The role of the hospital and health care system characteristics in readmissions after major surgery in California

Joy C. Chen, MD, MS,[a] Jeremy D. Shaw, MD, MS,[b] Yifei Ma, MS,[a] *and*
Kim F. Rhoads, MD, MS, MPH, FACS,[a] *Stanford and San Francisco, CA*

Background. *Hospital readmission after major surgery is a costly problem that has been associated with patient characteristics. Because hospitals are incentivized to join accountable care organizations, interventions on a hospital or health care system level may help reduce readmissions. Our objective was to identify hospital- and systems-level characteristics associated with readmissions after major operative procedures.*
Methods. *Retrospective analysis of California discharge abstracts with record linkage numbers for adult patients undergoing coronary artery bypass graft (CABG), colectomy or total hip/knee arthroplasty (TJA) in California acute, nonfederal hospitals in 2011. The record linkage number showed where patients were readmitted. Hierarchic logistic regression estimated the odds of readmission by hospital characteristics.*
Results. *There were 91,205 records analyzed: CABG (6.4%), colectomy (12.0%), and TJA (82.3%). There were 120 hospitals that performed CABG surgery; 296 performed colectomy; and 298 performed TJA. Readmission rates after CABG was 9.7%, colectomy 7.7%, and TJA 3.9%. After adjustment for patient factors, rural location was predictive of readmission after colectomy (odds ratio [OR] 2.08, 95% confidence interval [CI] 1.40–3.08). Low-volume (OR 1.54, 95% CI 1.13–2.10) and minority-serving hospitals (OR 1.18, 95% CI 1.05–1.33) were associated with greater odds of readmission after TJA.*
Conclusion. *Select hospital characteristics are associated with readmissions after major operative procedures. Because financial penalties may worsen performance in vulnerable or low-resource settings, policies aimed at reducing readmissions should be attentive to the potential unintended consequences. (Surgery 2016;159:381-8.)*

From the Department of Surgery,[a] Stanford University, Stanford; and Department of Orthopaedic Surgery,[b] University of California, San Francisco, San Francisco, CA

Health care reform has placed increasing emphasis on providing efficient and cost-effective care. A critical component of achieving this goal is the reduction of unnecessary hospital readmissions. Readmissions are costly and up to 75% are potentially preventable.[1,2] In 2013, the Centers for Medicare and Medicaid Services charged a total of 2,213 hospitals $280 million in readmission penalties through the Hospital Readmission Reduction Program.[3] Beginning in 2015, these penalties are linked to operative diagnoses.[4] Therefore, it is increasingly important to identify and address modifiable factors driving postoperative readmissions. Because policies will be implemented at the hospital level, certain hospital characteristics could potentially be targeted to reduce readmissions. Accountable-care organizations are emerging throughout the United States and may provide a model for reducing readmissions through restructuring hospitals into greater-level, coordinated systems of care where handoffs are more efficient across various health care settings.[5,6]

Numerous modifiable and nonmodifiable patient factors have been associated with increased readmissions after major surgery, including race,[7,8] comorbidities,[9,10] duration of stay,[11-13] insurance status,[14] and complications.[9] The importance of hospital factors in readmissions, however, is less well explored. Hospitals that are minority-serving,[7,8,15] low volume,[16,17] large, rural, or

Accepted for publication June 5, 2015.

Reprint requests: Joy C. Chen, MD, MS, 300 Pasteur Drive, Suite H3591, Stanford, CA 94305. E-mail: joy.chen@stanford.edu.

0039-6060/$ - see front matter

http://dx.doi.org/10.1016/j.surg.2015.06.016

teaching hospitals[18] have been associated with greater rates of readmission. However, most existing studies on hospital-level factors are limited to readmissions among Medicare beneficiaries or single-institution networks and thus may not reflect a more general population. Other studies focus on other operative outcomes such as mortality.[19,20] Therefore, it remains unclear how modifiable systems and hospital level factors impact postoperative readmissions.

The purpose of this study was to identify hospital- and systems-level characteristics associated with readmissions after major operative procedures. We hypothesized that after accounting for patient variables, select hospital- and systems-level factors would predict lower readmission rates. We tested this hypothesis across 3 common major surgical procedures by using a population-based approach with statewide data from California.

