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# Associations Between Short or Long Length of Stay and 30-Day Readmission and Mortality in Hospitalized Patients With Heart Failure

Maneesh Sud, MD,[a] Bing Yu, PhD,[a] Harindra C. Wijeysundera, MD, PhD,[a,b,c,d,e] Peter C. Austin, PhD,[a,b,d,e] Dennis T. Ko, MD, MSc,[a,b,c,d,e] Juarez Braga, MD,[e] Peter Cram, MD, MBA,[a,b,e,f] John A. Spertus, MD, MPH,[g] Michael Domanski, MD,[e,h] Douglas S. Lee, MD, PhD[a,b,e,h,i]

## ABSTRACT

**OBJECTIVES** This study sought to examine the associations between heart failure (HF)-related hospital length of stay and 30-day readmissions and HF hospital length of stay and mortality rates.

**BACKGROUND** Although reducing HF readmission and mortality rates are health care priorities, how HF-related hospital length of stay affects these outcomes is not fully known.

**METHODS** A population-level, multicenter cohort study of 58,230 patients with HF (age >65 years) was conducted in Ontario, Canada between April 1, 2003 and March 31, 2012.

**RESULTS** When length of stay was modeled as continuous variable, its association with the rate of cardiovascular readmission was nonlinear ($p < 0.001$ for nonlinearity) and U-shaped. When analyzed as a categorical variable, there was a higher rate of cardiovascular readmission for short (1 to 2 days; adjusted hazard ratio [HR]: 1.12; 95% confidence interval [CI]: 1.04 to 1.21; $p = 0.003$) and long (9 to 14 days; HR: 1.11; 95% CI: 1.04 to 1.19; $p = 0.002$) lengths of stay as compared with 5 to 6 days (reference). Hospital readmissions for HF demonstrated a similar nonlinear ($p = 0.005$ for nonlinearity) U-shaped relationship with increased rates for short (HR: 1.15; 95% CI: 1.04 to 1.27; $p = 0.006$) and long (HR: 1.14; 95% CI: 1.04 to 1.25; $p = 0.004$) lengths of stay. Noncardiovascular readmissions demonstrated increased rates with long (HR: 1.17; 95% CI: 1.07 to 1.29; $p < 0.001$) and decreased rates with short (HR: 0.87; 95% CI: 0.79 to 0.96; $p = 0.006$) lengths of stay ($p = 0.53$ for nonlinearity). The 30-day mortality risk was highest after a long length of stay (HR: 1.28; 95% CI: 1.14 to 1.43; $p < 0.001$).

**CONCLUSIONS** A short length of stay after hospitalization for HF is associated with increased rates of cardiovascular and HF readmissions but lower rates of noncardiovascular readmissions. A long length of stay is associated with increased rates of all types of readmission and mortality. (J Am Coll Cardiol HF 2017;■:■–■) © 2017 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

From the [a]Institute for Clinical Evaluative Sciences University Health Network, Toronto General Hospital, Toronto, Ontario, Canada; [b]Institute for Health Policy, Management, and Evaluation, University of Toronto, Toronto, Ontario, Canada; [c]Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada; [d]Schulich Heart Research Program, Sunnybrook Research Institute, Toronto, Ontario, Canada; [e]Division of Cardiology, Faculty of Medicine, University of Toronto, Toronto, Ontario, Canada; [f]Division of General Internal Medicine and Geriatrics, University Health Network and Sinai Health System, Toronto, Ontario, Canada; [g]University of Missouri, Kansas City, Saint Luke's Mid America Heart Institute, Kansas City, Missouri; [h]Peter Munk Cardiac Centre of the University Health Network, Toronto, Ontario, Canada; and the [i]Joint Department of Medical Imaging, University Health Network, Toronto, Ontario, Canada. Primary funding for this study was provided by the Canadian Institutes of Health Research. The Institute for Clinical Evaluative Sciences is supported in part by a grant from the Ontario Ministry of Health and Long Term Care. The opinions, results, and conclusions are those of the authors, and no endorsement by the Ministry of Health and Long-Term Care or by the Institute for Clinical Evaluative Sciences is intended or should be inferred. Parts of this material are founded

**ABBREVIATIONS AND ACRONYMS**

**CI** = confidence interval

**CIHI-DAD** = Canadian Institute for Health Information Discharge Abstract Database

**ED** = emergency department

**HF** = heart failure

**HR** = hazard ratio

**IQR** = interquartile range

**LOS** = length of stay

Early readmissions to the hospital are a priority issue for health care systems. Nearly 20% of discharged patients are readmitted, thus resulting in costs exceeding $17 billion annually in the United States alone (1). Heart failure (HF) is a leading cause of both hospitalization and readmission, with approximately 25% of patients readmitted within 30 days (2). Readmissions may be reduced by better understanding system- and patient-related factors that portend higher readmission risk (3) and then applying interventional strategies in higher-risk patients during transitional care (4).

