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Elements of the care environment influence coronary artery bypass surgery readmission

Michael P. Rogers, MD, MS [a,1], Evelena Cousin-Peterson, MD [a], Tara M. Barry, MD [a], Marshall S. Baker, MD, MBA [b], Paul C. Kuo, MD, MS, MBA [a], Haroon M. Janjua, MS [a,*]

[a] Department of Surgery, University of South Florida Morsani College of Medicine Tampa, FL, USA
[b] Division of Surgical Oncology, Department of Surgery, Loyola University Medical Center, Maywood, IL, USA

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ABSTRACT

Background: Coronary artery bypass grafting 30-day unplanned readmission is a focus for the CMS Hospital Readmissions Reduction Program. Awareness of the critical elements of the care delivery environment, including hospital infrastructure and patient clinical profiles that predispose toward readmission, is essential to proactively decrease readmissions.
Methods: The Healthcare Cost and Utilization Project-State Inpatient Database, American Hospital Association Annual Health Survey Database, and Healthcare Information Management Systems Society data sets were merged to create a single data set of patient- and hospital-level data from 8 states. Isolated coronary artery bypass grafting procedures were queried for all-cause 30-day readmission, and backwards stepwise logistic regression was performed. Readmission rate was then used to categorize hospitals into quartiles, and analysis focused on the hospitals with the lowest (Q1) and highest (Q4) readmission rates. Univariate analysis was performed comparing Q1 and Q4 hospitals.
Results: A total of 150,215 patients underwent isolated coronary artery bypass grafting with 23,244 (15.5%) readmitted patients among 903 hospitals. Model area under the curve was 0.709 (95% confidence interval, 0.702–0.716), with the top 3 readmission determinants related to discharge disposition. Compared to Q1, Q4 patients more often were female, were >70 years of age, and had Medicare as a primary payor ($P < .001$). Low readmission rate hospitals were characterized by higher costs; not-for-profit status; having Joint Commission accreditation; and higher total admissions, operative volume, hospital/ICU beds, full-time physicians, nurses, and ancillary personnel ($P < .001$).
Conclusion: Readmission after coronary artery bypass grafting is strongly influenced by discharge disposition. However, hospital factors such as scale, personnel, and ownership structure are significant contributors to readmission. Focus beyond patient factors to include the entire continuum of care is required to enhance outcomes, of which readmission is one surrogate measure.

INTRODUCTION

Unplanned hospital readmission following complex surgical intervention is thought to represent poor quality of care, inadequate care coordination, lack of effective discharge or transitional care planning, and premature hospital discharge [1–3]. Consequently, the Centers for Medicare & Medicaid Services introduced the Hospital Readmissions Reduction Program in an effort to provide incentive to improve communication and care coordination in discharge planning and ultimately reduce unplanned hospital readmission [4]. Unanticipated 30-day readmission following coronary artery bypass grafting (CABG) is a focus for the Hospital Readmissions Reduction Program [5]. To address, predict, and mitigate readmissions, awareness of the critical elements of the healthcare delivery macroenvironment is essential. Historically, attempts to create predictive models focused on patient demographic and biological characteristics [6,7]. Gradually, the medical community recognized that surgeon, hospital, and temporal factors impacted patient outcomes. Initially, these factors were considered in isolation but have increasingly been linked with patient factors to create a more inclusive set of relevant data elements used for analysis and model creation [8,9]. However, there are additional considerations in the current era of big data analytics that may add more nuanced predictive capacity. Hospital factors such as scale, personnel, information technology (IT)

* Corresponding author at: USF Department of Surgery, 2 Tampa General Circle, Room 7015, Tampa, FL 33606.
E-mail address: hmjanjua@usf.edu (H.M. Janjua).
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resources, and ownership structure may also be significant contributors to readmissions. Focus beyond patient factors and the surgical procedure to include the entire continuum of care is required to enhance outcomes, of which unplanned readmission is one surrogate measure.

In this study, we sought to identify novel factors contributing to 30-day unplanned readmission following CABG through consideration of the health care macroenvironment, including both patient- and hospital-level factors.