METHODS

Sources of data. After obtaining approval from the Committee for the Protection of Human Subjects of the State of California and the Institutional Review Board of Stanford University, we obtained a linked dataset from the California Office of Statewide Health Planning and Development (OSHPD). The Patient Discharge Database (PDD), which contains data on all discharges from a general acute, nonfederal hospital in the state, was linked at the patient level by unique record linkage number to all subsequent admissions to inpatient settings across the state. These nonpublic data were disclosed to the investigators and then subsequently linked at the hospital level by a unique hospital identifier to the publicly available OSHPD Hospital Annual Financial Data (HAFD).[21]

The PDD contains specific information about patient demographics, including age, sex, race/ethnicity, and insurance payer. In addition to the principal diagnosis for admission, clinical characteristics contained in the set include up to 24 secondary diagnoses with an indicator for whether the condition was present on admission. This indicator distinguishes preexisting or comorbid conditions from hospital-acquired conditions (ie, complications). Up to 19 additional procedure codes also are recorded and give insight into the severity of certain complications such as endotracheal intubation and intensive care unit admission. Dates of admission and discharge as well as dates of each procedure are recorded along with a calculated length of stay for each patient. By the use of a unique record linkage number generated by OSHPD, individual patient discharges are tracked to subsequent inpatient hospitalizations during the course of up to 4 years. Finally, the PDD contains a unique hospital identifier to indicate where treatment was delivered. This unique hospital ID was used to link the discharge to the HAFD. Thus, all-hospital readmissions were included, regardless of the index hospital of admission, to report true performance and outcomes.[22] HAFD provides hospital characteristics including hospital annual surgical volume, whether the facility is a teaching facility, whether it is rural in location, and whether it is a minority-serving hospital (MSH). Hospital annual volume for each procedure under study was calculated on the basis of annual discharges. Names and addresses of facilities are provided and help in the classification of healthcare system integration (HSI).

International Classification of Diseases, 9th edition Clinical Modification procedure codes were used to identify patients who underwent isolated coronary artery bypass graft (CABG) (36.10–19), colectomy (45.71–76, 45.79, 45.81–83, 17.31–36, 17.39), and total joint (hip or knee) arthroplasty (TJA) (81.51, 80.05, 00.70–73, 81.53, 81.54, 80.06, 81.55, 00.80–84) in California in 2011. All patients 18 years or older, and those who underwent scheduled procedures were included. Records coded as inpatient mortality or unplanned admissions were excluded from analysis. We also excluded patients who had unplanned admissions, to reduce variation in surgical acuity. Patients who underwent valve operations simultaneously performed with CABG were also excluded to minimize the potential for case-mix differences among hospitals as previously done.[23] Complications during the index hospitalization were defined when *International Classification of Diseases*, 9th edition Clinical Modification coding for secondary diagnoses appear with a corresponding present on admission indicator 'not present on admission'. Reasons for readmission were defined by the primary diagnosis for the readmission.

Measured outcomes. The primary outcome measured was hospital readmission within 30 days after discharge. The index hospital was defined as the hospital from which the patient was discharged.

Predictors and covariates. Patient level predictors of readmissions obtained from the OSHPD-PDD include age, sex, race/ethnicity, and Deyo-modified Charlson comorbidity index.[24]

The presence of complications was defined by a list of secondary diagnoses with a concomitant indicator that the condition was not present on admission. Our analysis accounted for >95% of all complications that occurred during the study period for each individual procedure. A marker for the presence of any complication was entered into regression models as a patient level predictor of readmission.

Hospital characteristics for comparison in this study include teaching status, rural location, and MSH. These variables are defined by the State of California and are found in the HAFD.[21] Annual hospital surgery volume was calculated on the basis of the number of discharge records for the specific surgical procedure in the OSHPD-PDD. MSH was defined as a hospitals with the greatest quartile of service to minority patients (ie, top 25% service to nonwhite patients as publicly reported by OSHPD).[25]

Hospitals were categorized into levels of health care system integration based on a modification of the definitions created by the Berkeley Forum for Improving California's Healthcare Delivery System.[26] Level of integration is defined by the Berkeley Forum based on medical group size: full integration is defined as care provided by a single, integrated entity responsible for all services including delivery of care, payment and risk management; high integration defined as groups with >100 physicians; moderate integration, medium-to-large groups or independent practice associations; and low integration, small groups, or having no affiliation to independent practice associations.[26] For the purpose of this study, we modified the Berkeley Forum classification into 3 tiers such that their fully integrated systems are referred to as "high integration" in our study; their high and moderate integration categories are combined into one category called "moderate integration" in our study; and low integration remains unchanged.