The hospital length of stay (LOS) is a factor that could influence readmission risk, both as a process of care and as a proxy of patient-related factors leading to increased risk (5). LOS is also directly related to the costs of care for hospitals and health payers. In the context of bundled payments for HF-related hospitalizations, there is an incentive for patient care teams and hospitals to reduce LOS (6,7). There is concern, however, that shortening LOS may lead to incomplete resolution of pulmonary or peripheral edema and may not allow for adequate identification of patients requiring community services during the discharge transition (8,9). Counterbalancing the benefits of avoiding very short LOS is the concern that longer LOS could pose additional potential risks of nosocomial infections, other acquired complications, and deconditioning (10).

Examining post-discharge morbidity and mortality rates associated with shorter or longer durations of hospitalization may provide greater insights into the implications of this metric on health outcomes. Accordingly, we leveraged a population-based database of HF-related hospitalizations to examine the association between LOS with 30-day all-cause and cause-specific readmission and mortality risk. Finally, to understand patient factors associated with LOS better, we identified predictors of short and long LOS.

## METHODS

**DATA SOURCES.** Patients were identified using the Canadian Institute for Health Information Discharge Abstract Database (CIHI-DAD), which contains information on all hospital admissions in Ontario, Canada. Admissions with a primary or most responsible diagnosis of HF (International Classification of Diseases-Tenth Revision Canadian Enhancement code I50) were identified. Code I50 has demonstrated a high degree of accuracy compared with the clinical Framingham criteria (11,12). Using the patients' unique encoded health card number, we linked the National Ambulatory Care Reporting System for emergency department (ED) visits, the Registered Persons Database for mortality, and the Ontario Registrar General Vital Statistics Database for cardiovascular deaths. The Ontario Drug Benefit Database was used to identify prescription medications, and the Ontario Diabetes Database was used to identify patients with diabetes. Diagnostic and interventional cardiac procedures were identified using the CIHI-DAD, the CIHI Same Day Surgery Database, and the Ontario Health Insurance Plan physician claims database. The accuracy of these databases has been described previously (13-15).

**STUDY POPULATION.** We conducted a population-based analysis between April 1, 2003 and March 31, 2012 of adult patients ≥65 years of age and residing in Ontario, Canada who were hospitalized with a primary diagnosis of HF (n = 178,905). To capture acute presentations of HF, hospitalizations in which patients were not admitted directly from the ED were excluded (n = 37,268). In the event of multiple HF admissions for the same patient, only the first admission was used (n = 48,786). We studied patients discharged home to independent living, excluding those who died before discharge from our primary cohort. Patients were also excluded if they were not discharged home (i.e., to another facility) from the hospital (n = 16,431), or were transferred from or to another acute care or long-term care facility

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(n = 1,305). Patients with missing demographic data (n = 228), left ventricular assist device or cardiac transplant recipients (n = 21), and patients with an admission date ≥1 days after the ED presentation date (n = 75) were also excluded. Because an increased risk was observed previously for very prolonged hospitalizations (i.e., >14 days) (16), we excluded these patients in the primary analysis. The primary study cohort consisted of 58,230 patients with a hospital LOS of 1 to 14 days.

**DEFINITIONS AND OUTCOMES.** We identified patients' comorbidities within 3 years before the index HF-related hospitalization by using the CIHI-DAD (17–19). Socioeconomic status was determined by quintile of median neighborhood income, and the admitting unit was defined as the intensive or coronary care unit if the first day of admission in the CIHI-DAD was coded as a special care unit. Hospital type was defined by the classification system of the Ontario Hospital Association (20).

