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Impact of Hospital Population Case-Mix, Including Poverty, on Hospital All-Cause and Infection-Related 30-Day Readmission Rates

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Background. Reducing hospital readmissions, including preventable healthcare-associated infections, is a national priority. The proportion of readmissions due to infections is not well-understood. Better understanding of hospital risk factors for readmissions and infection-related readmissions may help optimize interventions to prevent readmissions.

Methods. Retrospective cohort study of California acute care hospitals and their patient populations discharged between 2009 and 2011. Demographics, comorbidities, and socioeconomic status were entered into a hierarchical generalized linear mixed model predicting all-cause and infection-related readmissions. Crude verses adjusted hospital rankings were compared using Cohen's *kappa*.

Results. We assessed 30-day readmission rates from 323 hospitals, accounting for 213 879 194 post-discharge person-days of follow-up. Infection-related readmissions represented 28% of all readmissions and were associated with discharging a high proportion of patients to skilled nursing facilities. Hospitals serving populations with high proportions of males, comorbidities, prolonged length of stay, and populations living in a federal poverty area, had higher all-cause and infection-related readmission rates. Academic hospitals had higher all-cause and infection-related readmission rates (odds ratio 1.24 and 1.15, respectively). When comparing adjusted vs crude hospital rankings for infection-related readmission rates, adjustment revealed 31% of hospitals changed performance category for infection-related readmissions.

Conclusions. Infection-related readmissions accounted for nearly 30% of all-cause readmissions. High hospital infection-related readmissions were associated with serving a high proportion of patients with comorbidities, long lengths of stay, discharge to skilled nursing facility, and those living in federal poverty areas. Preventability of these infections needs to be assessed.

Keywords. hospital infections; readmissions; healthcare associated infections; poverty.

Hospital readmissions represent a major health and financial burden to patients. Nearly 30% of hospitalized patients are readmitted within 1 year of hospitalization, with over half occurring within 30 days of discharge [1, 2]. The Centers for Medicare and Medicaid Services (CMS) estimate rehospitalization cost among Medicare patients alone at $17 billion annually. Readmission rates serve as hospital quality indicators in an era of transparency, accountability, and best practices in healthcare delivery [3]. As of October 2012, CMS began restricting reimbursements for readmissions associated with congestive heart failure, acute myocardial infarctions, and pneumonia and are now implementing further financial restrictions for hospitals with elevated all-cause readmission rates [4–6].

The interest in readmission rates is driven, in part, by the recognition that a significant proportion of

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readmissions may be preventable. Among these, infection-related readmissions represent an important group of potentially preventable infections, including healthcare-associated infections (HAIs), which are a major contributor to hospital-associated morbidity, mortality, and readmissions [7, 8]. In 2014, CMS extended its 2008 restrictions on HAI reimbursements [9]. Although a few studies address individual risk factors for specific infection-related readmissions, (eg, methicillin-resistant *Staphylococcus aureus* [MRSA] or *Clostridium difficile* infections), no data exist on infection-related readmissions as a whole [10, 11].

The institution of financial disincentives for readmissions is predicated on a real and present need for hospitals to address opportunities to improve inpatient and post-discharge care plans. However, hospitals vary significantly in the patients and communities they serve, which may impact their readmission rates and strategies to mitigate risks for readmission. Although CMS assessments of readmissions adjust for gender and comorbidity, they do not account for factors such as socioeconomic status (SES) and nursing home residence, which could have significant impact on hospital readmission rates.

Hypothesizing that hospital case-mix significantly affects readmission rates and that readmission risk factors may be different for those related to infection, we sought to evaluate the impact of hospital-level population characteristics on all-cause and infection-related 30-day readmission rates and hospital rankings. We also hypothesized that factors not easily modified by hospitals, such as the percentage of patients living in poor communities, may raise hospital readmission rates.

METHODS

We conducted a retrospective cohort study of adults (≥18 years) hospitalized at 323acute-care hospitals in California between 1 January 2009–30 November 2011 to evaluate 30-day all-cause and infection-related readmission rates. We excluded hospitals dedicated to pediatrics, psychiatry, chemical dependency, and long-term acute care and those with <500 admissions per year or mean lengths-of-stay >25 days. We utilized the California mandatory hospitalization data set, which includes demographics, residence zip code, admission/discharge dates, insurance type, admission/discharge location, and up to 25 medical and procedural diagnosis codes [12]. Each patient is assigned a unique encrypted identifier (record linking number [RLN] generated from date of birth, gender, and social security number), allowing patient tracking and capture of readmissions across facilities statewide. We excluded patients lacking RLNs. (All exclusions are detailed in Supplementary Appendix B.)