Bivariate comparisons. Readmission rates were compared as a function of patient characteristics and hospital characteristics. χ^2 analyses were used to make unadjusted comparisons of patient and hospital characteristics with readmission rates. All tests of significance were 2-tailed. For tests of multiple comparisons, the Dunnett test[27] correction was applied.

Hierarchical modeling. Logistic regression models were used to estimate odds of readmission at the patient level, accounting for the covariates described previously. Select variables were treated categorically (ie, age, sex, race, insurance payer, Charlson comorbidity index, and the presence of any complication during the index admission). The hospital factors teaching status, rural hospital, MSH, and level of HSI also were treated as binary. Hospital volume was analyzed in quartiles. Because of the hierarchical nature of the data where patients are nested within hospitals and hospitals within delivery systems, we used multilevel logistic regression models to predict the odds of readmission in 30 days. The odds were not equal to 1 and the associated 95% confidence intervals excluded 1. All tests of significance were 2-tailed.

Using the proposed data set, we performed a power analysis. We found that we have 80% power to detect 0.4–4.2% differences between hospital characteristics for each of the 3 procedures, with the exception of detecting differences between rural and nonrural settings for readmissions after CABG surgery.

RESULTS

Patient demographics and hospital characteristics. A total of 91,205 patients underwent CABG, colectomy or TJA at a general, acute, nonfederal hospital in California in 2011. Of these, 5,813 (6.4%) patients underwent CABG, 10,966 (12.0%) underwent colectomy, and 75,056 (82.3%) underwent TJA. Demographic data and clinical characteristics of the study cohort are shown in Table I. Approximately one-quarter of patients who underwent CABG were female, whereas more than half of patients in the colectomy and TJA groups were female. Minority patients represented more than one-quarter of patients in all procedure groups. Medicare was the most common payer in all 3 procedure groups, ranging from 47.3 to 57.1%. The overall rate of any complication was 27.6% for patients undergoing CABG, 35.6% for colectomy, and 20.8% for TJA.

Patients underwent CABG at 120 hospitals, colectomy at 296 hospitals, and TJA at 298 hospitals. Characteristics of the index hospitals are shown in Table II. The majority of patients underwent surgery at hospitals that were nonteaching (range 83.6–91.3%) and located in a nonrural area (87.5–99.1%). Approximately one-quarter (23.3–27.9%) of patients undergoing CABG, colectomy or TJA received care at a MSH. The majority of patients were treated in hospitals with low level of HSI. A small proportion of patients (10%) received care at hospitals in the highest level of HSI.

Patient-level predictors of readmission. Overall, 30-day readmission rates were less than 10% for all

Table I. Demographic and clinical characteristics of patients hospitalized for a major operative procedure in California in 2011

	Number of patients (%) (N = 91,205)		
	CABG	*Colectomy*	*TJA*
Total patients	5,813	10,966	75,056
Mean age (years, SD)	66.5 (9.9)	63.2 (14.4)	66.7 (10.8)
Sex			
Male	3,994 (77.1)	5,199 (47.4)	30,202 (40.2)
Female	1,189 (22.9)	5,767 (52.6)	44,854 (59.8)
Race			
White	3,210 (61.9)	7,438 (67.8)	55,968 (74.6)
Black	182 (3.5)	657 (6)	4,162 (5.6)
Hispanic	912 (17.6)	1,703 (15.5)	10,097 (13.5)
API	646 (12.5)	843 (7.7)	2,920 (3.9)
Other	233 (4.5)	325 (3)	1,909 (2.5)
Insurance status			
Medicare	2,961 (57.1)	5,186 (47.3)	42,586 (56.7)
Medicaid	435 (8.4)	708 (6.5)	3,229 (4.3)
Private	1,707 (32.9)	4,950 (45.1)	26,169 (34.9)
None	41 (0.8)	76 (0.7)	276 (0.4)
Other	39 (0.8)	46 (0.4)	2,796 (3.7)
Charlson comorbidity index			
0	1,559 (30.1)	6,274 (57.2)	45,228 (60.3)
1	1,606 (31)	2,371 (21.6)	18,993 (25.3)
2	804 (15.5)	762 (7)	5,751 (7.7)
3+	1,214 (23.4)	1,559 (14.2)	5,084 (6.8)
Any in-hospital complication	3,184 (27.6)	7,398 (35.6)	17,757 (20.8)

API, Asian/Pacific Islander; *CABG*, coronary artery bypass graft; *SD*, standard deviation; *TJA*, total joint (hip/knee) arthroplasty.