The primary outcomes were cause-specific 30-day hospital readmissions for cardiovascular disease and noncardiovascular causes, as previously defined (21,22). Secondary outcomes included readmissions for HF and all causes. We also analyzed 30-day all-cause mortality data from hospital discharge, subdivided into cardiovascular and noncardiovascular mortality as described previously (23).

**STATISTICAL ANALYSIS.** Continuous variables were summarized as medians with interquartile ranges (interquartile range [IQR]: 25th, 75th percentiles) and compared between exposure categories using the Kruskal-Wallis test. Categorical variables were compared using the chi-square test. Hospital admission rates and 95% confidence intervals (CIs) were determined using the $\gamma$-distribution (24).

We used a marginal cause-specific hazard regression model with a robust (sandwich-type) variance estimator to account for clustering of patients within hospitals. We modeled the effect of LOS on the hazard of hospital readmission for a specific cause and treated mortality as a competing event (25). We then modeled the effect of LOS on the hazard of cardiovascular mortality and treated noncardiovascular mortality as a competing risk (and vice versa). Time was measured from the date of index hospital discharge.

Initially LOS was treated as a continuous predictor in the cause-specific Cox regression model. To test the hypothesis that the relationship between LOS and each outcome was nonlinear, we modeled LOS with restricted cubic splines with 3 knots at the 10th, 50th, and 90th percentiles corresponding to 2, 5, and 11 days, respectively. When reporting hazard ratios (HRs) with LOS as a continuous variable, the mean LOS (5.7 days) was used as the reference value. We performed a Wald test to test the null hypothesis that the relationship between LOS and the hazard of each outcome was linear. Subsequently, LOS was modeled using the following categories: 1 to 2 days, 3 to 4 days, 5 to 6 days, 7 to 8 days, and 9 to 14 days. We chose 5 to 6 days as the reference category because it reflected the mean and median LOS of our cohort and in previous reports (26).

Multivariable models were adjusted for variables identified in published risk models, including demographics (age, sex), cardiovascular comorbidities (myocardial infarction, angina, unstable angina, chronic atherosclerosis, coronary revascularization, implantable cardiac defibrillator, permanent pacemaker, hypertension, cerebrovascular disease, peripheral vascular disease, valvular and rheumatic heart disease, arrhythmias, and cardiopulmonary-respiratory failure and shock), and noncardiovascular comorbidities (diabetes, cancer, pneumonia, trauma, major psychiatric disorders, decubitus skin ulcers, chronic obstructive pulmonary disease, rheumatologic disease, renal disease, gastrointestinal disorders) (17–19). We adjusted for HF history according to whether there was a history of HF without previous hospitalization, 1 HF hospitalization, ≥2 HF-related hospitalizations, or no diagnosis of HF in either ambulatory or hospital-based settings within the previous 3 years. Additionally we adjusted for the following: day and year of admission; socioeconomic status; admitting unit (ward or intensive care unit); specialty of the responsible physician; and pre-admission medications (beta-adrenergic receptor blockers, angiotensin-converting enzyme inhibitors or angiotensin receptor blockers, digoxin, furosemide, metolazone, spironolactone, antiplatelet agents, warfarin, 3-hydroxy-3-methyl-glutaryl-coenzyme A reductase inhibitors) (Online Appendix).

To explore characteristics of patients with short or long LOS, we used multiple logistic regression models, with LOS category as the outcome. We developed parsimonious models for short LOS (1 to 2 days) versus nonshort LOS (3 to 14 days) (27). Then we developed a second model to predict long LOS (9 to 14 days) versus shorter LOS (1 to 8 days). Candidate predictor variables were considered for entry into the model if the univariate p value was $<0.25$, and they were retained in the final model if the multivariable p value was $<0.05$.

We performed sensitivity analyses to determine the robustness of our findings. We modeled the effects of LOS on each outcome, as described earlier, including the following: 1) patients with an LOS up to 35 days (n = 64,165); 2) patients ≥18 years of age (n = 71,586 without outpatient medication data); and 3) all index and repeat HF-related hospitalizations during the study period (n = 85,885). This last analysis of repeat 30-day hospitalizations was performed for each HF-related hospitalization occurring over the duration of follow-up, by resetting time to zero with each new hospital admission.

A 2-sided p value < 0.05 was considered statistically significant. All analyses were performed using SAS software version 9.3 (SAS Institute, Inc., Cary, North Carolina). Research ethics board approval was obtained from Sunnybrook Health Sciences Centre in Toronto.

