Associations Between Reduced Hospital Length of Stay and 30-Day Readmission Rate and Mortality: 14-Year Experience in 129 Veterans Affairs Hospitals

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Background: Reducing length of stay (LOS) has been a priority for hospitals and health care systems. However, there is concern that this reduction may result in increased hospital readmissions.

Objective: To determine trends in hospital LOS and 30-day readmission rates for all medical diagnoses combined and 5 specific common diagnoses in the Veterans Health Administration.

Design: Observational study from 1997 to 2010.

Setting: All 129 acute care Veterans Affairs hospitals in the United States.

Patients: 4 124 907 medical admissions with subsamples of 2 chronic diagnoses (heart failure and chronic obstructive pulmonary disease) and 3 acute diagnoses (acute myocardial infarction, community-acquired pneumonia, and gastrointestinal hemorrhage).

Measurements: Unadjusted LOS and 30-day readmission rates with multivariable regression analyses to adjust for patient demographic characteristics, comorbid conditions, and admitting hospitals.

Results: For all medical diagnoses combined, risk-adjusted mean hospital LOS decreased by 1.46 days from 5.44 to 3.98 days, or 2% annually ($P < 0.001$). Reductions in LOS were also observed for the 5 specific common diagnoses, with greatest reductions for acute myocardial infarction (2.85 days) and community-acquired pneumonia (2.22 days). Over the 14 years, risk-adjusted 30-day readmission rates for all medical diagnoses combined decreased from 16.5% to 13.8% ($P < 0.001$). Reductions in readmissions were also observed for the 5 specific common diagnoses, with greatest reductions for acute myocardial infarction (22.6% to 19.8%) and chronic obstructive pulmonary disease (17.9% to 14.6%). All-cause mortality 90 days after admission was reduced by 3% annually. Of note, hospitals with mean risk-adjusted LOS that was lower than expected had a higher readmission rate, suggesting a modest tradeoff between hospital LOS and readmission (6% increase for each day lower than expected).

Limitations: This study is limited to the Veterans Health Administration system; non–Veterans Affairs admissions were not available. No measure of readmission preventability was used.

Conclusion: Veterans Affairs hospitals demonstrated simultaneous improvements in hospital LOS and readmissions over 14 years, suggesting that as LOS improved, hospital readmission did not increase. This is important because hospital readmission is being used as a quality indicator and may result in payment incentives. Future work should explore these relationships to see whether a tipping point exists for LOS reduction and hospital readmission.

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The balance between improving hospital efficiency while simultaneously improving quality of care is a priority in our health care system. However, a marker of efficiency, hospital length of stay (LOS), may conflict with a marker of quality: hospital readmission rates. Hospitals are driven to improve efficiency as skyrocketing costs have outpaced reimbursement and face incentives to reduce LOS as part of the Medicare prospective payment system, diagnosis-related group–based third-party payments, and closed-system HMO care models (1). The adoption of hospitalist programs has been one response to improve LOS because such models have been associated with 10% to 15% reductions (2). Simultaneously, there is pressure to improve quality, as promoted by accreditation organizations (such as the Joint Commission) (3), professional societies (such as the Society of Hospital Medicine) (4), quality improvement organizations (such as the National Quality Forum) (5), payors of health care (such as Medicare), and health care systems (such as Veterans Affairs [VA]) (6). Incentives to reduce avoidable readmissions have been proposed through adjustment of diagnosis-related group payments for avoidable readmissions, performance-based diagnosis-related group payments (that is, bundling), or through public reporting of readmission rates (7).

Improving efficiency by reducing LOS should benefit both patients and hospitals. Unnecessary hospital days expose patients to potential iatrogenic injury, such as infections and cost burdens. However, there is emerging concern that excessive LOS reduction may be harmful because discharge before medical stability may result in increased hospital readmission or use of emergency department services. The actual existence of this association has not yet been described. Baker and colleagues (8) were the first to explore this question using Medicare data from 1991 to 1997 and found that reductions in LOS were associated with stable 30-day readmission rates. Similar results have

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been reported in a study showing reductions in LOS in a national U.S. and VA sample from 1996 to 1999 (9). However, these findings predate the hospitalist movement and aggressive LOS reduction initiatives by hospitals, which could lead to increased readmissions.

Readmission within 30 days for medical conditions is common and costly. In studies of Medicare patients, 30-day readmission rates range from 8% (8) to 21% (10), depending on diagnosis, with annual estimated costs of $17.4 billion (10). A recent Centers for Medicare & Medicaid Services Hospital Quality Alliance study reported readmission rates of 21% and 25% for pneumonia and heart failure (HF), respectively (11). The debate on readmissions centers on understanding which readmissions may be prevented by modifying care during the index admission or transitions of care and which are unavoidable events for patients with complex medical conditions. In 1 study using retrospective chart review, 8.8% of readmissions were considered preventable (12). A recent randomized, controlled trial using a packet of nursing and pharmacist discharge services to reduce readmissions found a reduction that was not statistically significant but estimated that 15% of readmissions could be prevented using their intervention (13). Regardless, hospital readmission is not an optimal outcome for patients or providers but may be financially advantageous for hospitals.

The objective of this study is to examine whether LOS improvements in VA health care have negatively affected 30-day readmission rates. Veterans Affairs is an optimal system in which to study this relationship because services are vertically integrated, including primary, specialty, acute, tertiary, home, and nursing home care. Enrolled veterans are eligible for a range of services that potentially lead to appropriate postdischarge care and reduced readmissions. Given efforts to aggressively reduce LOS and conflicting results of interventions to reduce 30-day readmission rates (14–16), we hypothesize that there is a tradeoff between readmission rates and LOS such that lower-than-expected LOS could result in increased 30-day readmission rates.

Context

There is concern that efforts to decrease hospital length of stay may inadvertently increase the risk for hospital readmission.

Contribution

In this study of patients admitted to Veterans Affairs hospitals for any of 5 acute diagnoses or chronic conditions from 1997 to 2010, the hospital length of stay and 30-day readmission and all-cause mortality rates decreased annually.

Implication

The goal of decreasing length of stay may not necessarily lead to increases in readmission rates.

—The Editors

METHODS

Data Sources

The primary data source to identify all acute medical admissions was the VA Patient Treatment File, a national administrative database of all inpatient admissions, including patient demographic characteristics, primary and secondary diagnoses and procedures (using International Classification of Diseases, Ninth Revision, Clinical Modification [ICD-9-CM], codes), admission source (for example, emergency department), hospital care units (for example, medical intensive care unit), and discharge disposition. The VA Vital Status File provided dates of death.