Table II. Characteristics of hospitals where patients underwent major surgical procedures in California in 2011

	Number of hospitals (%)		
	CABG	*Colectomy*	*TJA*
Total hospitals	120	296	298
Hospital annual surgical volume (cases)			
Q1 (lowest)	29 (24.2)	49 (16.6)	69 (23.2)
Q2	29 (24.2)	79 (26.7)	76 (25.5)
Q3	30 (25)	85 (28.7)	77 (25.8)
Q4 (highest)	32 (26.7)	83 (28)	76 (25.5)
Teaching hospital			
Yes	19 (16.4)	25 (8.8)	25 (8.7)
No	97 (83.6)	260 (91.2)	262 (91.3)
Geographic area			
Rural	1 (0.9)	38 (13.3)	36 (12.5)
Nonrural	115 (99.1)	247 (86.7)	251 (87.5)
MSH			
Yes	28 (23.3)	75 (25.3)	83 (27.9)
No	92 (76.7)	221 (74.7)	215 (72.2)
Level of HSI			
High	3 (2.5)	30 (10.1)	30 (10.1)
Medium	18 (15)	46 (15.5)	46 (15.4)
Low	99 (82.5)	220 (74.3)	222 (74.5)

Note that the total number of hospitals in this study is less than the sum of hospitals performing each procedure in this table, as several hospitals perform more than one type of procedure.
CABG, Coronary artery bypass graft; *HSI*, health care system integration; *MSH*, minority-serving hospital; *Q1*, first quartile, etc; *TJA*, total joint (hip/knee) arthroplasty.

procedure categories. Patient-level factors associated with readmission are shown in Table III. The readmission rate after CABG was 9.7%. Patients undergoing CABG who were older (68.3 years ± 9.8 vs 66.3 ± 9.8, $P < .001$) or female (13% vs 8.7% for male, $P < .001$) more often were readmitted compared with their counterparts. Patients undergoing colectomy were readmitted 7.7% of the time, with no significant differences between readmitted and nonreadmitted patients with respect to age, sex, or race. Of patients undergoing TJA, 3.9% were readmitted, with male (4.2% vs 3.7% for female, $P < .001$), older (68.9 ± 11.5 vs 66.7 ± 10.8, $P < .001$), and black (5.1%, $P < .001$) patients being readmitted in greater proportions compared with their counterparts. For all procedure groups, a greater percentage of patients with a greater Charlson comorbidity index were readmitted than those with a lower index (CABG: 16.3% for Charlson index 3+ vs 5.8% for Charlson index 0; colectomy: 18.7% vs 5.8%; TJA: 8.9% vs 2.9%; $P < .001$ for all comparisons).

Complications that occurred during the index hospitalization for each procedure are presented in Table III. Patients with complications were more often readmitted compared to patients overall in each procedure category. After CABG, 11.2% of patients who developed arrhythmias and 14.7% of those with pleurisy were readmitted compared with 9.7% overall ($P = .05$ and $P = .001$, respectively). After colectomy, 17% of patients with pneumonia, 11.5% of those with gastrointestinal complications, 9.6% with ileus, and 18.9% with other respiratory complications had greater rates of readmission compared with only 7.7% of patients overall ($P < .001$ for all comparisons). Patients with postoperative anemia after TJA required readmission 4.8% of the time compared with 3.9% overall ($P < .001$).

Hospital-level predictors of readmission. Unadjusted readmission rates based on hospital factors are shown in Table IV. After we adjusted for patient variables including the presence of in-hospital