## RESULTS

**BASELINE CHARACTERISTICS.** Between April 1, 2003 and March 31, 2012, there were 58,230 unique hospitalized patients, admitted from the ED, with LOS between 1 to 14 days. Baseline characteristics, including demographics, comorbidities, and pre-admission medications by LOS category, are presented in Table 1. Admission characteristics and care processes are shown in Table 2. The median age of the cohort was 80 years (IQR: 74 to 85 years), and 50% of the patients were male. The distribution of LOS is shown in Online Figure 1. The median LOS was 5 days (IQR: 3 to 8 days). Patients who died in the hospital (n = 9,999) and thus ineligible for evaluation of readmissions were older, more often women, and had more cardiac and noncardiac comorbidities than patients discharged alive (Online Table 1). Patients who died in the hospital also had a longer LOS than those who were discharged home (median LOS 7 days [3 to 15 days] vs. 5 days [3 to 8 days]; p < 0.001).

**ASSOCIATION OF HOSPITAL LENGTH OF STAY WITH RISK-ADJUSTED READMISSION.** We observed a nonlinear relationship between LOS and the rate of all-cause 30-day readmission (p = 0.04), with higher rates among patients with longer LOS (Figure 1A). The association with LOS was nonlinear for cardiovascular (p < 0.001) and HF (p = 0.005) readmissions; both demonstrated a U-shaped relationship with increased rates at shorter and longer LOS (Figures 1B and 1C). The relationship between LOS and noncardiovascular readmissions, however, was linear (p = 0.53), with rates increasing as LOS increased (Figure 1D).

When compared with LOS of 5 to 6 days, the adjusted rate of 30-day all-cause readmission was 15% higher in patients with a long LOS (9 to 14 days; HR: 1.15; 95% CI: 1.09 to 1.22; p < 0.001). The adjusted rates and HRs for readmissions stratified by LOS categories are presented in Figures 2A to H. Among patients with the shortest LOS (1 to 2 days), the adjusted rate of 30-day cardiovascular readmission was 12% higher (HR: 1.12; 95% CI: 1.04 to 1.21; p = 0.003), compared with that in patients with LOS of 5 to 6 days. The cardiovascular readmission rate was also 11% (HR: 1.11; 95% CI: 1.04 to 1.19; p = 0.002) higher in patients with the longest LOS (9 to 14 days). The adjusted rate of 30-day HF readmission was increased by 15% in patients with the shortest LOS (1 to 2 days; HR: 1.15; 95% CI: 1.04 to 1.27; p = 0.006) and by 14% in patients with the longest LOS (9 to 14 days; HR: 1.14; 95% CI: 1.04 to 1.25; p = 0.004) in comparison with LOS of 5 to 6 days.

Noncardiovascular readmissions were affected differently by short or long LOS. Patients with the shortest LOS (1 to 2 days) exhibited a 13% reduction in noncardiovascular hospitalization rates (HR: 0.87; 95% CI: 0.79 to 0.96; p = 0.006) compared with the reference group. Conversely, patients with the longest LOS (9 to 14 days) demonstrated a 17% increase in the adjusted rate of 30-day noncardiovascular readmissions (HR: 1.17; 95% CI: 1.07 to 1.29; p < 0.001).

**ASSOCIATION OF INDEX HOSPITAL LENGTH OF STAY WITH RISK-ADJUSTED MORTALITY.** We observed a nonlinear association between LOS and the hazard of 30-day all-cause (p = 0.01) and noncardiovascular (p = 0.01) mortality, but not cardiovascular mortality (p = 0.18) (Online Figure 2). Although the rate of mortality increased in nonlinear fashion as LOS increased above the mean, the relationship was not U-shaped. The stratified adjusted rates and rates of all-cause, cardiovascular, and noncardiovascular mortality within 30 days after index HF discharge are presented in Table 3. These results demonstrate that both cardiovascular and noncardiovascular mortality rates were highest in patients with the longest LOS (9 to 14 days). There was no significant interaction between LOS and socioeconomic status for 30-day mortality rates.