For each hospitalization, readmissions were identified within 30 days of discharge. Admissions resulting in death were excluded from readmissions analyses. If multiple readmissions occurred within 30 days, only the first was evaluated to prevent double counting. Each readmission was then defined as an index hospitalization to evaluate whether a subsequent readmission occurred within 30 days of discharge, per CMS readmission definitions [13]. We evaluated readmissions due to infection-related causes by identifying the subset of readmissions with infection codes (Supplementary Appendix A) as the primary or secondary admission diagnosis. We excluded codes for conditions unlikely to be acquired while hospitalized (eg, salmonella, encephalitis, tick-borne illness); these represented 11% of the total infection-related readmissions.

Evaluating Hospital Case-Mix

We assessed individual and hospital-level descriptors for admissions resulting in all-cause and infection-related readmissions within 30 days of discharge. Hospitals were described by the proportion of each characteristic in their admitted patients. Distributions of these characteristics across all hospitals in the state were described as the means and standard deviations of these proportions (Table 1). We further categorized hospitals as having high vs low readmission rates, defined as rates above or below the mean readmission rate across all hospitals. Hospital case-mix characteristics were compared within these strata using paired t-tests. Additional hospital characteristics including the number of licensed beds and academic teaching status were obtained from publicly available datasets [14]. Hospital comorbidity case-mix was evaluated using Elixhauser classification [15]. Since Romano score is a well-studied indicator of overall illness severity, we calculated mean Romano comorbidity index for each hospitalization [16].

To generate SES indices for each hospital, we aggregated data associated with patient residential zip code. Residential zip codes were linked to US Census American Community Survey (ACS) data from 2009 to 2011 and characterized by poverty (defined as >20% living below federal poverty line) and crowding (defined as >1 person per room on average per housing unit) [17]. Residential zip code characteristics were aggregated to the hospital level to generate hospital-specific descriptors of community catchment areas served.

Assessing Risk Factors Associated With All-Cause and Infection-Related Hospital Readmissions

We evaluated patient characteristics associated with all-cause hospital readmissions and infection-related readmissions using both bivariate tests and multivariate models. Bivariate testing involved χ^2 tests for categorical variables and t-tests for continuous variables. To identify predictors of all-cause and infection-related readmissions, we used a hierarchical generalized linear mixed model (procGLIMMIX, SAS version 9.3) that included a random intercept term accounting for clustering [18, 19]. Each outcome was modeled separately. This approach