Table III. Patient-level factors associated with readmissions

	Number of patients (%)											
	CABG				Colectomy				TJA			
	Not readmitted (%)	*Readmitted (%)*	*Total discharges*	*P value*	*Not readmitted (%)*	*Readmitted (%)*	*Total discharges*	*P value*	*Not readmitted (%)*	*Readmitted (%)*	*Total discharges*	*P value*
Total patients	4,680 (90.3%)	503 (9.7%)	5,183	—	10,122 (92.3%)	844 (7.7%)	10,966	—	72,139 (96.1%)	2,917 (3.9%)	75,056	—
Sex												
Male	3,646 (91.3)	348 (8.7)	3,994	<.001	4,798 (92.3)	401 (7.7)	5,199	.95	28,937 (95.8)	1,265 (4.2)	30,202	<.001
Female	1,034 (87)	155 (13)	1,189		5,324 (92.3)	443 (7.7)	5,767		43,202 (96.3)	1,652 (3.7)	44,854	
Mean age (years, SD)	66.3 (9.8)	68.3 (9.8)	66.5 (9.9)	<.001	63.2 (14.3)	63.6 (15.4)	63.2 (14.4)	.49	66.7 (10.8)	68.9 (11.5)	66.7 (10.8)	<.001
Race												
White	2,904 (90.5)	306 (9.5)	3,210		6,901 (92.8)	537 (7.2)	7,438		53,808 (96.1)	2,160 (3.9)	55,968	
Black	162 (89)	20 (11)	182		593 (90.3)	64 (9.7)	657		3,952 (95)	210 (5.1)	4,162	
Hispanic	819 (89.8)	93 (10.2)	912	.75	1,560 (91.6)	143 (8.4)	1,703	.07	9,712 (96.2)	385 (3.8)	10,097	<.001
API	580 (89.8)	66 (10.2)	646		772 (91.6)	71 (8.4)	843		2,826 (96.8)	94 (3.2)	2,920	
Other	215 (92.3)	18 (7.7)	233		296 (91.1)	29 (8.9)	325		1,841 (96.4)	68 (3.6)	1,909	
Insurance												
Medicare	2,621 (88.5)	340 (11.5)	2,961		4,752 (91.6)	434 (8.4)	5,186		263 (95.3)	13 (4.7)	276	
Medicaid	388 (89.2)	47 (10.8)	435		633 (89.4)	75 (10.6)	708		40,668 (95.5)	1,918 (4.5)	42,586	
Private	1,598 (93.6)	109 (6.4)	1,707	<.001	4,630 (93.5)	320 (6.5)	4,950	<.001	3,058 (94.7)	171 (5.3)	3,229	<.001
None	37 (90.2)	4 (9.8)	41		67 (88.2)	9 (11.8)	76		25,422 (97.2)	747 (2.9)	26,169	
Other	36 (92.3)	3 (7.7)	39		40 (87)	6 (13)	46		2,728 (97.6)	68 (2.4)	2,796	
Charlson comorbidity index												
0	1,468 (94.2)	91 (5.8)	1,559		5,910 (94.2)	364 (5.8)	6,274		43,905 (97.1)	1,323 (2.9)	45,228	
1	1,484 (92.4)	122 (7.6)	1,606	<.001	2,257 (95.2)	114 (4.8)	2,371	<.001	18,196 (95.8)	797 (4.2)	18,993	<.001
2	712 (88.6)	92 (11.4)	804		688 (90.3)	74 (9.7)	762		5,407 (94)	344 (6)	5,751	
3+	1,016 (83.7)	198 (16.3)	1,214		1,267 (81.3)	292 (18.7)	1,559		4,631 (91.1)	453 (8.9)	5,084	
Main complications												
Arrhythmias	996 (88.7)	126 (11.2)	1,122	.05	—	—	—	—	—	—	—	—
Pleurisy	297 (85.3)	51 (14.7)	348	.001	—	—	—	—	—	—	—	—
GI complications	—	—	—	—	781 (88.6)	101 (11.5)	882	<.001	—	—	—	—
Ileus	—	—	—	—	1,597 (90.4)	169 (9.6)	1,766	.001	—	—	—	—
Pneumonia	—	—	—	—	153 (83.2)	31 (16.9)	184	<.001	—	—	—	—
Respiratory complications	—	—	—	—	103 (81.1)	24 (18.9)	127	<.001	—	—	—	—
Postoperative bleed/anemia	—	—	—	—	—	—	—	—	14,247 (95.2)	712 (4.8)	14,959	<.001

Main complications represent the most common, which are >95% of all complications by procedure. For main complications, *P* value refers to comparison between readmission rates associated with the specific complication versus the overall procedure-specific readmission rate.
API, Asian/Pacific Islander; *GI*, gastrointestinal.