**PREDICTORS OF SHORT OR LONG LENGTH OF STAY.** We identified variables that were associated with a short LOS (1 to 2 days) or a long LOS (9 to 14 days) (Online Table 2). Previous cardiac conditions increased the odds of a short LOS while reducing the odds of a long LOS. In contrast, greater noncardiac comorbidity burden increased the odds of a long LOS. Pre-admission use of beta-adrenoceptor antagonists, angiotensin-converting enzyme inhibitors, or angiotensin receptor blockers increased the odds of a short LOS, whereas greater exposure to diuretics and spironolactone increased the odds of a long LOS.

**TABLE 1 Cohort Characteristics**

| | All Patients (N = 58,230) | Length of Stay (Days) 1-2 (n = 9,938) | 3-4 (n = 15,288) | 5-6 (n = 12,439) | 7-8 (n = 8,786) | 9-14 (n = 11,779) | p Value |
|---|---|---|---|---|---|---|---|
| Demographics | | | | | | | |
| Male | 29,046 (49.9) | 5,353 (53.9) | 7,865 (51.4) | 6,130 (49.3) | 4,178 (47.6) | 5,520 (46.9) | <0.001 |
| Age, yrs | | | | | | | |
| 65 to <75 | 15,496 (26.6) | 3,053 (30.7) | 4,128 (27.0) | 3,210 (25.8) | 2,192 (24.9) | 2,913 (24.7) | <0.001 |
| ≥75 | 42,734 (73.4) | 6,885 (69.3) | 11,160 (73.0) | 9,229 (74.2) | 6,594 (75.1) | 8,866 (75.3) | |
| Comorbidities | | | | | | | |
| HF history | | | | | | | |
| No history | 20,583 (35.3%) | 3,477 (35.0) | 5,278 (34.5) | 4,564 (36.7) | 3,192 (36.3) | 4,072 (34.6) | <0.001 |
| HF without previous hospitalization | 20,882 (35.9) | 3,633 (36.6) | 5,555 (36.3) | 4,431 (35.6) | 3,098 (35.3) | 4,165 (35.4) | – |
| 1 HF hospitalization | 10,676 (18.3) | 1,768 (17.8) | 2,862 (18.7) | 2,174 (17.5) | 1,621 (18.4) | 2,251 (19.1) | – |
| ≥2 HF hospitalizations | 6,089 (10.5) | 1,060 (10.7) | 1,593 (10.4) | 1,270 (10.2) | 875 (10.0) | 1,291 (11.0) | – |
| Myocardial infarction | 9,024 (15.5) | 1,683 (16.9) | 2,495 (16.3) | 1,931 (15.5) | 1,269 (14.4) | 1,646 (14.0) | <0.001 |
| Ischemic heart disease | 20,619 (35.4) | 3,764 (37.9) | 5,644 (36.9) | 4,319 (34.7) | 2,931 (33.4) | 3,961 (33.6) | <0.001 |
| Previous PCI | 2,947 (5.1) | 628 (6.3) | 824 (5.4) | 601 (4.8) | 420 (4.8) | 474 (4.0) | <0.001 |
| Previous CABG | 2,137 (3.7) | 453 (4.6) | 612 (4.0) | 411 (3.3) | 276 (3.1) | 385 (3.3) | <0.001 |
| Atrial fibrillation or flutter | 13,903 (23.9) | 2,358 (23.7) | 3,677 (24.1) | 2,899 (23.3) | 2,086 (23.7) | 2,883 (24.5) | 0.285 |
| Valvular heart disease | 4,437 (7.6) | 775 (7.8) | 1,201 (7.9) | 931 (7.5) | 618 (7.0) | 912 (7.7) | 0.164 |
| Ventricular arrhythmias | 1,363 (2.3) | 265 (2.7) | 394 (2.6) | 265 (2.1) | 176 (2.0) | 263 (2.2) | 0.003 |
| Cardiorespiratory failure or shock | 1,716 (2.9) | 278 (2.8) | 467 (3.1) | 342 (2.7) | 254 (2.9) | 375 (3.2) | 0.240 |