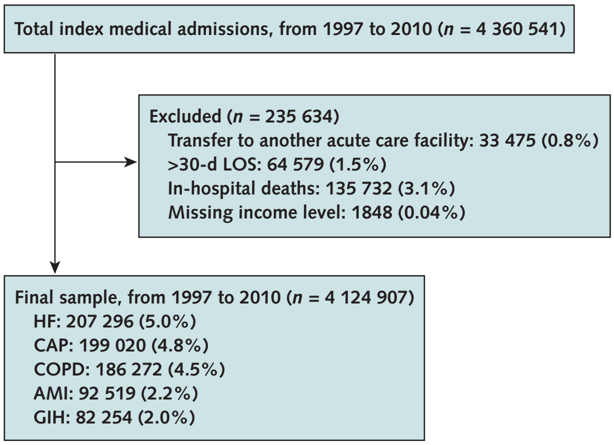
Patients

Creation of the study cohort involved several steps (**Figure**). First, all acute medical admissions to 129 VA hospitals during fiscal years (FYs) 1997 to 2010 (October 1996 to September 2010) were identified. The sample included all VA hospitals with acute inpatient medical services, exclusive of VA hospitals that provide only psychiatric or long-term care. Readmissions were determined if they occurred within 30 days of the date of discharge from the index admission and were linked to the relevant index admission (10). Admissions more than 30 days after a previous admission discharge date were considered new index admissions. Second, index admissions were excluded if the patient was transferred to another acute care facility (0.8%), stayed longer than 30 days during index admission (1.5%), died during index admission (3.2%), or had missing income (<0.01%). Overall, 5.5% of index admissions were excluded (categories were not mutually exclusive), resulting in a final sample of 4 124 907 admissions. Lastly, we used the Agency for Healthcare Research and Quality Clinical Classifications Software (17) to classify ICD-9-CM codes for index admissions into commonly cited clinical categories and identify 5 high-volume diagnoses: 2 chronic conditions (HF [n = 207 296] and chronic obstructive pulmonary disease [COPD] [n = 186 272]) and 3 acute conditions (acute myocardial infarction [AMI] [n = 92 519], community-acquired pneumonia [n = 199 020], and gastrointestinal hemorrhage [n = 82 254]).

Data Elements

Analyses examined 2 primary outcomes. Hospital LOS was defined as the number of days from patient admission until discharge using time of discharge minus time of admission in hours, divided by 24; hospital readmission rate was defined as the proportion of index admissions readmitted within 30 days of discharge. A secondary outcome was death occurring within 30 or 90 days of admission, either in the hospital or after discharge. Independent variables were age, sex, marital status, income, VA service–connected eligibility, admission source, intensive care unit transfer, comorbid conditions as defined by Elixhauser and

Figure. **Study flow diagram.**



AMI = acute myocardial infarction; CAP = community-acquired pneumonia; COPD = chronic obstructive pulmonary disease; GIH = gastrointestinal hemorrhage; HF = heart failure; LOS = length of stay.

colleagues (18), and year of index admission. To simplify analysis, we combined FYs into 2-year increments using FY1997–1998 as the referent with subsequent 2-year periods; FY2009–2010 is the most recent period.

Statistical Analysis

First, unadjusted trends in LOS and readmission rates from FY1997–1998 to FY2009–2010 for all medical diagnoses combined and the 5 specific common diagnoses were evaluated. Because patients are clustered within hospitals, *P* values for evaluating trends in LOS and readmission rate trends were based on generalized linear mixed models, which were estimated using the adaptive quadrature algorithm and included random effects for the admitting hospitals. We assumed a γ distribution and log link for analysis of LOS and a binomial distribution and logit link for readmissions. Each model included indicator variables for FY of discharge (coded in 2-year increments) to assess the increase (or decrease) in LOS or readmission rates during that 2-year time frame relative to FY1997–1998.

Additional analyses expanded the models for LOS and readmissions to control for patient variables described previously as well as the admitting hospital, in accordance with previous studies based on administrative data (19–21). Models were developed separately for each disease cohort. Patient characteristics to be included in the models were identified using a multistep process that included literature review, bivariate inspection of patient characteristics, multivariable analyses, and clinical interpretation. During each step, model discrimination, calibration, and condition indices (that is, collinearity) were evaluated. After defining the final model for each cohort, coefficients associated with each 2-year indicator variable were used to calculate LOS and readmission rates in 2-year increments, adjusted for patient characteristics and the clustering of patients within hospitals.

We note that a few patients had more than 1 admission during the observation period. Specifically, the proportion of patients with several index admissions in any given year was 2%, 2%, 4%, 12%, and 12% for AMI, gastrointestinal hemorrhage, community-acquired pneumonia, HF, and COPD, respectively. Nevertheless, analyses did not control for the clustering of admissions within patients because of the estimation problems with such a large data set and the fact that most subsequent admissions were at least 90 days from the previous inpatient encounter, making it more likely that they were independent.

A second set of models for readmission rates were estimated to evaluate the relationship between hospital-level LOS and readmission rates, after controlling for patient characteristics and patient LOS. Two measures of LOS were included in these models: patient-level LOS and deviation in mean LOS during the year of discharge between the admitting hospital and across all hospitals. Coefficients associated with these 2 measures represent the relationship between a patient's LOS and likelihood of readmission and the relationship between hospital-level LOS practices and the likelihood of readmission. A detailed description of the modeling process, including the derivation of these final models and final model parameter estimates, is provided in the **Appendix** (available at www.annals.org).

Finally, 30- and 90-day logistic regression all-cause mortality models were created, controlling for patient demographic characteristics and comorbid conditions and using random intercepts for admitting hospital. Risk-adjustment variables were selected using a multistep selection process as in the 30-day readmission model. This model was included to evaluate evidence of clinical harm, as measured by mortality, due to reductions in LOS. The model also evaluated whether the reduction in readmission rates could be explained by an increase in deaths after discharge.

All analyses were done using SAS, version 9.1 (SAS Institute, Cary, North Carolina).