METHODS

Study Design and Data Sources. The Healthcare Cost and Utilization Project-State Inpatient Database (HCUP-SID), the American Hospital Association Annual Health Survey Database (AHA), and the Healthcare Information Management Systems Society (HIMMS) data sets were merged to create a single data set of patient- and hospital-level data from 8 states (California, Florida, Iowa, Massachusetts, Maryland, New York, Washington, and Wisconsin) between 2009 and 2015 (details for the years used for each state, is provided in supplementary material link). The HCUP-SID is an administrative, all-payer data set sponsored by the Agency for Healthcare Research and Quality that includes discharge records from 47 participating states [10]. Similarly, the AHA data set is released annually and composed of data from more than 6,000 hospitals and 400 systems with nearly 1,000 data fields describing hospital personnel, organizational structure, financial performance, and facilities and services [11]. When combined with the HIMMS data sets, information regarding detailed clinical and nonclinical patient- and hospital-level variables was available for analysis. Nine separate *International Classification of Disease, Ninth Revision, Clinical Modification* (*ICD-9-CM*) procedure codes were used to capture patients 18 years or older undergoing isolated single or multivessel CABG procedures (Table 1). Patients undergoing concomitant procedures (ie, aortic root replacement or valve replacement) or patients with inpatient mortality at the index hospitalization were excluded from further analysis. The resultant combined data set contained 122 (51 patient-level and 71 hospital-level) total variables for analysis.

Analytic Approach and Statistical Modeling. Data preparation and cleaning were performed using Stata software, version 13 (StataCorp, College Station, TX). Statistical analysis including algorithmic computation and machine learning modeling was performed in RStudio (RStudio, Inc., Boston, MA). The combined data set was split into 70% and 30% training and testing cohorts, respectively, to train the model and validate performance on the testing cohort. To examine all-cause 30-day CABG readmission, logistic regression modeling was implemented with backwards stepwise selection to eliminate insignificant variables and identify final predictors. Model performance was evaluated according to area under the curve (AUC). Odds ratios (ORs) for the categorical variables were calculated with 95% confidence intervals (CIs).

Table 1
ICD-9 procedure codes used for querying

	ICD-9 *Code*	*Description*
1	3610	Aortocoronary bypass for heart revascularization, not otherwise specified
2	3611	Aortocoronary bypass of 1 coronary artery
3	3612	Aortocoronary bypass of 2 coronary arteries
4	3613	Aortocoronary bypass of 3 coronary arteries
5	3614	Aortocoronary bypass of 4 or more coronary arteries
6	3615	Single internal mammary-coronary artery bypass
7	3616	Double internal mammary-coronary artery bypass
8	3617	Abdominal-coronary artery bypass
9	3619	Other bypass anastomosis for heart revascularization

The results of logistic regression readmission modeling determined that patient disposition at discharge plays a vital role in 30-day CABG readmission. To investigate this relationship further, disposition variables were isolated and the model was recomputed using a stepwise logistic regression approach to evaluate the factors that have significant contribution to 30-day readmission in the absence of patient disposition.

Categorizing Hospital Readmission. In an effort to further characterize differences between high and low readmission hospitals, CABG readmission rates for each hospital within each year were calculated and used to categorize hospitals into quartiles based on readmission volume. Further analysis focused on differences between low (Q1) and high (Q2) volume readmission hospitals belonging to the first and last quartiles (top 25% and bottom 25% for readmission, respectively). Univariate analysis was performed to evaluate the relationship between patient, hospital volume, hospital infrastructure and capacity, hospital human resource factors (ie, staffing), and hospital IT components between low and high readmission hospitals separately. Pearson χ^2 test was used for categorical variables, and *t* test was performed for continuous variables to evaluate statistical significance.

RESULTS

A total of 150,215 isolated CABG patients were identified, with 23,244 (15.5%) readmitted patients among 903 hospitals. When stratified by quartile into low and high volume readmission hospitals, 209 hospitals (6,233 patients) were identified in Q1 and 249 hospitals (53,386 patients) were identified in Q4. The 30-day CABG readmission rates were 8.2% and 14.5% for Q1 and Q4 hospitals, respectively.