Table 1. Hospital-Level Descriptors, California Hospitals 2009–2011

Characteristic of Hospital Patient Population	All Admissions Mean of Each Hospital-Level Value (Mean or Proportion) (SD)	Admissions Not Resulting in Readmission Mean of Each Hospital-Level Value (Mean or Proportion) (SD)	30-Day All-Cause Readmissions Mean of Each Hospital-Level Value (Mean or Proportion) (SD)			30-Day Infection Readmissions Mean of Each Hospital-Level Value (Mean or Proportion) (SD)		
			Low	High	*P* Value	Low	High	*P* Value
Hospitals (N)	323	323	187	136		188	135	
Academic Teaching Hospital (N)	20	20	0	20		8	12	
Mean Length of Stay during Index admission (days)	4.2 (1.5)	4.0 (1.5)	5.1 (1.5)	5.8 (2.2)	<.001	6.2 (1.5)	7.2 (2.7)	<.001
Male (%)	39.2 (7.4)	38.2 (7.6)	44.3 (6.2)	48.3 (5.5)	<.001	45 (6.3)	46.4 (5.3)	.024
Age (%)								
18–44	29 (12.8)	30.5 (13.3)	19.3 (12.2)	17.4 (7.1)	.104	14.5 (11.6)	11.4 (5.2)	.004
45–54	13.3 (4.0)	13.2 (4.0)	12.7 (3.9)	15.9 (4.9)	<.001	12.1 (5)	12.2 (4.6)	.873
55–64	15.7 (4.0)	15.3 (4.1)	16.5 (3.8)	19.2 (4.2)	<.001	16.2 (4.8)	16.9 (4.4)	.172
65–84[a]	31.1 (8.4)	30.4 (8.5)	37.8 (8.5)	35.3 (9.1)	.014	40.5 (9.9)	41.5 (7.3)	.288
>85[a]	10.8 (5.0)	10.5 (5.0)	13.8 (5.7)	12.3 (6)	.021	16.8 (7.4)	18 (7.2)	.135
Race								
White	70.2 (22)	70.1 (21.9)	77.8 (18.4)	61 (22.8)	<.001	77.6 (18.9)	66.6 (21.7)	<.001
Black	8.6 (10.4)	8.3 (10.0)	7 (8.8)	15.9 (14.6)	<.001	8.1 (10.1)	11.7 (12.3)	.002
Asian	7.8 (10.0)	7.9 (10.0)	5 (5.1)	10.2 (12.9)	<.001	5.6 (5.2)	10.1 (13.7)	<.001
Other	13.4 (14.5)	13.7 (14.8)	10.6 (12.4)	13.3 (14.3)	.087	10.5 (12.1)	12.8 (13.9)	.086
Non-White	29.8 (21.9)	29.9 (21.9)	22.2 (18.4)	39 (22.8)	<.001	22.7 (18.9)	33.9 (22.4)	<.001
Hispanic Ethnicity (%)	23.8 (1.9)	24.2 (1.9)	18.9 (16.1)	24.8 (18.6)	.003	19.1 (17)	22.4 (17)	.087
Insurance Status (%)								
Commercial	27.8 (15.0)	29.2 (15.5)	22.1 (11.5)	13.6 (10.3)	<.001	17.6 (10.8)	11.7 (8.8)	<.001
Medicare	44.8 (13.0)	43.2 (13.1)	56.5 (12.6)	54.6 (13.7)	.195	61.6 (14.8)	64.6 (11.6)	.054
Medicaid	19.1 (13.3)	19.0 (13.4)	15.1 (11.3)	24.6 (12.8)	<.001	14.8 (12.7)	19 (11)	.003
County and Other Indigent Programs	3.1 (4.9)	3.2 (5.2)	2.4 (3.2)	2.8 (4.4)	.274	2.6 (4.0)	1.6 (2.8)	.015
Work compensation	4.7 (3.2)	4.9 (3.4)	3.2 (2.4)	3.9 (2.5)	.020	2.9 (2.7)	2.6 (1.7)	.243
Pre-Admission Location (%)								
Home	89.6 (10.5)	90.1 (10.3)	88.7 (10.3)	83.8 (13.1)	<.001	85.9 (10.4)	76.6 (16.9)	<.001
SNF	4.3 (5.8)	4.0 (5.5)	4.4 (3.8)	9.2 (9.7)	<.001	6.7 (5.8)	15.7 (14.1)	<.001
Inpatient acute care facility	2.3 (7.5)	2.2 (7.4)	2.9 (8.1)	3.1 (8.4)	.709	3 (7.9)	3.5 (9.1)	.475
Post-Discharge Location (%)								
Home	68.1 (10.5)	69.5 (10.4)	60.9 (10.3)	57.5 (12.9)	.008	50.7 (12.3)	42.3 (13.1)	<.001
SNF	11.2 (7.0)	10.2 (6.6)	15.5 (7.2)	19.9 (11.2)	<.001	22.4 (10.3)	32.8 (14.2)	<.001
Percentage living in a crowded home within zip code of patient's primary residence	2.7 (1.4)	2.7 (1.4)	2.3 (1.3)	3.1 (1.4)	<.001	2.4 (1.4)	3.1 (1.5)	<.001
Percentage living in federal poverty area[a]	17.5 (20.7)	17.3 (20.5)	14.1 (19.6)	24.1 (22.7)	<.001	16 (20.2)	21.4 (22.9)	.026
Mean Romano Score	2.6 (0.7)	2.3 (0.6)	3.8 (0.8)	4.5 (0.7)	<.001	4.0 (0.9)	4.8 (0.7)	<.001
Elixhauser Comorbidity (%)								
Hypertension	45.4 (10.2)	44.9 (9.5)	53.4 (9.3)	55.9 (8.6)	.016	55.7 (10)	58.7 (8.4)	.005
Congestive Heart Failure	8.1 (3.5)	7.3 (3.0)	13.3 (4.5)	13.4 (4.8)	.756	15.4 (5.6)	17.5 (5.7)	<.001
Valvular Disease	3.1 (1.7)	29.5 (1.6)	5 (2.4)	3.4 (1.8)	<.001	5.4 (2.8)	4.3 (2.7)	<.001
Pulmonary Circulation Disorders	1.5 (0.9)	1.4 (0.77)	2.7 (1.5)	2.2 (1.2)	<.001	3 (1.8)	2.8 (1.7)	.226
Peripheral Vascular Disease	5.2 (3.3)	4.9 (3.1)	8.8 (5.8)	7.1 (3.9)	.004	9.4 (5.9)	8.8 (5.4)	.355
Paralysis	2.8 (2.1)	2.6 (1.8)	3.6 (2.3)	4.4 (2.2)	.003	4.9 (2.4)	6.7 (3.6)	<.001
Neurologic Disorders	7.2 (3.0)	6.8 (2.9)	8.7 (2.5)	10.5 (4)	<.001	10.8 (3.6)	14.4 (5.3)	<.001
Chronic Pulmonary Disease	16.9 (5.5)	15.9 (5.1)	22.2 (5.5)	23.2 (7.3)	.169	25.1 (6.6)	27.9 (7.8)	<.001