Role of the Funding Source

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Results

Patient Characteristics

The final cohort consisted of 4 124 907 admissions over 14 years of observation. Characteristics of all patients admitted in FY1997–1998 and FY2009–2010 are described in **Table 1**, including the readmission rates for each category. Between FY1997–1998 and FY2009–2010, the

Table 1. **Characteristics of All Patients Admitted to Acute Care Medical Services**

Characteristic	Fiscal Year 1997–1998 (*n* = 515 542)		Fiscal Year 2009–2010 (*n* = 691 989)	
	Patients*	Readmission Rate, %	Patients*	Readmission Rate, %
Mean age (SD), *y*	63.8 (13.1)	–	65.5 (13.1)	–
Age				
<45 y	45 570 (8.8)	12.3	33 523 (4.8)	9.7
45–54 y	94 772 (18.4)	14.7	86 914 (12.6)	13.2
55–64 y	100 084 (19.4)	17.2	241 940 (35.0)	15.0
65–74 y	158 681 (30.8)	17.8	136 771 (19.8)	16.1
75–84 y	103 300 (20.0)	17.7	132 111 (19.1)	16.9
≥85 y	13 135 (2.5)	16.7	60 730 (8.8)	16.3
Male sex	500 845 (97.1)	16.7	662 324 (95.7)	15.4
Income				
≤$20 000	417 804 (81.0)	16.6	417 783 (60.4)	15.1
$20 001–$40 000	80 854 (15.7)	16.4	205 809 (29.7)	15.6
$40 001–$60 000	10 095 (2.0)	15.2	34 830 (5.0)	14.8
>$60 000	6789 (1.3)	15.4	33 567 (4.9)	14.3
Admission source				
Transferred from another hospital	12 774 (2.5)	16.5	14 022 (2.0)	15.1
Admission from nursing home	11 987 (2.3)	19.6	10 465 (1.5)	21.1
Direct admission to ICU	110 210 (21.4)	16.0	106 209 (15.4)	15.8
Comorbid conditions				
Alcohol abuse	66 507 (12.9)	14.6	79 843 (11.5)	15.7
Arrhythmia	82 210 (15.9)	18.4	154 379 (22.3)	17.3
Cerebral vascular disease	53 049 (10.3)	14.6	52 626 (7.6)	14.3
COPD	128 740 (25.0)	18.2	180 214 (26.0)	16.9
Depression	37 740 (7.3)	14.8	108 895 (15.7)	14.1
Deficiency anemia	16 835 (3.3)	19.4	32 880 (4.8)	18.3
Dementia	14 531 (2.8)	12.9	15 917 (2.3)	15.5
Diabetes				
Complicated	26 106 (5.1)	19.4	48 112 (7.0)	18.5
Not complicated	104 616 (20.3)	17.5	196 669 (28.4)	16.1
Drug abuse	15 845 (3.1)	12.4	33 073 (4.8)	15.4
Fluid–electrolyte imbalance	55 078 (10.7)	19.0	125 067 (18.1)	17.8
Hemiparaplegia	16 720 (3.2)	14.6	7008 (1.0)	15.9
HF	80 344 (15.6)	20.9	119 983 (17.3)	19.8
Hypertension				
Complicated	15 252 (3.0)	22.5	98 201 (14.2)	19.4
Not complicated	200 139 (38.8)	16.0	357 958 (51.7)	14.5
Hypothyroidism	16 004 (3.1)	17.1	47 250 (6.8)	16.1
Liver disease				
Mild	23 021 (4.5)	20.4	50 633 (7.3)	19.3
Severe	6820 (1.3)	25.4	11 881 (1.7)	24.0
Lymphoma	5666 (1.1)	33.8	8540 (1.2)	27.8
Malignancy	54 204 (10.5)	27.9	81 358 (11.8)	22.3
Myocardial infarction	40 505 (7.9)	19.3	40 528 (5.9)	18.1
Neurological disorder	41 294 (8.0)	14.8	42 727 (6.2)	15.6
Obesity	14 564 (2.8)	12.9	38 962 (5.6)	13.2
Paralysis	19 705 (3.8)	14.8	10 917 (1.6)	16.1
Peripheral vascular disease	49 745 (7.2)	18.1	25 066 (3.6)	24.6
Pulmonary circulatory disorder	21 407 (4.2)	19.0	30 275 (4.4)	19.9
Renal disease	25 066 (4.9)	24.6	113 127 (16.3)	19.7
Valve disorder	19 193 (3.7)	20.8	32 691 (4.7)	19.0
Weight loss	26 953 (5.2)	19.0	20 816 (3.0)	19.0

COPD = chronic obstructive pulmonary disease; HF = heart failure; ICU = intensive care unit.
* Values reported are numbers (percentages), unless otherwise stated. Percentages may not sum to 100 due to rounding.

mean age of patients increased from 63.8 to 65.5 years, with the proportion of patients aged 85 years or older more than tripling from 2.5% to 8.8%, whereas the proportion younger than 45 years decreased by nearly half (from 8.8% to 4.8%). There were also sizable increases in the prevalence of several comorbid conditions, including arrhythmia, depression, diabetes, fluid–electrolyte imbalance, hypertension, obesity, and renal disease. Notably, the prev-

Table 2. **Unadjusted Mean Hospital LOS**

Fiscal Year	Unadjusted Mean Hospital LOS (SD), *d*					
	All Admissions	HF	COPD	AMI	CAP	GIH
1997–1998	5.97 (5.3)	6.37 (4.8)	5.82 (4.5)	7.01 (4.7)	7.36 (5.2)	5.37 (4.4)
1999–2000	5.13 (4.8)	5.70 (4.5)	5.12 (4.2)	6.31 (4.5)	6.48 (4.9)	4.82 (4.1)
2001–2002	4.98 (4.7)	5.57 (4.5)	4.89 (4.0)	5.85 (4.5)	6.14 (4.8)	4.60 (4.0)
2003–2004	4.88 (4.7)	5.43 (4.4)	4.71 (3.9)	5.66 (4.6)	5.96 (4.8)	4.46 (3.8)
2005–2006	4.63 (4.5)	5.03 (4.1)	4.45 (3.6)	5.41 (4.5)	5.66 (4.6)	4.32 (3.7)
2007–2008	4.50 (4.5)	4.88 (4.1)	4.23 (3.5)	5.02 (4.4)	5.48 (4.5)	4.13 (3.5)
2009–2010	4.28 (4.3)	4.70 (3.9)	4.03 (3.4)	4.62 (4.2)	5.22 (4.3)	3.95 (3.5)
Change from 1997 to 2010	−1.69*	−1.67*	−1.79*	−2.39*	−2.14*	−1.42*

AMI = acute myocardial infarction; CAP = community-acquired pneumonia; COPD = chronic obstructive pulmonary disease; GIH = gastrointestinal hemorrhage; HF = heart failure; LOS = length of stay.
* *P* values for differences in LOS relative to 1997–1998 are statistically significant ($P < 0.001$). *P* values are based on generalized linear model with γ-distributed errors, log link, and random intercepts for hospitals.

alence of renal disease more than tripled from 4.9% to 16.4% during the observation period. Overall, most patients had several comorbid conditions, with only 7% having no reported comorbid condition.