Description of Q1 and Q4 hospitals and patient populations. Low volume readmission (Q1) hospitals were more frequently general medical and surgical, not-for-profit, urban hospitals with more than 100 beds. These facilities were more likely to be Joint Commission accredited, possess Accreditation Council for Graduate Medical Education residency programs, be affiliated with a medical school, and be members of the Council of Teaching Hospitals of the Association of American Medical Colleges (Table 2). With regard to information technology resources, Q1 facilities were more apt to have bed management technology, cardiology information systems, clinical decision support, emergency department information systems, physician portals, and electronic medical record systems. Low volume readmission hospitals were characterized by younger patients with fewer chronic conditions and increased total charges and costs but had similar lengths of stay and number of diagnoses and procedures when compared to Q4 hospitals (Table 3). Low volume readmission hospitals also had significantly more total facility admissions (13,450 vs 7,275 admissions, $P < .001$), total inpatient and outpatient surgical procedures, total outpatient visits, average daily census, and emergency room visits. These facilities also had significantly increased capacity with greater total bed numbers (280 vs 179 average total beds, $P < .001$), medical and surgical intensive care beds, total number of staffed beds, and total number of operating rooms. In a similar fashion, when considering staffing, Q1 hospitals had significantly more full-time physicians and dentists, medical residents, registered nurses, radiology technicians, laboratory technicians, pharmacists, and respiratory therapists (all comparisons $P < .001$).

Logistic Regression Modeling. Fifty-seven predictors were used to start the logistic regression modeling with backwards stepwise method eliminating 20 predictors. The final model contained 37 predictors of 30-day hospital readmission. Model AUC was 0.7092 (95% CI, 0.702–0.716). The top 3 readmission determinants were related to patient disposition at discharge: transfer to a short-term hospital (OR 4.65, 95% CI 3.98–5.43, $P < .001$), discharge to other facilities (including skilled nursing facility [SNF], intermediate care facility [ICF], or another type of facility and destination unknown) (OR 4.17, 95% CI 3.95–4.39, $P < .001$), and

Table 2
Baseline patient characteristics of hospital readmission quartiles. Values presented as percentage of total patients for each quartile or mean value. Charges and cost in US dollars. Comparisons between Q1 and Q4 hospitals were statistically significant except for values denoted with *

	Q1	*Q2*	*Q3*	*Q4*
Patients	7610	33133	71007	64435
Hospitals	209	240	205	249
Readmission rate	8.1	12.0	13.0	14.5
Age	65.42	65.72	66.05	67.18
Length of stay	8.87*	9.24	8.92	8.84*
Number of chronic conditions	6.88	7.01	7.05	7.04
Total number of diagnoses at discharge	13.11*	13.35	13.14	13.00*
Total number of procedures at discharge	6.06*	6.44	6.55	6.08*
Total mean charges	171,335	158,748	158,684	143,937
Total mean cost	53,409	48,412	44,296	40,138
Male gender	77.2	76.6	75.6	74.4
Charlson Comorbidity Index				
Low	18.4	18.8	18.8	19.2
Moderate	28.5	28.8	29.0	29.2
Severe	53.1	52.4	52.2	51.6
Patient location				
Large metropolitan areas at least 1 million residents	74.2	72.5	58.4	48.9
Small metropolitan areas <1 million residents	19.1	20.3	31.2	36.8
Micropolitan areas	3.8	4.3	6.8	9.4
Not metropolitan or micropolitan	2.9	2.9	3.6	4.9
Patient race				
White	67.5	66.2	76.8	83.2
Black	7.5	6.7	5.4	4.3
Hispanic/Latino	14.1	12.4	9.7	6.7
Asian or Pacific Islander	6.5	4.7	3.6	2.6
Native American	0.2	0.3	0.3	0.2
Others	4.2	9.6	4.2	3.0
Primary payor				
Medicare	50.3	52.7	55.1	60.1
Medicaid	10.7	10.2	7.0	5.5
Private insurance	30.5	31.1	31.0	28.6
Self-pay	3.3	2.8	2.9	2.7
No charge	1.6	0.5	0.9	0.8
Others	3.6	2.9	3.1	2.2
Median household income				
Q1 (low)	22.2	23.0	22.5	25.1
Q2	27.8	25.8	28.6	29.8
Q3	24.8	26.0	26.1	25.0
Q4 (high)	25.2	25.2	22.8	20.1
Patient disposition at discharge				
Routine disposition	40.3	36.6	36.6	31.3
Transfer to short-term hospital	2.7	1.4	1.1	1.5
Transfer to other facility (SNF, ICF, another type of facility, discharged alive destination unknown)	15.5	18.0	17.7	20.3
Home health care	41.3	43.9	44.5	46.8
Against medical advice or disposition unknown	0.3	0.2	0.1	0.1
Weekend vs weekday admission				
Weekday admission (%)	86.1	88.6	87.7	87.8
AHRQ comorbidity measures				
Alcohol abuse	3.0*	3.4	3.2	3.0*
Iron deficiency anemia	22.5	21.1	22.0	21.4
Chronic anemia	1.0	1.4	1.5	1.8
Chronic pulmonary disease	18.2	19.0	21.5	22.9
Coagulopathy	12.4	15.9	16.0	14.6
Congestive heart failure	3.9*	3.1	3.0	4.1*
Depression	5.4	6.4	6.3	7.2
Diabetes (uncomplicated)	37.5	36.6	36.3	35.6
Diabetes (with chronic complications)	8.3	8.4	8.2	7.5
Drug abuse	1.9	1.9	1.5	1.2
Fluid and electrolyte disorders	29.7*	31.0	28.0	28.7*
Hypertension	81.2	81.2	80.8	80.0
Hypothyroidism	8.4	8.9	9.8	10.3
Liver disease	1.4*	1.6	1.4	1.2*
Obesity	17.4	19.1	21.4	21.4
Paralysis	1.3	1.8	1.5	1.8
Peripheral vascular disorders	13.9	14.6	14.3	14.9
Psychoses	1.9*	1.9	1.8	1.9*
Renal failure	13.9*	14.9	14.4	14.6*
Solid tumor without metastasis	1.4	1.3	1.1	1.0
Valvular disease	1.2*	1.1	1.0	1.3*
Weight loss	2.3*	3.0	2.4	2.5*