Table 1 continued.

Characteristic of Hospital Patient Population	All Admissions Mean of Each Hospital-Level Value (Mean or Proportion) (SD)	Admissions Not Resulting in Readmission Mean of Each Hospital-Level Value (Mean or Proportion) (SD)	30-Day All-Cause Readmissions Mean of Each Hospital-Level Value (Mean or Proportion) (SD)			30-Day Infection Readmissions Mean of Each Hospital-Level Value (Mean or Proportion) (SD)		
			Low	High	*P* Value	Low	High	*P* Value
Diabetes, uncomplicated	17.0 (5.8)	16.5 (5.5)	19.6 (6.5)	24.9 (5.4)	<.001	21.2 (7)	26.5 (6.6)	<.001
Diabetes, complicated	5.7 (4.2)	5.3 (3.9)	10 (7.1)	9.2 (5)	.305	10.1 (7.1)	10.2 (5.5)	.940
Hypothyroidism	10.3 (3.3)	10.1 (3.1)	13.5 (3.4)	10.8 (3.3)	<.001	14.8 (4.3)	13.3 (3.9)	.002
Renal Failure	11.5 (5.0)	10.5 (4.4)	18.9 (7)	21.2 (7.5)	.006	19.5 (7.5)	21.9 (7.4)	.005
Liver disease	3.5 (1.6)	3.3 (1.5)	5.1 (1.8)	6 (2.4)	<.001	5.2 (2.7)	5.3 (1.9)	.840
Peptic Ulcer Disease	0.4 (0.06)	0.04 (0.5)	0.1 (0.1)	0.1 (0.1)	.593	0.1 (0.1)	0.1 (0.1)	.137
AIDS	0.19 (0.3)	0.2 (0.3)	0.2 (0.3)	0.5 (0.6)	<.001	0.2 (0.4)	0.3 (0.5)	.042
Lymphoma	0.66 (0.4)	0.6 (0.4)	1.3 (0.7)	1.1 (0.8)	.126	1.4 (0.9)	1.3 (1)	.284
Metastatic Cancer	2.0 (1.7)	1.8 (1.7)	3.5 (1.6)	3.2 (2.8)	.187	3.6 (1.9)	3.6 (3.3)	.987
Solid tumor without metastasis	1.8 (0.8)	1.7 (0.8)	3.1 (1.1)	2.9 (1.3)	.128	3.4 (1.4)	3.2 (1.5)	.404
Rheumatoid Arthritis/ collagen vascular diseases	2.3 (0.8)	2.2 (0.7)	3.3 (1.1)	2.7 (1.1)	<.001	4 (1.8)	3.2 (1.4)	<.001
Coagulopathy	4.1 (1.7)	3.8 (1.6)	6.2 (2.5)	6.6 (2.5)	.244	6.6 (2.9)	7.2 (2.8)	.089
Obesity	10.8 (4.8)	10.8 (4.8)	12.1 (4.8)	10.7 (4.4)	.008	12.7 (5.5)	11.5 (4.2)	.031
Weight Loss	5.0 (5.0)	4.6 (4.8)	7 (5.2)	9.8 (8.6)	<.001	9 (6.7)	13.9 (11.1)	<.001
Fluid and electrolyte disorders	21.1 (8.3)	20.2 (8.1)	28.5 (8.4)	31.3 (9.4)	.005	32.3 (10)	38.2 (9.6)	<.001
Blood loss anemia	2.6 (1.7)	2.7 (1.8)	2.7 (1.3)	1.9 (0.9)	<.001	2.4 (1.5)	1.9 (1.1)	<.001
Deficiency anemias	19.1 (6.9)	18.5 (6.3)	27 (7.5)	31.1 (8.7)	<.001	30.6 (8.6)	36 (9.6)	<.001
Alcohol Abuse	4.3 (2.4)	4.2 (2.3)	5.7 (2.8)	6 (3.1)	.384	5.2 (3.1)	4.5 (2.5)	.036
Drug Abuse	3.5 (2.6)	3.3 (2.4)	4.5 (3)	5.3 (3.7)	.020	4.2 (3.4)	3.9 (3)	.384
Psychoses	5.4 (5.2)	5.2 (5.2)	5.9 (3.5)	8.7 (7.6)	<.001	6.5 (4.5)	8.7 (7.1)	<.001
Depression	8.2 (3.5)	7.9 (3.2)	11.1 (4.5)	9.4 (3.6)	<.001	11.3 (4.8)	10.2 (4.6)	.038