Unadjusted Analyses

Over the 14 years, mean LOS significantly decreased for the entire cohort by 1.69 days, from 5.97 days to 4.28 days ($P < 0.001$). Decreases in mean LOS varied by condition, with a minimum decrease of 1.42 days for gastrointestinal hemorrhage and maximum decrease of 2.39 days for AMI (**Table 2**). Likewise, the overall 30-day readmission rate showed a similar significant reduction, from 16.6% to 15.2% overall ($P < 0.001$). However, within individual conditions, readmission rates decreased significantly only for COPD (17.6% to 15.8%; $P < 0.001$) (**Table 3**).

Adjusted Analysis

Table 4 shows risk-adjusted LOS, controlling for hospital effects as well as differences in patient characteristics. The risk-adjusted LOS during each 2-year increment reflects the LOS expected for the average patient at the average hospital in the entire data set (that is, predicted LOS holding all patient risk factors and hospital factors constant at the mean value). Risk-adjusted LOS for all medical diagnoses combined decreased during the 14-year period from 5.44 to 3.98 days. This 1.46-day reduction in risk-adjusted LOS from FY1997–1998 to FY2009–2010 represents a 26.8% relative decrease (that is, 3.98 days ÷ 5.44 days = 0.73). Of patients with the 5 individual conditions, those with acute conditions had greater decreases in risk-adjusted LOS; AMI decreased by 2.85 days and community-acquired pneumonia decreased by 2.22 days.

Multivariable analyses of 30-day readmission rates show similar results (**Table 5**), with a decrease from 16.5% to 13.8%, an absolute difference of 2.7 percentage points, or a 16.4% relative decrease. Within individual conditions, COPD showed the greatest absolute reduction over the 14-year observation period (17.9% to 14.6%; 18.4% relative decrease), followed by AMI (22.6% to 19.8%; 12.4% relative decrease).

Relationship of LOS and Readmissions

In the model of all medical conditions that included patient-level LOS and hospital mean LOS during the discharge year, the coefficient associated with hospital year-

Table 3. **Unadjusted 30-Day All-Cause Hospital Readmission Rates***

Fiscal Year	Unadjusted 30-Day All-Cause Hospital Readmission Rate, %					
	All Admissions	HF	COPD	AMI	CAP	GIH
1997–1998	16.6	20.2	17.6	21.7	14.7	14.2
1999–2000	16.2 ($P < 0.001$)	19.9 ($P = 0.49$)	16.9 ($P = 0.182$)	21.7 ($P = 0.94$)	14.3 ($P = 0.28$)	14.7 ($P = 0.32$)
2001–2002	15.6 ($P < 0.001$)	19.8 ($P = 0.26$)	16.6 ($P < 0.001$)	20.6 ($P = 0.022$)	14.7 ($P = 0.96$)	13.8 ($P = 0.34$)
2003–2004	15.6 ($P < 0.001$)	19.5 ($P = 0.038$)	15.9 ($P < 0.001$)	20.1 ($P < 0.001$)	14.3 ($P = 0.103$)	13.7 ($P = 0.157$)
2005–2006	15.2 ($P < 0.001$)	19.8 ($P = 0.193$)	15.5 ($P < 0.001$)	19.7 ($P < 0.001$)	14.1 ($P = 0.034$)	13.5 ($P = 0.069$)
2007–2008	15.4 ($P < 0.001$)	20.6 ($P = 0.25$)	16.1 ($P < 0.001$)	20.4 ($P = 0.024$)	14.3 ($P = 0.077$)	14.2 ($P = 0.81$)
2009–2010	15.2 ($P < 0.001$)	20.5 ($P = 0.40$)	15.8 ($P < 0.001$)	20.8 ($P = 0.178$)	15.2 ($P = 0.144$)	13.7 ($P = 0.22$)
Change from 1997 to 2010	−1.4	0.3	−1.8	−0.9	0.5	−0.5

AMI = acute myocardial infarction; CAP = community-acquired pneumonia; COPD = chronic obstructive pulmonary disease; GIH = gastrointestinal hemorrhage; HF = heart failure.
* *P* values for differences in readmission rates relative to 1997–1998. *P* values are based on generalized linear model with binomial distributed errors, logit link, and random intercepts for hospitals.

Table 4. **Risk-Adjusted Mean Hospital LOS***

Fiscal Year	Risk-Adjusted Mean LOS (95% CI), d					
	All Admissions	HF	COPD	AMI	CAP	GIH
1997–1998	5.44 (5.33–5.56)	6.33 (6.17–6.49)	5.68 (5.51–5.85)	6.63 (6.36–6.90)	7.18 (6.97–7.39)	5.08 (4.94–5.22)
1999–2000	4.93 (4.83–5.04)	5.75 (5.61–5.89)	5.06 (4.91–5.22)	5.86 (5.62–6.10)	6.39 (6.20–6.57)	4.61 (4.49–4.74)
2001–2002	4.67 (4.57–4.77)	5.51 (5.37–5.64)	4.73 (4.59–4.88)	5.26 (5.05–5.47)	5.96 (5.79–6.14)	4.34 (4.22–4.46)
2003–2004	4.54 (4.45–4.64)	5.31 (5.18–5.44)	4.53 (4.39–4.67)	4.90 (4.70–5.10)	5.74 (5.58–5.91)	4.17 (4.05–4.28)
2005–2006	4.32 (4.23–4.41)	4.85 (4.73–4.97)	4.30 (4.17–4.43)	4.53 (4.34–4.72)	5.46 (5.30–5.62)	4.03 (3.92–4.15)
2007–2008	4.17 (4.08–4.26)	4.61 (4.50–4.73)	4.10 (3.98–4.23)	4.13 (3.96–4.30)	5.26 (5.11–5.42)	3.84 (3.74–3.95)
2009–2010	3.98 (3.89–4.06)	4.40 (4.29–4.51)	3.89 (3.77–4.00)	3.78 (3.63–3.94)	4.96 (4.81–5.10)	3.68 (3.58–3.78)
Change from 1997 to 2010	−1.46	−1.93	−1.79	−2.85	−2.22	−1.40