Table 3
Institutional characteristics of hospital readmission quartiles. Values presented as mean and percentage of quartile total. Comparisons between Q1 and Q4 were statistically significant except when denoted by *

	Q1	*Q2*	*Q3*	*Q4*
Hospitals (*n*)	209	240	205	249
Total facility admissions	13,449.5	12,308.4	13,576.4	7274.5
Inpatient surgical operations	3241.3	3142.4	3902.3	1900.8
Outpatient surgical operations	5812.0	5701.2	5771.4	3149.8
Total surgical operations	9053.3	8843.6	9673.8	5050.7
Total outpatient visits	23,0723.1	21,5467.2	24,1227.8	106,244.7
Average daily census	195.3	181.1	192.0	122.8
Emergency room visits	49,044.5	43,201.2	43,251.9	225,03.4
Total hospital beds	279.8	257.2	276.3	178.4
Medical surgical intensive care beds	15.1	14.6	17.3	11.1
Total number of staffed beds	258.0	227.0	237.2	160.6
Total number of operating rooms	10.0	9.8	10.8	6.8
Full-time physicians and dentists	43.6	33.6	48.5	14.9
Full-time medical residents and interns	44.2	59.5	52.9	11.4
Full-time registered nurses	377.0	376.7	426.0	222.5
Full-time radiology technicians	34.3	36.0	41.2	20.0
Full-time laboratory technicians	33.2	33.9	40.2	18.3
Full-time pharmacists	17.5	16.1	16.9	8.8
Full-time respiratory therapists	20.6	20.9	23.8	13.9
(All values below expressed as percentage of quartile total)				
Hospital type investor owned under 100 beds	2.9	3.3	3.9	20.1
Hospital type investor owned 100 beds or more	17.2	9.6	14.2	10.4
Hospital type not-for-profit rural, under 100 beds	1.4	4.6	11.2	21.3
Hospital type not-for-profit rural, 100 beds or more	1.0	3.8	5.4	4.4
Hospital type not-for-profit urban, under 100 beds	3.4	10.8	9.3	9.6
Hospital type not-for-profit urban, 100 beds or more	42.1	42.9	24.9	19.3
Hospital type not-for-profit urban, 300 beds or more	32.1	25.0	31.2	14.9
Independent practice association hospital	9.6*	10.8	12.7	7.6*
Health maintenance organization (HMO) hospital	9.1*	10.4	9.3	5.6*
Preferred provider organization (PPO) hospital	5.3*	5.0	7.3	5.2*
Adult cardiac surgery hospital	13.4	32.1	49.8	30.9
Accreditation by the Joint Commission	93.3	89.6	91.7	75.5
Participating site recognized for 1 or more Accreditation Council for Graduate Medical Education accredited programs	39.2	30.0	26.8	17.3
Medical school affiliation reported to American Medical Association	45.0	39.2	34.2	18.1
Member of Council of Teaching Hospital of the Association of American Medical	12.4	11.7	10.7	4.0
Admission, discharge, transfer technology	90.9	92.9	90.2	94.4
Technology for bed management	47.9	47.1	47.8	37.4
Cardiology information system	75.6	67.9	71.7	41.0
Electronic chart deficiency management system	90.4*	90.8	91.7	87.2*
Chart tracking/locator system	89.0	91.3	90.2	83.1
Clinical data repository	85.2*	89.6	86.3	84.3*
Clinical decision support system	86.6	90.4	88.8	76.7
Computerized practitioner order entry	48.8*	52.1	47.8	48.6*
Electronic medication administration record	63.6	70.0	69.3	67.5
Emergency department information system	85.2	82.5	82.4	58.2
Laboratory information system	92.8*	95.0	92.7	93.6*
Patient scheduling system	90.0*	93.3	90.7	92.4*
Physician portal	45.5	43.8	54.6	37.8
Radiology information system	87.6*	93.3	92.2	91.2*
Electronic medical record system	36.8	37.1	38.5	26.1
Clinical guidelines and pathways for nurses	54.1*	55.4	53.7	64.3*
PACS image distribution critical care unit	53.6	51.3	56.1	70.3
PACS image distribution operating room	48.8	45.0	50.7	60.6