Table IV. Hospital-level factors associated with readmissions

	Number of patients (%)								
	CABG			*Colectomy*			*TJA*		
	Not readmitted	*Readmitted*	*P value*	*Not readmitted*	*Readmitted*	*P value*	*Not readmitted*	*Readmitted*	*P value*
Hospital annual surgical volume (cases)									
Q1	342 (90)	38 (10)		132 (89.2)	16 (10.8)		1,062 (94.8)	58 (5.2)	
Q2	730 (90)	81 (10)	.94	882 (91.7)	80 (8.3)	.07	6,291 (95.7)	285 (4.3)	<.001
Q3	1,035 (90)	115 (10)		2,355 (91.5)	220 (8.5)		18,895 (95.8)	825 (4.2)	
Q4	2,573 (90.5)	269 (9.5)		6,753 (92.8)	528 (7.3)		45,891 (96.3)	1,749 (3.7)	
Teaching hospital									
Yes	627 (91)	62 (9)	.43	1,495 (91.5)	139 (8.5)	.23	8,470 (95.7)	380 (4.3)	.06
No (ref)	3,817 (90)	422 (10)		8,201 (92.4)	678 (7.6)		58,239 (96.1)	2,352 (3.9)	
Geographic area									
Rural	37 (86.1)	6 (14)	.36	305 (87.1)	45 (12.9)	<.001	2,670 (96.7)	92 (3.3)	.10
Nonrural	4,407 (90.2)	478 (9.8)		9,391 (92.4)	772 (7.6)		64,039 (96)	2,640 (4)	
MSH									
Yes	821 (90)	91 (10)	.76	1,498 (91.4)	141 (8.6)	.14	9,966 (95.5)	472 (4.5)	<.001
No	3,859 (90.4)	412 (9.7)		8,624 (92.5)	703 (7.5)		62,173 (96.2)	2,445 (3.8)	
Level of HSI									
High	433 (91.4)	41 (8.7)	.57	2,429 (92.8)	190 (7.3)	.10	13,378 (96.3)	516 (3.7)	.12
Medium	676 (90.9)	68 (9.1)		1,582 (93.3)	114 (6.7)		10,969 (95.8)	481 (4.2)	
Low	3,571 (90.1)	394 (9.9)		6,111 (91.9)	540 (8.1)		47,792 (96.1)	1,920 (3.9)	

HSI, Health care system integration; *MSH*, minority-serving hospital.

complications, certain hospital factors were predictive of readmissions (Table V). For CABG, there were no correlations between any hospital characteristics and readmission. For colectomy, rural hospitals were associated with greater readmissions (odds ratio [OR] 2.08, 95% confidence interval [95% CI] 1.40–3.08). For TJA, decreasing hospital surgical volume (OR 1.16, 95% CI 1.06–1.28 in volume quartile 3; OR 1.54, 95% CI 1.13–2.10 in volume quartile 1) was associated with increased odds of readmission. Service provided in MSH (OR 1.18, 95% CI 1.05–1.33) was associated with a greater odds of readmission after TJA. There was no significant association between level of HSI and readmission after CABG, colectomy, or TJA.

DISCUSSION

The purpose of this study was to identify hospital characteristics associated with hospital readmissions after major operative procedures. We found that after accounting for patient characteristics, select hospital level factors were independently associated with increased postoperative readmissions. Low hospital surgical volume and MSH both predicted readmission after TJA. Rural location was predictive of readmission after colectomy. Hospital factors did not predict readmissions after CABG. We did not find any significant association between readmissions and greater health care system integration in any surgical procedure.

In agreement with previous studies, our work suggests that patient factors are important in determining readmissions after major surgery.[7-14] In particular, we found that postoperative complications play an important role in predicting readmission. This relationship has been well described previously.[28-30] We found a correlation between MSH and readmission, which is also in agreement with other studies.[7,8] Although we initially suspected that greater rates of complication in MSH settings might explain our findings, we instead found that complication rates do not vary significantly between MSH and non-MSH for any procedure. These results suggest that other, unmeasured characteristics of MSH may explain the greater risk for readmissions after major surgery. The fact that MSH have greater of readmissions[31] and receive larger payment cuts under the Hospital Readmission Reduction Program[32] raise specific concern for unintended consequences of financial penalties.