AMI = acute myocardial infarction; CAP = community-acquired pneumonia; COPD = chronic obstructive pulmonary disease; GIH = gastrointestinal hemorrhage; HF = heart failure; LOS = length of stay.
* All values are statistically different from 1997–1998 (baseline) values at $P < 0.010$. Risk-adjusted hospital LOS was calculated using multivariable risk-adjustment models to adjust for age, sex, income, comorbid conditions, intensive care unit admission, admission source, and Veterans Affairs facility. Risk-adjusted LOS was estimated using model coefficients associated with the year of discharge and patient characteristic variables to calculate the expected LOS for the "average" patient at the "average" hospital across all years.

specific mean LOS was significant and negative (**Table 6**). The odds ratio of 0.94 suggests that hospitals with mean risk-adjusted LOS that is 1 full day lower than the average risk-adjusted LOS across all hospitals have 6% higher readmission rates, compared with rates in hospitals with risk-adjusted LOS equal to the average across all hospitals. In contrast, the coefficient associated with patient LOS was significant and positive. Thus, after accounting for the hospital mean LOS, every additional day that a patient stayed beyond the average LOS within the hospital was associated with a 3% relative increase in the likelihood of readmission. In analysis of specific diseases, higher individual LOS was still associated with higher likelihood of readmission (approximately 2% to 3% more likely per additional day of stay), and lower mean hospital LOS was associated with increases in the likelihood of readmission ranging from 4% to 7%.

Unadjusted 30-day mortality decreased by 25%, from 6.4% to 4.8%, whereas 90-day mortality decreased by 18%, from 11.46% to 9.35%. Logistic regression analyses, adjusted for patient demographic characteristics and comorbid conditions and hospital random effects, found similar reductions ($P < 0.001$).

DISCUSSION

This study began with the hypothesis that the intense focus on efficiency improvement had resulted in significant declines in patient LOS, but at the expense of increases in readmission rates. The analysis of 14 years of VA data, including 129 hospitals and more than 4 million admissions, does not support this hypothesis. Although LOS decreased by 27% (1.46 days) in adjusted analyses, there was no increase in readmissions. In fact, adjusted relative readmission rates decreased by 16% over the same period. These findings hold across the 5 individual diagnoses evaluated (6% to 18%) after adjustment for appropriate patient and facility characteristics. Concomitant improve-

Table 5. **Risk-Adjusted 30-Day Hospital Readmission Rates***

Fiscal Year	Risk-Adjusted 30-Day Hospital Readmission Rate (95% CI), %					
	All Admissions	HF	COPD	AMI	CAP	GIH
1997–1998	16.5 (16.2–16.8)	20.4 (19.7–21.0)	17.9 (17.3–18.5)	22.6 (21.7–23.6)	14.7 (14.1–15.2)	14.1 (13.4–14.8)
1999–2000	16.2 (15.9–16.5)†	20.2 (19.6–20.8)	17.0 (16.4–17.5)†	22.3 (21.4–23.2)	14.4 (13.8–14.9)	14.6 (13.9–15.3)
2001–2002	15.3 (15.0–15.6)†	19.7 (19.1–20.4)	16.4 (15.9–17.0)†	20.9 (20.0–21.7)†	14.4 (13.9–14.9)	13.5 (12.8–14.2)
2003–2004	15.0 (14.7–15.2)†	19.3 (18.7–19.9)†	15.5 (14.9–16.0)†	20.2 (19.4–21.1)†	13.7 (13.2–14.2)†	13.1 (12.4–13.7)
2005–2006	14.3 (14.0–14.6)†	19.2 (18.6–19.7)†	14.8 (14.3–15.3)†	19.2 (18.3–20.0)†	13.3 (12.7–13.8)†	12.6 (11.9–13.2)†
2007–2008	14.1 (13.8–14.3)†	19.4 (18.8–20.0)†	15.1 (14.6–15.6)†	19.6 (18.7–20.4)†	13.1 (12.7–13.6)†	12.8 (12.2–13.5)†
2009–2010	13.8 (13.6–14.1)†	19.0 (18.5–19.6)†	14.6 (14.1–15.1)†	19.8 (18.8–20.7)†	13.8 (13.3–14.2)†	12.2 (11.5–12.8)†
Change from 1997 to 2010	−2.7	−1.4	−3.3	−2.8	−0.9	−1.9

AMI = acute myocardial infarction; CAP = community-acquired pneumonia; HF = heart failure; COPD = chronic obstructive pulmonary disease; GIH = gastrointestinal hemorrhage; LOS = length of stay.
* Risk-adjusted readmission rates were calculated using multivariable risk-adjustment models to adjust for age, sex, income, comorbid conditions, intensive care unit admission, admission source, and Veterans Affairs facility. Risk-adjusted readmission rates were estimated using model coefficients associated with the year of discharge and patient characteristic variables to calculate the expected LOS for the "average" patient at the "average" hospital across all years.
† Values are statistically different from 1997–1998 readmission rates at $P < 0.010$.

ment in hospital readmission rates demonstrates that the reduction in LOS did not put patients at risk for readmission, a common concern for earlier hospital discharge.

In further analyses, we found that patients with longer LOS have higher readmission rates (3% increase for each additional day of stay), which has been shown (22) and is likely to be due to unmeasured severity that affects both readmission and LOS. In contrast, hospitals that tend to discharge patients sooner than expected, given their illness level and general trends in LOS, also have higher readmission rates (6% increase for each day lower than expected). These findings suggest a modest tradeoff between hospital LOS and readmission rates. Nevertheless, this tendency does not seem to have reversed the general trend in decreasing readmissions.

Another important finding was no evidence for increased mortality rates. In fact, all-cause mortality at 30 and 90 days after admission, including deaths both in and outside the hospital, decreased by 3.4% and 3.0% annually, respectively. This finding suggests that reductions in LOS and readmission rates were not achieved at the expense of higher mortality. In fact, quality improved by all 3 measures.

