essentially the same). The only independent variable not related to patient characteristics was postoperative length of stay in the index admission.

COMMENT
Although CABG surgery has been studied extensively and has been the procedure for which hospitals and surgeon performance have been scrutinized and assessed the most frequently, our knowledge about CABG surgery is still incomplete. First, little has been done to identify the processes of care that are the most effective in achieving optimal short-term and long-term outcomes. Second, mortality is the outcome measure that has been most studied.

This study examined details concerning patients who were readmitted to an acute care hospital within 30 days after having undergone CABG surgery in a New York State hospital in 1999 for reasons judged to be related to the surgery. Our main findings were that 15.3% of all CABG surgery patients discharged alive were readmitted within 30 days, and 12.9% were readmitted for reasons related to the surgery, with the most common being infection, heart failure, myocardial ischemia/infarction, and arrhythmias. We believe this is the first peer-reviewed population-based study of the causes and predictors of readmissions for CABG surgery conducted in the United States. However, the findings of this study are fairly similar to those of earlier studies, which reported CABG surgery readmission rates ranging from 13% to 16%.11,12,14,15

Consistent with other groups, we found that female sex,11,12,14,15 older age,11,12,14,15 and African American race15 were all associated with higher chances of readmission following CABG surgery. In addition, we found several comorbidities (femoral/popliteal dis-

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ease, congestive heart failure, chronic obstructive pulmonary disease, diabetes, hepatic failure, and renal failure) to be associated with higher readmission rates. After controlling for these significant patient risk factors for readmissions, patients who had longer lengths of stay, who underwent surgery performed by surgeons with low CABG surgery volumes or at hospitals with higher risk-adjusted mortality rates, and who were discharged to nursing homes and rehabilitation/acute care facilities were found to have higher readmission rates. This same set of patient characteristics, operative and postoperative factors, and provider characteristics were the significant predictors of any readmission within 30 days, regardless of whether it was judged to be related to complications of the CABG surgery, and the discrimination of the statistical model was very similar.

Some of the patient risk factors that were significant predictors of readmissions were also significant predictors of mortality. Race and body surface area, in addition to 3 comorbidities (femoral/popliteal disease, chronic obstructive pulmonary disease, and congestive heart failure) were identified as significant risk factors for readmissions but not for in-hospital mortality of patients who underwent CABG surgery in New York in 1999, whereas 3 measures of hemodynamic state (shock, hemodynamic instability, and need for cardiopulmonary resuscitation within 1 hour before surgery), and 3 other comorbidities (calcified ascending aorta, carotid/cerebrovascular disease, and aortoiliac disease) were identified as significant risk factors for mortality but not for readmissions. Older age, female sex, diabetes, hepatic failure, renal failure, previous myocardial infarction, and previous open heart surgery were identified as significant patient-level risk factors for both outcome measures.2

One of the primary purposes of this study was to explore the use of readmissions as a supplemental measure to mortality in assessing the quality of care for patients undergoing CABG surgery. A concern is that despite the fact that hospital risk-adjusted mortality rate was a significant independent predictor of readmission following CABG surgery, the hospital-level correlation between risk-adjusted mortality rate and readmission rate was 0.07, which was not statistically significant. This may suggest that readmissions are not as strongly associated with hospital-level factors as hospital mortality.
admission rate is not a good quality measure because it does not correlate strongly enough with mortality, which is generally regarded as the most important quality measure.

However, Silber et al.25-26 found that mortality rate does not correlate well with the complication rate but does correlate well with the failure rate (the tendency for patients with complications to die). Thus, it would appear that the ability to prevent complications and the ability to discharge alive patients who have experienced complications are 2 different complementary components of quality that should both be captured when assessing quality of care. Because readmissions are delayed complications, the risk-adjusted complication rate would appear to be a good complement to the risk-adjusted mortality rate. Also, readmission rates will capture an increasing percentage of CABG surgery complications that do not occur during the index admission as lengths of stay continue to decline with ever-increasing cost concerns.

Another caveat related to the use of readmissions for assessing quality of care is that despite the fact that the readmission prediction models included operative/postoperative factors and provider characteristics, the c statistic for the logistic regression model that predicted readmissions was quite low (0.62). In comparison, the c statistics that predict mortality for CABG surgery are generally between 0.76 and 0.82.2-10 Furthermore, an attempt to predict specific causes of readmission did not substantially improve the predictive ability of the models (the c statistic increased to 0.65-0.66), as it did to a greater extent in other readmission studies.12 These findings suggest that there are other unmeasured reasons for readmissions after discharge for CABG surgery. Some of these causes may be process measures that were unavailable in this study (eg, use of aspirin and β-blockers on discharge following CABG surgery, early extubation). If these reasons account for a large amount of the unexplained variability, then risk-adjusted readmission rates (with only patient preoperative severity of illness measures used in the risk-adjustment process) may be a legitimate supplemental measure for quality of care.