Despite some similarities with existing studies, our findings are novel in demonstrating that select hospital factors are independent predictors of readmission rates after a variety of major surgical procedures. Our study also raises important policy

Table V. Multivariable models predicting the odds of readmission by hospital characteristics after adjustment for patient factors

	Odds ratio (95% Confidence interval)		
	CABG	*Colectomy*	*TJA*
Hospital annual surgical volume (cases)			
Q1	1.08 (0.66–1.75)	1.48 (0.78–2.78)	1.54 (1.13–2.10)*
Q2	1.14 (0.80–1.63)	1.09 (0.82–1.46)	1.15 (0.99–1.33)
Q3	1.07 (0.78–1.46)	1.12 (0.92–1.36)	1.16 (1.06–1.28)*
Q4 (ref)	—	—	—
Teaching hospital			
Yes	0.92 (0.63–1.34)	1.06 (0.83–1.33)	1.08 (0.95–1.23)
No (ref)	—	—	—
Geographic area			
Rural	1.81 (0.51–6.50)	2.08 (1.40–3.08)*	0.85 (0.68–1.07)
Nonrural (ref)	—	—	—
MSH			
Yes	0.97 (0.70–1.36)	0.97 (0.76–1.23)	1.18 (1.05–1.33)*
No (ref)	—	—	—
Level of HSI			
High	0.85 (0.54–1.34)	0.95 (0.78–1.17)	0.97 (0.87–1.09)
Medium	0.86 (0.60–1.24)	0.80 (0.63–1.02)	1.11 (0.99–1.25)
Low (ref)	—	—	—

*Indicates statistical significance.
CABG, Coronary artery bypass graft; *HSI*, health care system integration; *MSH*, minority-serving hospital; *Q1*, first quartile, etc; *TJA*, total joint (hip/knee) arthroplasty.

implications. Because low-volume, minority-serving, and rural hospital characteristics are associated with greater odds of readmissions, these settings, which may already be resource limited, may face further resource constraints as the result of penalties levied under HRPP. Although previous studies have focused on Medicare patients only, our study provides some insight into how select value based purchasing programs may play out across the general population. Therefore, our results may guide the development of healthcare delivery systems structured to reduce surgical readmissions and avoid future penalties across the country.

Our study has some limitations. Because we have used administrative data and retrospective study design, we cannot prove causation. Nonetheless, the associations we have found point to potential targets for quality improvement interventions at the hospital level. This is important because penalties will be applied at the hospital level. Patient selection may also introduce variation in readmissions due to differential distribution of patients across different hospital settings. To address this, we used hierarchical modeling, thereby increasing the strength of the associations reported. Therefore, we believe the correlations reported in this study to be important for informing the development of strategies targeting hospital settings at high risk for readmission and associated financial penalties.

Only select hospital-level factors are associated with readmissions after operative procedures. More research may be needed to better understand the exact drivers of readmissions in low-volume, minority-serving, and rural hospitals. Future policies should be cautiously designed to avoid creating further financial stress in low resource settings, where resource limits may increase adverse consequences.

REFERENCES

1. Jencks SF, Williams MV, Coleman EA. Rehospitalizations among patients in the Medicare fee-for-service program. N Engl J Med 2009;360:1418-28.
2. Hansen LO, Young RS, Hinami K, et al. Interventions to reduce 30-day rehospitalization: a systematic review. Ann Intern Med 2011;155:520-8.
3. Centers for Medicare and Medicaid Services. Shared Savings Program. Available from: https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/sharedsavingsprogram/index.html. Accessed July 1, 2014.
4. Center for Medicare and Medicaid Services. FY 2015 Proposed Rule Data Files. Available from: http://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/AcuteInpatientPPS/FY2015-IPPS-Proposed-Rule-Home-Page.html. Accessed July 1, 2014.