There are several possible explanations for the finding of improvement in LOS without an adverse effect on 30-day hospital readmission. First, the VA health care system may have had inefficiencies in care that resulted in prolonged hospitalizations beyond what was needed for the care of patients. Thus, a reduction in LOS would not lead to a premature discharge resulting in rehospitalization. Specifically, a 1982 U.S. General Accounting Office report suggested that 43% of days in VA hospitals were "medically avoidable" (23). Further, our previous work demonstrated inefficiencies in VA care, such that the reduction in LOS in VA hospitals lagged behind private-sector hospitals but was improving quickly (9). Second, the VA initiated a national effort in 2006 to improve hospital flow (for example, LOS and discharge time of day) with the Flow Improvement Inpatient Initiative (24). Although the focus was on inpatient flow, these efforts may have resulted in changes in transitions of care that also improved readmission rates. Third, during the study period, the VA initiated extensive medication reconciliation efforts at the time of hospital transitions of care, an initiative shown to reduce readmissions (25). Fourth, the VA has rapidly adopted a hospitalist model of care, with hospitalists employed in 10% of VA hospitals in 1997 and increasing to more than 65% in 2007 (26). The use of hospitalists for inpatient care has been shown to reduce LOS by up to 15% and improve other measures of quality, although no studies have reported reduced readmissions (2).

This study has several important implications for current policy. First, it demonstrates that LOS reductions have not, thus far, adversely affected the likelihood of hospital readmission in 1 large health care system. Second, overall trends in readmissions have decreased over 14 years,

Table 6. **Results of the Multivariable Model That Includes Patient LOS and Hospital Mean LOS During Discharge Year***

Condition	Hospital-Level Readmission OR (95% CI)†	Patient-Level Readmission OR (95% CI)‡	*P* Value
All admissions	0.94 (0.93–0.95)	1.03 (1.02–1.03)	<0.001
AMI	0.96 (0.94–0.98)	1.02 (1.01–1.02)	<0.001
CAP	0.96 (0.94–0.98)	1.03 (1.03–1.03)	<0.001
HF	0.93 (0.91–0.95)	1.02 (1.02–1.03)	<0.001
COPD	0.95 (0.93–0.97)	1.03 (1.02–1.03)	<0.001
GIH	0.95 (0.92–0.99)	1.04 (1.03–1.04)	<0.001

AMI = acute myocardial infarction; CAP = community-acquired pneumonia; COPD = chronic obstructive pulmonary disease; GIH = gastrointestinal hemorrhage; HF = heart failure; LOS = length of stay; OR = odds ratio.
* The ORs were derived using a multivariable logit model with random hospital effects, patient characteristics, year of discharge, individual LOS, and hospital relative mean LOS during year of discharge. See Results section for OR interpretations and the **Appendix** (available at www.annals.org) for model details.
† The ORs reflect the relative odds of readmission associated with a 1 day–greater hospital mean LOS during the discharge year relative to the overall mean LOS during the discharge year.
‡ The ORs correspond to the relative odds of readmission associated with a 1-day increase in individual LOS.

possibly due to improvements in hospital discharge procedures, increased access to postdischarge care, and improvements in hospital technology and preventive measures. Nevertheless, many readmissions are preventable and opportunities for improvement exist. Third, recent discussions about proposed modifications to the Medicare prospective payment system, such as payments by acute care episode (27, 28) (that is, bundled payments), raise important questions about identification of appropriate rates of hospital readmission. For chronic illnesses, such as COPD and cancer, repeated hospital admissions may represent appropriate care. Even patients with terminal conditions who are enrolled in hospice care are readmitted for symptom management to improve quality of life. Thus, it is neither possible nor desirable to expect complete elimination of 30-day readmissions, and efforts to reduce readmissions may have unintended consequences. Reporting hospital readmission rates should be coupled with rates of return to the emergency department, use of home care services, and outpatient clinic care to identify shifting of resource use. Instead of reducing or eliminating payment for a readmission, further research is necessary to determine whether readmission costs more or less than the index admission and change payment based on the actual cost of care.

In contrast, the potential for reducing readmissions after acute illness, such as pneumonia or gastrointestinal hemorrhage, may be considerable, especially in patients without underlying chronic illness. Regardless of the underlying disease, the important question is whether readmissions can be prevented and, if so, how to identify preventable readmissions. A systematic review by van Walraven and colleagues (29) concluded that the "true proportion of hospital readmissions that are potentially avoidable remains unclear," but did find that the median proportion of readmissions deemed avoidable was 27.1%; subsequent meta-analysis suggested that the rate was 23.1% (30). In one of the only studies to assess preventability using physician chart review, Frankl and colleagues (12) determined that only 8.8% of readmissions were preventable. In an attempt to predict which patients were at risk for readmission, a validated readmission prediction model identified 7 factors as significant predictors of readmission but with only fair model discrimination (c-statistic, 0.65) (22). Future studies and quality improvement efforts should continue to evaluate hospital readmission and determine factors that can be addressed to reduce preventable readmissions.

The readmission rates we report in this VA population are similar to or less than previous reports based on private-sector patients. For example, the 30-day readmission rate reported by Jencks and colleagues (10) from 2004 Medicare data was 21.1%. When limiting our results to FY2004 and patients aged 65 or older, the VA 30-day readmission rate was 16.6% (data not shown). Another study by Ross and colleagues (31) in patients with HF used Medicare data from 2004 to 2006 and found a consistent rate of 30-day readmission of 23.0%, 23.3%, and 22.9%, demonstrating no change over these 3 years nationally (31). Our 30-day unadjusted HF readmission rates were similarly steady at approximately 20%, although they were reduced by 7% over the study period in adjusted analyses. Further work in non-VA settings is needed to validate our findings.

This study has several limitations. First, it was performed in a single health care system, limiting generalizability. Veterans Affairs provides both inpatient and outpatient care to veterans who are more likely to be male and have more chronic illness, substance abuse, and lower income. Second, only VA records were available and readmissions to non-VA hospitals were not identified. However, previous work suggests that among VA hospital discharges, veterans also enrolled in Medicare have an 18.2% readmission rate to VA hospitals within 30 days, whereas only another 2.9% will be admitted to non-VA hospitals within that interval (14, 32). We performed sensitivity analyses on readmissions for patients younger than 65 years and those older than 65 years to determine whether our conclusions were similar among patients who are and are not eligible for Medicare, and results were similar. For patients younger than 65 years, the relative odds of readmission decreased by 17% in FY2009–2010, whereas for patients older than 65 years, the relative odds of readmission decreased by 14%. Third, the study used administrative claims data that do not include important prognostic and clinical indicators. Fourth, this study did not make any attempt to distinguish preventable readmissions from all other readmissions. Although use of administrative data to determine preventability of readmissions has been explored, preventability is subjective and administrative data can be used only to determine whether the readmission was potentially related to the index hospitalization (33).