Results of t-tests comparing hospital level characteristics of (a) all admissions to all-cause readmissions and (b) all-cause readmissions to infection-related readmissions were all statistically significant, with *P* values <.05 with the exception of the following: Asian race, Insurance status "Other," and peptic ulcer disease comorbidity.

Abbreviations: SD, standard deviation; SNF, skilled nursing facility.

[a] Federal poverty area defined as zip code where 20% or greater persons live below the federal poverty level.

enables a statistical analysis that (1) uses patient-level data to evaluate hospital outcomes, (2) accounts for patient clustering within hospitals, and (3) includes a risk-adjustment methodology designed to determine the degree to which a hospital influences the outcomes. A sensitivity analysis of the final infection-related readmission model was performed limiting the infection-related readmission diagnosis code to the primary position.

Comparing Adjusted and Unadjusted Hospital Rankings for 30-Day Infection-Related Readmissions

In order to assess how hospital infection-related readmissions performance rankings were affected by hospital case-mix adjustment, an analytical model was implemented based on the standards for statistical models for public reporting of hospital quality metrics [18, 20]. We calculated crude readmission rates for each hospital; crude confidence intervals were obtained using the California state method for hospital infection quality metrics, based on the Poisson distribution [21]. Predicted confidence intervals for infection-related readmissions were obtained using bootstrap simulation of the hierarchical model. These intervals were then applied according to the CA state methodology, categorizing hospitals as "worse-than-statewide rate," "no-different-than-statewide rate," and "better-than-statewide rate" if the hospital's readmission rate was below, within, or above the state hospital 95% confidence interval (CI), respectively [21]. Agreement between crude and adjusted California ratings was measured by Cohen's *kappa* [22, 23]. All statistical analyses and simulations were implemented in SAS, version 9.3 (SAS Institute, Cary, North Carolina).

RESULTS

Readmission rates were evaluated for 323 California hospitals, accounting for 7 793 945 admissions and 213 879 194

Table 2. Top 10 Primary or Secondary Infection Diagnoses at Readmission

Infection Categories	% Among All Readmissions	% Among Infection-Related Readmissions
1. Sepsis	10.2	29.9
2. Pneumonia	7.8	22.9
3. Genitourinary Infections	5.0	14.6
4. Skin/Soft Tissue Infections	3.1	9.0
5. Post-Operative Infections	1.9	5.4
6. *Clostridium difficile* Infections	1.4	4.2
7. Gastrointestinal Infections	1.4	4.0
8. Osteomyelitis/Septic Arthritis	0.8	2.2
9. Device Associated Infections	0.6	1.8
10. Other	2.0	5.9
Total	34%	100.0%

For readmissions in which both primary and secondary diagnoses were infection-related, both diagnoses were included separately to reflect the total number of infection-related diagnoses present on readmission.

post-discharge person-days of follow-up. A total of 1 107 202 admissions resulted in readmission for any cause with a statewide mean 30-day all-cause hospital readmission rate of 14.1% (standard deviation [SD] 4.1%); among these, 28% or 309 448 admissions were infection-related, (readmission rate 4.1%, SD 1.5%). The majority of readmissions (70.8% and 72.2% for all-cause and infection-related readmissions, respectively) occurred at the same hospital; however, this ranged from 2.9% to 91.9% for all-cause and 0.7%–94.6% for infection-related readmissions. Data regarding excluded hospitals, admissions, and missing data are detailed in Supplementary Appendix B.