5. Berwick DM. Making good on ACOs' promise—the final rule for the Medicare shared savings program. N Engl J Med 2011;365:1753-6.
6. Van Citters AD, Larson BK, Carluzzo KL, et al. Toward accountable care: four health care organizations' efforts to improve patient care and reduce costs. New York: The Commonwealth Fund; 2011.
7. Girotti ME, Shih T, Revels S, Dimick JB. Racial disparities in readmissions and site of care for major surgery. J Am Coll Surg 2014;218:423-30.
8. Tsai TC, Orav EJ, Joynt KE. Disparities in surgical 30-day readmission rates for Medicare beneficiaries by race and site of care. Ann Surg 2014;259:1086-90.
9. Kassin MT, Owen RM, Perez SD, et al. Risk factors for 30-day hospital readmission among general surgery patients. J Am Coll Surg 2012;215:322-30.
10. Schneider EB, Hyder O, Brooke BS, et al. Patient readmission and mortality after colorectal surgery for colon cancer: impact of length of stay relative to other clinical factors. J Am Coll Surg 2012;214:390-9.
11. Vorhies JS, Wang Y, Herndon J, et al. Readmission and length of stay after total hip arthroplasty in a national Medicare sample. J Arthroplasty 2011;26(6 Suppl):119-23.
12. Cram P, Lu X, Kates SL, et al. Total knee arthroplasty volume, utilization, and outcomes among Medicare beneficiaries, 1991-2010. JAMA 2012;308:1227-36.
13. Hendren S, Morris AM, Zhang W, Dimick J. Early discharge and hospital readmission after colectomy for cancer. Dis Colon Rectum 2011;54:1362-7.
14. Schairer WW, Vail TP, Bozic KJ. What are the rates and causes of hospital readmission after total knee arthroplasty? Clin Orthop Relat Res 2014;472:181-7.
15. Joynt KE, Orav EJ, Jha AK. Thirty-day readmission rates for Medicare beneficiaries by race and site of care. JAMA 2011; 305:675-81.
16. Sutton JM, Wima K, Wilson GC, et al. Factors associated with 30-day readmission after restorative proctocolectomy with IPAA: a national study. Dis Colon Rectum 2014;57: 1371-8.
17. Wilson GC, Cutler Quillin R 3rd, Sutton JM, Wima K, Shaw JJ, Hoehn RS, et al. Factors related to readmission after major elective surgery. Dig Dis Sci 2015;60:47-53.
18. Tsai TC, Joynt KE, Orav EJ, et al. Variation in surgical-readmission rates and quality of hospital care. N Engl J Med 2013;369:1134-42.
19. Markar SR, Karthikesalingam A, Thrumurthy S, Low DE. Volume-outcome relationship in surgery for esophageal malignancy: systematic review and meta-analysis 2000-2011. J Gastrointest Surg 2012;16:1055-63.
20. Bilimoria KY, Bentrem DJ, Ko CY, et al. Multimodality therapy for pancreatic cancer in the U.S.: utilization, outcomes, and the effect of hospital volume. Cancer 2007;110: 1227-34.
21. California Office of Statewide Health Planning and Development. Hospital Annual Financial Data for California, Selected Data File Documentation. Available from: http://www.oshpd.ca.gov/HID/Products/Hospitals/AnnFinanData/HAFDDoc2004.pdf. Accessed July 1, 2014.
22. Gonzalez AA, Shih T, Dimick JB, Ghaferi AA. Using same-hospital readmission rates to estimate all-hospital readmission rates. J Am Coll Surg 2014;219:656-63.
23. Shih T, Dimick JB. Reliability of readmission rates as a hospital quality measure in cardiac surgery. Ann Thorac Surg 2014;97:1214-8.
24. Deyo RA, Cherkin DC, Ciol MA. Adapting a clinical comorbidity index for use with ICD-9-CM administrative databases. J Clin Epidemiol 1992;45:613-9.
25. California Office of Statewide Health Planning and Development. Patient Discharge Data, Patient Discharge Pivot Files. Available from: http://www.oshpd.ca.gov/HID/Products/PatDischargeData/PivotTables/PatDischarges/default.asp. Accessed July 1, 2014.
26. The Berkeley Forum for Impreportng California's Healthcare Delivery System. A New Vision for California's Healthcare System. 2013. Available from: http://berkeleyhealthcareforum.berkeley.edu/report/.
27. Dunnett CW, Tamhane AC. Step-down multiple tests for comparing treatments with a control in unbalanced one-way layouts. Stat Med 1991;10:939-47.
28. Merkow RP, Ju MH, Chung JW, Hall BL, Cohen ME, Williams MV, et al. Underlying reasons associated with hospital readmission following surgery in the United States. JAMA 2015;313:483-95.
29. Tevis SE, Weber SM, Kent KC, Kennedy GD. Nomogram to predict postoperative readmission in patients who undergo general surgery. JAMA Surg 2015;150:505-10.
30. Glance LG, Kellermann AL, Osler TM, et al. Hospital readmission after noncardiac surgery: the role of major complications. JAMA Surg 2014;149:439-45.
31. Shih T, Ryan AM, Gonzalez AA, Dimick JB. Medicare's Hospital Readmission Reduction Program in Surgery May Disproportionately Affect Minority-Serving Hospitals. Ann Surg 2014 May 30. [Epub ahead of print] PubMed PMID: 24887984; PubMed Central PMCID: PMC4248020. Accessed July 15, 2015.
32. Joynt KE, Jha AK. Characteristics of hospitals receiving penalties under the Hospital Readmissions Reduction Program. JAMA 2013;309:342-3.