patients leaving against medical advice (OR 2.85, 95% CI 0.71–9.85, $P = .11$), when the reference was routine hospital discharge. Other notable factors associated with increased odds of readmission were Charlson Comorbidity Index (CCI) level 2 (severe sickness) (OR 1.23, 95% CI 1.15–1.32, $P < .001$), history of drug abuse (OR 1.23, 95% CI 1.06–1.40, $P < .001$), other neurological disorders (OR 1.26, 95% CI 1.16–1.37, $P < .001$), and if the hospital was designated as critical access (OR 1.42, 95% CI 1.23–1.64, $P < .05$). Complete results from the modeling summary containing ORs as they contribute to hospital readmission are summarized in Table 4.

DISCUSSION

Unplanned 30-day readmission following complex surgical procedures, including CABG, remains a focus of the Centers for Medicare and Medicaid Services, surgeons, patients, and hospital systems alike. To this end, several authors have proposed risk calculators and models to better predict and mitigate 30-day CABG readmissions [2,6,8,12,13]. The Society of Thoracic Surgeons Adult Cardiac Surgery data showed risk-standardized CABG readmission rates from 12.6% to 23.6% [14]. Analysis of the New York State database also found 44% of CABG patients readmitted within 2 years following the index operation [15]. Our analysis reports an overall 30-day readmission rate of 15.5%, consistent with this national average. A wide variety of factors may impact patient outcomes and readmission likelihood following surgical intervention. By considering the entire continuum of care to include patient-specific and health care system influences, we sought to create a more inclusive set of relevant data elements used for analysis and model creation. This examination of multistate patient- and hospital-level data adds to this growing body of literature aimed at reducing unplanned readmissions and their associated costs by identifying

Table 4
Logistic regression model ORs corresponding to contribution to readmission. Reference levels have been highlighted for multiple-level categorical variables, all others are two-level categorical variables, and the reference level is NO or absence of that category. *Transfer others (SNF, ICF, another type of facility, discharged alive destination unknown)