Infection-Related Readmission Diagnoses

The most common causes of infection-related readmissions (Table 2), included sepsis (29.9%), pneumonia (22.9%), and urinary tract infections (14.6%). HAIs identifiable by administrative data, including post-operative infections, *C. difficile* colitis, and device-associated infections, were among the top 10 most common causes of infection-related readmissions, and when pooled together became the 4th most common infection category (11.4%).

Hospital Characteristics by Readmission Subsets

Proportional means of a hospital's patients with various characteristics are shown in Table 1 and compared across hospitals. Hospitals with a higher all-cause readmission rate had higher proportions of patients who were male, older, non-White, non-commercially insured, had longer lengths of stay, were more often admitted from and discharged to skilled nursing facility (SNF), and resided in crowded or poor zip codes. These hospitals also had higher comorbidity scores. Similar observations were

Table 3. Hierarchical Fixed-Effects Model for Predictors of All-Cause and Infection-Related Readmissions

Descriptive Variable	All-Cause Readmissions Odds Ratio (CI)	Infection-Related Readmissions Odds Ratio (CI)
Male gender	1.14 (1.14–1.15)	1.07 (1.06–1.08)
Length of Stay > 5 days	1.47 (1.46–1.47)	1.97 (1.95–1.98)
Age (years)		
18–44	1	1
45–54	1.27 (1.26–1.29)	1.51 (1.48–1.53)
55–64	1.17 (1.16–1.18)	1.49 (1.47–1.52)
65–84	0.92 (.92–.93)	1.38 (1.36–1.40)
>85	0.87 (.86–.88)	1.47 (1.44–1.49)
Insurance Status		
Private	1	1
Medicaid, County	1.52 (1.52–1.53)	1.49 (1.47–1.51)
Medicare	1.45 (1.44–1.46)	1.44 (1.43–1.46)
Other[a]	1.18 (1.17–1.20)	1.09 (1.07–1.12)
Admission from SNF at index admission	0.90 (.89–.91)	1.26 (1.24–1.28)
Discharged to SNF at Index Admission	1.37 (1.36–1.38)	1.95 (1.94–1.97)
Patients living in a Federal Poverty Area[b]	1.04 (1.03–1.04)	1.02 (1.02–1.05)
Academic Hospital Status	1.47 (1.13–1.38)	1.12 (1.95–1.98)
Mean Romano Score[a]	1.15 (1.15–1.15)	1.39 (1.10–1.10)

Abbreviations: CI, confidence interval; SNF, skilled nursing facility.

[a] Other insurance status includes: self-pay, worker's compensation, or unknown.

[b] Federal poverty area defined as zip code where 20% or greater persons live below the federal poverty level. All *P*-values were statistically significant with $P < .0001$. Covariance parameter estimates for all-cause and infection-related readmissions were 0.04 and 0.05, respectively while within-hospital correlation among patient outcomes was estimated to be small, at 0.014, except academic hospital status for infection-related readmissions, $P = .002$.

noted when comparing the case-mix of hospitals with higher vs lower infection-related readmission rates.

Variables Associated with Hospital Readmissions

With few exceptions, bivariate analyses were statistically significantly correlated with both outcomes. Table 3 shows variables associated with increased all-cause and infection-related hospital readmissions in hierarchical mixed-effects regression models. Covariance parameters for all-cause and infection-related readmissions were 0.04 (standard error 0.003) and 0.05 (standard error 0.004), respectively, indicating significant variability between hospitals. However the estimated variance within hospitals was 0.014, suggesting minimal variation in the correlation

Table 4. Agreement Between Crude vs Adjusted Infection-Related Readmissions Rating Among California Hospitals (N=323)

	Unadjusted Rating		
Adjusted Rating	Worse Than State Mean	No Different Than State Mean	Better Than State Mean
Hospitals N (% of Total)			
Worse than State Mean	92 (28%)	22 (7%)	26 (8%)
No Different than State Mean	12 (4%)	8 (2%)	14 (4%)
Better than State Mean	13 (4%)	12 (4%)	124 (38%)