Hospital efforts to improve LOS should continue while simultaneously monitoring hospital readmission rates. With increased attention to quality of care transitions in and out of the hospital, LOS and readmissions can be simultaneously improved, as demonstrated in VA health care, an integrated health care system of acute and chronic care. Future work should address preventability of hospital readmissions and focus on processes of care that could be generalized for all patients (for example, medication reconciliation) and identify disease-specific interventions that can improve the care for high-risk conditions. Payors of health care and quality organizations should carefully examine both intended and unintended consequences of financial incentives for episodes of care in our often fragmented health care system.

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Appendix: Modeling Process

For LOS and readmission models, bivariate relationships between log-transformed LOS or readmission and individual patient risk factors were examined using the *t* test for dichotomous risk factors and analysis of variance for ordinal or continuous variables. Variables significantly related ($P < 0.010$) to log-transformed LOS or readmission were identified and flagged as potential candidates for inclusion in multivariable models (**Appendix Tables 1** and **2**). The model-development process involved repeated steps in which candidate variables were entered into multivariable regression models and discrimination, calibration, and the variance inflation factor (that is, collinearity) were evaluated. Model estimation involved the use of stepwise, forward, backward, and best subset variable selection methods. Models also included indicator variables for FY of discharge (coded in 2-year increments) to assess trends in adjusted LOS and readmissions over the 14-year observation period. For readmission models, discrimination was measured using the c-statistic, which is equal to the area under the receiver-operating characteristic curve. Calibration was measured by the Hosmer–Lemeshow statistic and by plotting actual and predicted readmission rates across deciles of increasing risk. For LOS, model fit and misspecification were assessed by plotting model residuals versus predicted values and inspecting plots for evidence of nonlinearity, heteroscedasticity, or possible unmeasured covariates. Final models were generated as generalized linear mixed models with random effects for hospitals, using γ-distributed errors and a log link for LOS, and binomial distributed errors and a logit link for readmissions.

The models for estimating the relationship between LOS and readmission posed important statistical challenges. Because overall readmission rates and LOS decreased during the observation period, it was necessary to distinguish the effect of hospital-level LOS on hospital-level readmission rates from general trends. After exploring multiple model structures, we estimated the model as a mixed logit model with readmission as the dependent variable. Independent variables included patient risk factors, year (in 2-year increments), and 3 measures of LOS representing individual patient LOS, mean LOS over all hospitals during the 2-year increment in which a patient was discharged, and deviation between hospital mean LOS during the 2-year increment and overall mean LOS during the 2-year increment. The model is:

$$\mathrm{Log}(R_{ijt}/1 - R_{ijt}) = \beta_0 + \beta_{1x}{*}\mathrm{RiskFactors}_{xijt} + \beta_2{*}\mathrm{year9900}_{i.t} + \beta_3{*}\mathrm{year0102}_{i.t} + \ldots + \beta_7{*}\mathrm{year0910}_{i.t} + \beta_8{*}\,\mathrm{LOS}_{ijt} + \beta_9{*}(\mathrm{HospitalMeanLOS}_{.jt} - \mathrm{MeanLOS}_{..t}) + \beta_{10}{*}\mathrm{MeanLOS}_{..t} + e_{j.}$$

Where:

R_{ijt} indicates whether patient *i* discharged from hospital *j* during period *t* was readmitted within 30 days;

$\mathrm{RiskFactors}_{xijt}$ is a set of *X* risk factors for patient *i* discharged from hospital *j* during period *t* and β_{1x} are the *X*-associated regression coefficients;

Variables $\mathrm{year9900}_{i.t}$, $\mathrm{year0102}_{i.t}$, etc. indicate the period during which patient *i* was discharged (for example, for a patient discharged during FY1999–2000, the indicator $\mathrm{year9900}_{i.t}$ is set to 1; all other period indicators are set to 0). The reference period is FY1997–1998. Coefficients β_2 through β_7 therefore reflect general trends in readmission over time.

LOS_{ijt} is the LOS for patient *i* during the index admission, and coefficient β_8 reflects the relationship between individual patient LOS and the likelihood of readmission.

$(\mathrm{HospitalMeanLOS}_{.jt} - \mathrm{MeanLOS}_{..t})$ is the difference between the mean LOS for hospital *j* during period *t* and the mean LOS overall during period *t*. The coefficient β_9 reflects the relationship between the relative hospital LOS (compared with the national average) and the likelihood of readmission.

The coefficient β_{10} was not statistically significant in final models and the variable $\mathrm{MeanLOS}_{..t}$ was dropped. We also developed a model in which the hospital-specific mean LOS was centered around the hospital rather than the mean (that is, $[\mathrm{HospitalMeanLOS}_{.jt} - \mathrm{MeanLOS}_{..t}]$ was replaced by $[\mathrm{HospitalMeanLOS}_{.jt} - \mathrm{MeanLOS}_{.j.}]$). Although results based on this model were similar to the results presented here, there was residual collinearity between the hospital mean-centered LOS and general trends in LOS.

Appendix Table 1. **Multivariable Model for LOS With γ-Distributed Errors and Log Link***