	OR	*95% CI*	
Charlson Comorbidity Index			
Moderate	1.05	0.99	1.12
Severe	1.23	1.15	1.32
Expected primary payer			
Medicaid	1.20	1.12	1.29
No charge	0.81	0.77	0.84
Others	0.89	0.79	1.00
Private insurance	0.97	0.78	1.19
Self-pay	0.77	0.69	0.87
Patient race			
Black	1.23	1.14	1.33
Hispanic	1.17	1.10	1.24
Asian or Pacific Islander	1.07	0.97	1.18
Native American	1.28	0.91	1.77
Others	0.93	0.85	1.01
Disposition of patient at discharge			
Transfer to short-term hospital	4.65	3.98	5.43
Discharge is to others*	4.17	3.95	4.39
Home health care	1.19	1.13	1.25
Left against medical advice	2.85	0.71	9.85
Discharged alive destination unknown	2.10	1.17	3.58
Hospital type (reference: investor owned < 100 beds)			
Investor owned > 100 beds	0.70	0.55	0.90
Not-for-profit rural > 100 beds	0.58	0.43	0.78
Not-for-profit urban < 100 beds	0.51	0.28	0.87
Not-for-profit urban 100–299 beds	0.65	0.51	0.84
Not-for-profit urban >300 beds	0.64	0.50	0.82
Hospital state (reference: Florida)			
California	1.12	1.05	1.19
Iowa	1.56	1.31	1.85
Massachusetts	0.55	0.48	0.62
Maryland	0.91	0.80	1.03
New York	1.02	0.95	1.09
Washington	0.95	0.88	1.04
Wisconsin	0.80	0.72	0.89
Patient sex			
Female	1.16	1.12	1.21
AHQR comorbidity measures			
Deficiency anemia	1.04	0.99	1.08
Chronic pulmonary disease	1.09	1.04	1.14
Diabetes (uncomplicated)	1.06	1.02	1.11
Diabetes (with chronic complications)	1.16	1.09	1.24
Drug abuse	1.22	1.06	1.40
Hypothyroidism	0.95	0.89	1.00
Fluid and electrolyte disorders	0.96	0.93	1.00
Other neurological disorders	1.26	1.16	1.37
Obesity	1.09	1.05	1.14
Peripheral vascular disorders	1.04	0.99	1.09
Renal failure	1.12	1.07	1.18
Postoperative complications			
Postoperative pneumonia	1.11	1.02	1.19
Postoperative cardiac complications	1.06	1.00	1.12
Hospital designations			
Accreditation by the Joint Commission	1.16	1.08	1.25
Residency training approval by Accreditation Council for Graduate Medical Education	0.95	0.89	1.01
Medical school affiliation reported to American Medical Association	0.94	0.88	1.00
Accreditation by Commission on Accreditation of Rehabilitation Facilities	0.95	0.90	0.99
Member of Council of Teaching Hospital of the Association of American Medical Colleges	1.28	1.20	1.37
Residency approved by American Osteopathic Association	0.90	0.84	0.96
Catholic Church operated	1.06	1.01	1.12
Critical access hospital	1.42	1.23	1.64
Rural referral center	0.73	0.63	0.83

pertinent patient- and hospital-level contributors. These newly proposed factors may help highlight previously unknown influences on 30-day CABG readmissions and allow for mitigation strategies to improve this important health care quality metric.

Patient disposition at time of discharge conferred the largest patient predictor for readmission. Indeed, the top 3 readmission determinants were related to patient disposition at discharge and were found to include transfer to a short-term hospital, discharge to other facilities (including SNF, ICF, and unknown discharge destinations), and patients leaving against medical advice, although leaving against medical advice did not reach statistical significance. These factors may relate to readmission through the need for additional rehabilitation or further care following surgery. In these instances, patients may have ongoing medical issues that may contribute to an increased probability of needing a higher level of care than may be provided at a rehabilitation or short-term hospital, thus increasing the chance of readmission to the index hospital. Additionally, those that leave the hospital prematurely against medical advice may return if complications arise thereafter as a result of the incomplete hospital stay. Our determinants reaffirm previous works highlighting the contribution of patient disposition at time of discharge on 30-day hospital readmission for CABG [12]. Shah and colleagues' recent investigation using the National Readmissions Database also found patient discharge to skilled nursing facility to be associated with unplanned readmission [12]. These similar findings likely highlight patient functional status postsurgery as an important determinant in requiring readmission to the index hospital.