Percentages calculated among all hospitals (n = 323).

of outcomes within hospitals. Academic status was associated with a 1.25 and 1.15 times higher risk for all-cause and infection-related readmission rate, respectively. Among the top predictors of infection-related readmissions were length of stay (LOS) >5 days, discharge to SNF at index admission, and medical/county insurance status, after adjusting for demographics and comorbidity. Living in a high-poverty area was significantly associated with both all-cause and infection-related readmission rates (Table 3). This variable and insurance status was found to be collinear with race and ethnicity. The predictive effect of the variables presented in Table 3 remained significant on sensitivity analysis limiting infection-related diagnosis codes to primary position only; similar results were also found when restricting the time frame to one year at a time.

Ranking by Crude Versus Adjusted Readmission Rates

Agreement was moderate between crude and adjusted hospital rankings for infection-related readmission (Cohen's *kappa* 0.48; 95% CI, .41–.56). Overall, 31% of hospitals changed performance category for infection-related readmissions, respectively, after adjustment (Table 4). Crude vs risk-adjusted infection-related readmissions for all hospitals in our cohort are shown in Supplementary Appendix C.

For infection-related readmissions, among 117 hospitals ranked worse-than-state average, 25 (21%) were actually no different or better than average upon adjustment. Among 44 hospitals previously ranked as average, 32 (80%) were found to be reclassified upon adjustment (Table 4). Similar results were found when restricting the population of hospitals to academic facilities only.

DISCUSSION

We found that infection-related readmissions accounted for nearly 30% of all readmissions and represent a segment of potentially preventable readmissions. Sepsis, pneumonia, and urinary tract infections were the top 3 infection diagnoses present at readmission, followed by surgical site infections, device-associated infections, and *C. difficile* infections. Each of the latter 3 has been a focus for reducing HAIs during hospitalization and has been identified as a source of ongoing HAI risk in the immediate post-discharge period [11, 24, 25]. In addition, to our knowledge this is the first study to assess hospital-level risk factors for infection-related readmissions as a whole. Our findings emphasize the impact that HAI prevention efforts may achieve if extended into the 30-day post-discharge period and the need for further study to define the full extent of readmissions due to HAIs. Furthermore, the finding that sepsis was the top infection-related readmission is noteworthy as it may include a subset of potentially preventable HAIs.

Our findings suggest that hospital strategies to reduce infection-related readmissions should include a focus on partnership with SNFs. Discharge to SNF was associated with a 2-fold increased risk of infection-related readmission. National trends show a rise in hospitalizations among SNF residents, with over 2 million Medicare-insured patients admitted in 2009 [26, 27]. Residents of SNFs are known to be at high risk for infection, particularly with multidrug resistant organisms and HAIs [28]. Specific efforts to reduce infection readmissions among nursing home residents may represent a large and important opportunity for readmission prevention.

In this all-payer assessment of hospital readmissions, we found that underinsured populations such as those with Medicaid and county insurance programs carry higher risk for both all-cause and infection-related readmissions. Similarly, we found that hospitals serving a larger proportion of patients living in high poverty areas had higher readmission rates. Although its effect size was small, neighborhood poverty area remained significant despite adjustment for major predictors such as comorbidity, insurance, and academic status. Though indirect, prior studies have shown neighborhood poverty area correlates well with patient-specific SES [29]. Given that this measure may not fully capture the extent of the impact of poverty on readmissions, its significance in our model is even more noteworthy. Further work is needed to fully describe the impact of poverty on readmissions. The impact of SES on individual patient health status is recognized [30]. Our study highlights the impact of poverty in the post-discharge period, which may be manifested through readmission rates at the hospital level. Poverty may negatively affect adherence to discharge recommendations via medication or medical supply affordability, lack of reliable transportation to appointments, crowded or unsanitary housing, and health literacy affecting adherence to post-discharge instructions [31–33].

Current CMS algorithms for hospital risk adjustment for readmissions do not account for nursing home residence or SES. Reimbursement restrictions and financial penalties that do not account for upstream social determinants of health may risk unintended consequences for hospitals struggling to meet the needs of under-resourced communities. Rather, investments are needed to understand how hospital and community post-discharge support systems can improve individual and community health in poor neighborhoods such that proportionate resources can be allocated to improving post-discharge care [34].