Variable	Exponentiated Estimate	Lower CL	Upper CL	*P* Value
Fiscal year (reference: 1997–1998)				
1999–2001	0.906	0.903	0.909	<0.001
2001–2002	0.858	0.856	0.861	<0.001
2003–2004	0.835	0.832	0.837	<0.001
2005–2006	0.794	0.791	0.797	<0.001
2007–2008	0.766	0.764	0.769	<0.001
2009–2010	0.731	0.728	0.733	<0.001
Age	1.006	1.006	1.007	<0.001
Sex (female vs. male)	0.952	0.948	0.957	<0.001
Marriage status (reference: married)				
Never married	1.139	1.136	1.143	<0.001
Widow	1.071	1.068	1.075	<0.001
Divorced	1.083	1.081	1.086	<0.001
Other	1.095	1.081	1.109	<0.001
Income category (reference: $0–$20 000)				
$20 001–$40 000	0.988	0.986	0.990	<0.001
$40 001–$60 000	0.976	0.971	0.980	<0.001
>$60 000	0.970	0.966	0.975	<0.001
First bed section (reference: ICU)				
Acute medicine	0.815	0.813	0.817	<0.001
Observation	0.389	0.388	0.391	<0.001
Comorbid conditions				
AIDS	1.350	1.338	1.361	<0.001
Alcohol abuse	1.082	1.079	1.085	<0.001
Arrhythmia	1.099	1.097	1.102	<0.001
Arthritis	1.174	1.167	1.182	<0.001
Blood anemia	1.140	1.131	1.149	<0.001
Coagulation disorder	1.247	1.240	1.254	<0.001
COPD	1.091	1.089	1.093	<0.001
Cerebrovascular disease	1.119	1.115	1.122	<0.001
Deficiency anemia	1.142	1.138	1.147	<0.001
Dementia	1.237	1.230	1.244	<0.001
Depression	1.027	1.024	1.030	<0.001
Diabetes				
Complicated	1.262	1.257	1.266	<0.001
Noncomplicated	1.044	1.041	1.046	<0.001
Drug abuse	1.002	0.997	1.006	0.4865
Fluid disorder	1.238	1.235	1.241	<.0001
Hemiparaplegia	1.005	0.991	1.018	0.4979
Hypertension				
Complicated	1.003	0.998	1.008	0.2676
Noncomplicated	0.969	0.967	0.971	<0.001
Hypothyroidism	1.013	1.010	1.017	<0.001
Liver disease	1.104	1.100	1.109	<0.001
Lymphoma	1.116	1.106	1.125	<0.001
Malignancy	1.252	1.248	1.256	<0.001
Metastatic cancer	1.265	1.259	1.272	<0.001
Myocardial infarction	1.065	1.062	1.069	<0.001
Neurological disorder	1.178	1.174	1.183	<0.001
Paralysis	1.337	1.322	1.352	<0.001
Obesity	1.058	1.054	1.063	<0.001
Pulmonary circulatory disorder	1.279	1.271	1.286	<0.001
Peripheral vascular disease	1.116	1.112	1.119	<0.001
Renal disease	1.124	1.119	1.129	<0.001
Severe liver	1.125	1.116	1.133	<0.001
Ulcer without bleeding	1.019	1.012	1.026	<0.001
Valve disorder	1.161	1.156	1.166	<0.001
Weight loss	1.415	1.408	1.422	<0.001

CL = confidence limit; COPD = chronic obstructive pulmonary disease; ICU = intensive care unit; LOS = length of stay.
* Model includes random effects for the admitting hospital.

Appendix Table 2. Multivariable Risk-Adjustment Models for Readmission Within 30 Days of Discharge and LOS*

Variable	OR	Lower CL	Upper CL	*P* Value
Fiscal year (reference: 1997–1998)				
1999–2001	0.981	0.971	0.991	<0.001
2001–2002	0.916	0.906	0.925	<0.001
2003–2004	0.893	0.884	0.903	<0.001
2005–2006	0.846	0.838	0.855	<0.001
2007–2008	0.832	0.823	0.841	<0.001
2009–2010	0.813	0.804	0.821	<0.001
Age	1.005	1.005	1.005	<0.001
Sex (female vs. male)	1.139	1.121	1.157	<0.001
Marital status (reference: never married)				
Married	0.966	0.957	0.976	<0.001
Widow	0.996	0.984	1.008	0.52
Divorced	1.021	1.011	1.031	<0.001
Other	0.768	0.733	0.804	<0.001
Income category (reference: $0–$20 000)				
$20 001–$40 000	1.017	1.010	1.024	<0.001
$40 001–$60 000	0.958	0.943	0.973	<0.001
>$60 000	0.933	0.918	0.948	<0.001
First bed section (reference: ICU)				
Acute medicine	1.035	1.027	1.042	<0.001
Observation	0.900	0.889	0.912	<0.001
Admission source (reference: all other)				
Transferred from other hospital	0.970	0.952	0.989	0.002
Admission from nursing home	0.759	0.745	0.773	<0.001
Comorbid conditions				
AIDS	1.389	1.354	1.425	<0.001
Alcohol abuse	0.981	0.972	0.991	<0.001
Arrhythmia	1.143	1.135	1.151	<0.001
Arthritis	1.130	1.107	1.154	<0.001
Blood anemia	1.209	1.180	1.238	<0.001
Coagulation disorder	1.198	1.179	1.217	<0.001
COPD	1.145	1.138	1.152	<0.001
Cerebrovascular disease	0.919	0.910	0.929	<0.001
Deficiency anemia	1.130	1.116	1.144	<0.001
Dementia	0.969	0.951	0.987	<0.001
Depression	0.985	0.976	0.994	<0.001
Diabetes				
Complicated	1.313	1.299	1.327	<0.001
Noncomplicated	1.137	1.130	1.145	<0.001
Drug abuse	0.962	0.947	0.976	<0.001
Fluid–electrolyte imbalance	1.148	1.139	1.156	<0.001
Hemiparaplegia	0.907	0.870	0.946	<0.001
Hypertension				
Complicated	0.983	0.968	0.998	0.031
Noncomplicated	0.957	0.952	0.963	<0.001
Hypothyroidism	1.026	1.013	1.038	<0.001
Lymphoma	1.216	1.178	1.255	<0.001
Malignancy	2.187	2.129	2.247	<0.001
Metastatic cancer	1.410	1.391	1.430	<0.001
Myocardial infarction	1.268	1.256	1.281	<0.001
Mild liver disease	1.335	1.319	1.352	<0.001
Neurological disorder	1.036	1.025	1.048	<0.001
Obesity	0.900	0.887	0.913	<0.001
Paralysis	1.163	1.122	1.205	<0.001
Peptic ulcer	0.885	0.855	0.917	<0.001
Pulmonary circulatory disorder	1.137	1.118	1.157	<0.001
Peripheral vascular disease	1.250	1.237	1.263	<0.001
Renal disease	1.323	1.273	1.376	<0.001
Renal failure	1.078	1.035	1.123	<0.001
Severe liver	1.531	1.499	1.564	<0.001
Ulcer without bleeding	1.102	1.057	1.148	<0.001
Valve disorder	1.265	1.250	1.281	<0.001
Weight loss	1.168	1.151	1.185	<0.001

CL = confidence limit; COPD = chronic obstructive pulmonary disease; ICU = intensive care unit; LOS = length of stay; OR = odds ratio.
* Model includes patient age, sex, marital status, income, admission source, comorbid conditions, and random effects for the admitting hospital.