It is quite possible that a large portion of the unmeasured variability in readmission rates is a result of practice pattern variations among hospitals and surgeons that are unrelated to quality of care. For example, some surgeons may prefer to manage postdischarge atrial fibrillation or large pleural effusions on an outpatient basis and others may prefer to readmit the patient. For some patients, the insurer may be a factor because early readmissions may not be reimbursed. Also, if hospital quality were evaluated at least partially on the basis of readmission rates, there would be a perverse incentive for hospitals to game the system by avoiding readmission of patients who are sick and perhaps unwisely treat them with aggressive outpatient management and/or delay readmission beyond 30 days.

Readmission to hospital shortly after CABG is a common problem. Although we identified a number of important predictors for readmission, much variability in readmission rates remains unexplained. Future research will be needed to better understand why many patients require readmission after undergoing CABG surgery and whether readmission may be useful for quality assessment.

### Table 4. Logistic Regression Results Identifying Factors Significantly Associated With Readmission Related to Infection Within 30 Days Following Discharge After CABG Surgery*

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Adjusted Odds Ratio (95% Confidence Interval)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, per 10 years</td>
<td>1.15 (1.05-1.26)</td>
<td>.002</td>
</tr>
<tr>
<td>Women</td>
<td>1.50 (1.24-1.81)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Body surface area, per m²</td>
<td>2.98 (2.06-4.31)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>3-Vessel disease</td>
<td>1.25 (1.06-1.49)</td>
<td>.01</td>
</tr>
<tr>
<td>Femoral/popliteal disease</td>
<td>1.24 (0.96-1.61)</td>
<td>.10</td>
</tr>
<tr>
<td>Hemodynamically unstable</td>
<td>1.82 (1.02-3.24)</td>
<td>.04</td>
</tr>
<tr>
<td>Calcified aorta</td>
<td>1.33 (0.97-1.82)</td>
<td>.08</td>
</tr>
<tr>
<td>Diabetes</td>
<td>1.64 (1.38-1.94)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Dialysis</td>
<td>1.95 (1.13-3.37)</td>
<td>.02</td>
</tr>
<tr>
<td>Sepsis</td>
<td>3.80 (2.12-6.83)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Annual hospital volume &lt;300 cases</td>
<td>1.60 (1.23-2.08)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Postsurgical LOS between 5-7 d</td>
<td>1.33 (1.05-1.70)</td>
<td>.02</td>
</tr>
<tr>
<td>Postsurgical LOS ≥8 d</td>
<td>1.78 (1.38-2.31)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

*Abbreviations: CABG, coronary artery bypass graft; LOS, length of stay.

### Table 5. Logistic Regression Results Identifying Factors Significantly Associated With Readmission Related to Heart Failure Within 30 Days Following Discharge After CABG Surgery*

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Adjusted Odds Ratio (95% Confidence Interval)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, per 10 years</td>
<td>1.14 (1.02-1.28)</td>
<td>.02</td>
</tr>
<tr>
<td>Previous open heart procedures</td>
<td>1.84 (1.28-2.65)</td>
<td>.001</td>
</tr>
<tr>
<td>Stroke</td>
<td>1.46 (1.03-2.05)</td>
<td>.03</td>
</tr>
<tr>
<td>Aortoiliac disease</td>
<td>1.47 (1.09-2.19)</td>
<td>.06</td>
</tr>
<tr>
<td>Congestive heart failure, this admission</td>
<td>2.34 (1.79-3.05)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Congestive heart failure, previous admission</td>
<td>1.83 (1.26-2.66)</td>
<td>.002</td>
</tr>
<tr>
<td>Renal failure, dialysis, or creatinine level ≥2.5 mg/dL</td>
<td>1.57 (1.01-2.44)</td>
<td>.05</td>
</tr>
<tr>
<td>Postsurgical LOS ≥8 d</td>
<td>1.46 (1.16-1.85)</td>
<td>.001</td>
</tr>
</tbody>
</table>

*Abbreviations: CABG, coronary artery bypass graft; LOS, length of stay.

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Author Contributions: Study concept and design: Hannan, Racz, Jones. Acquisition of data: Hannan, Racz, Jones. Analysis and interpretation of data: Hannan, Racz, Walford, Ryan, Isom, Bennett, Jones. Drafting of the manuscript: Hannan, Racz. Critical revision of the manuscript for important intellectual content: Hannan, Racz, Walford, Ryan, Isom, Bennett, Jones. Statistical expertise: Hannan, Racz, Jones. Administrative, technical, or material support: Hannan, Racz, Walford, Ryan, Isom, Bennett. Study supervision: Hannan, Ryan, Isom. Acknowledgment: We thank Kenneth Shine, MD, the chair of New York State's Cardiac Advisory Committee (CAC), and the remainder of the CAC for their encouragement and support of this study; and Donna Doran, BA, Casey Roark, MPH, Rosemary Lombardo, BA, and the cardiac surgery departments of all participating hospitals for their tireless efforts to ensure the timeliness, completeness, and accuracy of the registry data.

REFERENCES


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