Academic status remained a strong, independent hospital-level predictor of all-cause and infection-related readmissions despite adjustment for comorbidities and the proportion of patients from poor communities. This may reflect unmeasured confounders and insufficient capture of illness severity or socioeconomic disadvantage among patient groups [35]. It could also raise concerns about the quality of care provided by trainees. Specifically with regard to infection-related readmissions, medical students and trainees are the least adherent to infection prevention practices [36]. Nevertheless, teaching facilities also have been associated with better hospital safety metrics, surgical care performance, cardiac outcomes, and mortality rates, and it is possible that unmeasured confounders are affecting this analysis [35, 37]. The paradoxical relationship between readmission rates and quality measures highlights the problems associated with broad application of mandates that incompletely adjust for readmissions risk, with teaching hospitals receiving the highest CMS penalties for hospital 30-day readmissions despite high performance on quality-of-care measures [38]. Although not uniformly true across all teaching hospitals, further work is needed to understand whether the strong association between academic status and readmissions reflects high-quality care of sicker patients for which penalty systems should be sympathetic, or whether teaching status confers risk that may be preventable.

LOS longer than 5 days was the strongest predictor of infection-related readmissions, after adjustment for demographics and comorbidities. This finding suggests that a significant proportion of infection-related readmissions could be hospital-acquired and warrants further study [39]. This 5-day threshold provides a potential target for identifying patients at high risk for infection and implementing prevention strategies. It emphasizes the importance of minimizing delays in discharge and optimizes strategies that may facilitate discharge such as patient mobilization, removal of devices, and transitioning to oral medications at the earliest opportunity.

Factors involved in the chain of events ultimately leading to hospital readmission are complex, with likely significant overlap and interplay between predisposing elements at the patient, community, and hospital level. We attempted to describe risk factors that may impact hospital readmissions rates beyond patient-level factors (eg, gender, comorbidity). We found substantial disagreement between crude and adjusted rankings, with 99 (31%) hospitals being misclassified for infection-related readmission rates.

LIMITATIONS

Our study has several limitations. First, we were unable to exclude planned readmissions; CMS estimates that exclusion of such would decrease readmissions by 0.7%–1.5% [40]. Second, we do not have insight into emergency department or primary care visits associated with the post-hospitalization period either as a contributor to post-discharge preventable healthcare utilization or a mitigation strategy for readmission. Third, this work does not address risk factors unavailable in administrative data, such as access to care, language, or mental health barriers. Fourth, while the administrative data set provided a large volume of data allowing tracking of readmissions across all California hospitals, use of diagnostic codes needs further validation for accurate representation of common reasons for readmission. Fifth, we were unable to assess readmissions for patients lacking RLNs; however, this group represents a small subset (8.2%) of the total. Finally, our data are limited to one state, affecting generalizability; nevertheless, California represents approximately 13% of the nation's population and is sociodemographically diverse.

CONCLUSIONS

Infection-related readmissions comprise nearly 30% of all-cause readmissions. Our study is among the first to identify risk factors associated with infection-related readmissions which contain a subgroup of potentially uniquely preventable readmissions. Our findings highlight the importance of strategic partnerships with SNFs to limit infection-related readmissions. Factors beyond gender and comorbidity bear further evaluation and consideration for interhospital comparisons and penalties, such as hospital case-mix of patients living in poor communities. Adjusting for such factors resulted in substantial shifts in hospital rankings in all-cause and infection-related readmissions.

Strategies to affect change in post-discharge health outcomes, including the risk for readmissions, necessitate consideration of both patient and community-level impacts on health. Fair benchmarking and allocation of hospital readmission reimbursement penalties should account for SES factors such as neighborhood poverty and provide resources and investments to help hospitals meet the challenges such patients face in obtaining quality care. To the extent that a hospital's practices, protocols, and prevention strategies may impact readmission risk, increased efforts should be made to identify and mitigate modifiable contributors to readmission rates and improve patient care.

Supplementary Data

Supplementary materials are available at *Clinical Infectious Diseases* online (http://cid.oxfordjournals.org). Supplementary materials consist of data provided by the author that are published to benefit the reader. The posted materials are not copyedited. The contents of all supplementary data are the sole responsibility of the authors. Questions or messages regarding errors should be addressed to the author.

Notes

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All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Conflicts that the editors consider relevant to the content of the manuscript have been disclosed.

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