Our analysis also focused on hospital factors and information technology as they relate to readmission as part of the health care continuum. When comparing low and high readmission hospitals, those with lower readmission had significantly larger hospital capacities with a greater number of overall beds, intensive care unit beds, and total number of operating rooms. They also had more full-time physicians, nurses, technicians, pharmacists, and respiratory therapists. Low readmission rate hospitals had a greater amount of overall hospital admissions, performed more overall operations, and had more emergency department visits. These large, teaching-affiliated, metropolitan-based, operative heavy, and clinically busy hospitals boast a large compliment of clinical and support staff with more operative experience that likely contributes to lower rates of hospital readmission following surgery by extension of their expertise and larger compliment of support staff. Although not directly evaluated in this analysis, postoperative care and rehabilitation by ICU and floor nursing staff, physical and occupational therapy, dieticians, social workers, and other members of the health care team likely contribute to lower hospital readmission through strength training, nutrition, and ensuring appropriate patient disposition at time of discharge. The benefit of clinical programs with the ability to provide these services cannot be understated. Additionally, elements of hospital information technology infrastructure appear to play a role in mitigating unplanned 30-day hospital readmission following CABG with lower readmission hospitals to be more likely to have some technology systems. Technology for evaluating hospital bed availability and clinical support tools may help physicians and support staff make decisions regarding movement of patients within the hospital and identify those requiring abnormally long lengths of stay or other outlier information. Additionally, the presence of an electronic medical record and IT related to cardiology admissions appear more frequently in lower readmission hospitals. Some IT factors, however, did not appear with higher frequency in Q1 hospitals. Counterintuitively, technology related to tracking admissions, transfers, and discharges was present more frequently in high readmission hospitals along with picture archiving and communication system (PACS) capabilities (Table 3). Although not all IT systems were found with more frequency in low readmission hospitals, it does appear that the adoption of technology is more prevalent among hospitals with lower readmission.

Congestive heart failure (CHF) has consistently been cited to be the leading cause of hospital readmission across all major series in this patient cohort [7,12,16]. Similar to previously reported studies, CHF alone was not a significant independent predictor of hospital readmission in our analysis as it did not survive stepwise elimination and therefore was not included in the final logistic regression model.

Nevertheless, efforts at mitigating CHF exacerbation events should be encouraged among those patients at higher risk. These endeavors may include increased care coordination and earlier postoperative follow-up as may be more available in Q1-level hospitals given the overall increased number of staff.

Several limitations should be considered in this analysis. Although robust, our patient cohort was derived from only 8 states and is likely not representative of the entirety of the United States. Additionally, HCUP-SID only allows for analysis of readmission within the same state, and thus, readmissions to hospital out-of-state are not appropriately captured. Patient presentation, including those presenting in cardiogenic shock requiring emergent bypass; overall indication for CABG; preoperative risk scoring; or individual surgeon practices were not evaluated and may further explain factors contributing to unplanned readmission. Interestingly, dedicated adult cardiac surgical hospitals had an increased number of readmissions, although the exact contributing factors could not be readily elucidated from this data set.

Previous analyses of 30-day CABG readmission have evaluated patient factors, social determinants, median household income, and patient demographics [12,17–19]. We report similar findings with regard to contributing patient factors; however, we also acknowledge the role of hospital and disposition factors and information technology systems and their influence on unplanned readmission in this patient cohort. Overall, a combination of these identified factors contributing to the entire hospital stay should be considered as ways to mitigate readmission. By considering patient, hospital, and IT factors, a more robust strategy for reducing readmission may be employed. Hospital systems striving to reduce 30-day unplanned readmission in this cohort should consider seeking certification by the Joint Commission and adoption of information technology, and carefully consider patient disposition at discharge.

In conclusion, unplanned 30-day hospital readmissions after CABG are strongly influenced by patient disposition at discharge. However, hospital factors such as scale, personnel, IT resources, and ownership structure are also significant contributors to readmissions. Focus beyond patient factors and the surgical procedure to include the entire continuum of care is required to enhance outcomes, of which readmission is one surrogate measure.

Supplementary Material

All the code (STATA and R) involving various steps of data preparation and modeling can be accessed via below link https://github.com/onetomapanalytics/CABG_Readmissions.

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