| Chronic atherosclerosis | 16,665 (28.6) | 3,089 (31.1) | 4,534 (29.7) | 3,471 (27.9) | 2,375 (27.0) | 3,196 (27.1) | <0.001 |
| Other unspecified heart disease | 4,245 (7.3) | 742 (7.5) | 1,119 (7.3) | 871 (7.0) | 608 (6.9) | 905 (7.7) | 0.166 |
| Diabetes | 26,408 (45.4) | 4,343 (43.7) | 6,880 (45.0) | 5,690 (45.7) | 3,976 (45.3) | 5,519 (46.9) | <0.001 |
| Anemia | 9,601 (16.5) | 1,597 (16.1) | 2,449 (16.0) | 2,004 (16.1) | 1,473 (16.8) | 2,078 (17.6) | 0.002 |
| COPD | 8,480 (14.6) | 1,325 (13.3) | 2,143 (14.0) | 1,841 (14.8) | 1,323 (15.1) | 1,848 (15.7) | <0.001 |
| Hypertension | 50,798 (87.2) | 8,662 (87.2) | 13,338 (87.2) | 10,876 (87.4) | 7,647 (87.0) | 10,275 (87.2) | 0.937 |
| Cerebrovascular disease | 3,415 (5.9) | 589 (5.9) | 918 (6.0) | 755 (6.1) | 483 (5.5) | 670 (5.7) | 0.358 |
| Peripheral vascular disease | 4,168 (7.2) | 712 (7.2) | 1,109 (7.3) | 862 (6.9) | 626 (7.1) | 859 (7.3) | 0.823 |
| Cirrhotic liver disease | 303 (0.5) | 43 (0.4) | 75 (0.5) | 64 (0.5) | 45 (0.5) | 76 (0.6) | 0.257 |
| Cognitive impairment | 7,084 (12.2) | 1,208 (12.2) | 1,822 (11.9) | 1,521 (12.2) | 1,047 (11.9) | 1,486 (12.6) | 0.453 |
| Cancer | 4,192 (7.2) | 750 (7.5) | 1,012 (6.6) | 968 (7.8) | 638 (7.3) | 824 (7.0) | 0.002 |
| Long-term dialysis | 619 (1.1) | 197 (2.0) | 153 (1.0) | 99 (0.8) | 71 (0.8) | 99 (0.8) | <0.001 |
| Rheumatic disease | 677 (1.2) | 102 (1.0) | 163 (1.1) | 147 (1.2) | 104 (1.2) | 161 (1.4) | 0.126 |
| Peptic ulcer disease | 284 (0.5) | 53 (0.5) | 75 (0.5) | 54 (0.4) | 44 (0.5) | 58 (0.5) | 0.878 |
| Pneumonia | 8,187 (14.1) | 1,273 (12.8) | 2,090 (13.7) | 1,803 (14.5) | 1,251 (14.2) | 1,770 (15.0) | <0.001 |
| Chronic kidney disease | 9,839 (16.9) | 1,624 (16.3) | 2,482 (16.2) | 2,036 (16.4) | 1,552 (17.7) | 2,145 (18.2) | <0.001 |
| Fluid or electrolyte disorders | 5,747 (9.9) | 947 (9.5) | 1,452 (9.5) | 1,196 (9.6) | 893 (10.2) | 1,259 (10.7) | 0.006 |
| Protein-calorie malnutrition | 125 (0.2) | 21 (0.2) | 28 (0.2) | 28 (0.2) | 16 (0.2) | 32 (0.3) | 0.558 |
| Urinary tract disorder | 5,747 (9.9) | 901 (9.1) | 1,428 (9.3) | 1,191 (9.6) | 918 (10.4) | 1,309 (11.1) | <0.001 |
| Decubitus ulcer or skin ulcer | 1,189 (2.0) | 181 (1.8) | 259 (1.7) | 258 (2.1) | 189 (2.2) | 302 (2.6) | <0.001 |
| Other GI disorders | 16,490 (28.3) | 2,854 (28.7) | 4,280 (28.0) | 3,470 (27.9) | 2,471 (28.1) | 3,415 (29.0) | 0.244 |
| Trauma | 3,798 (6.5) | 528 (5.3) | 959 (6.3) | 832 (6.7) | 617 (7.0) | 862 (7.3) | <0.001 |
| Depression | 1,029 (1.8) | 164 (1.7) | 238 (1.6) | 205 (1.6) | 185 (2.1) | 237 (2.0) | 0.004 |
| Major psychiatric disorder | 4,931 (8.5) | 848 (8.5) | 1,214 (7.9) | 1,012 (8.1) | 784 (8.9) | 1,073 (9.1) | 0.003 |
| Previous medications | | | | | | | |
| ACE inhibitor or ARB | 35,587 (61.1) | 6,197 (62.4) | 9,537 (62.4) | 7,663 (61.6) | 5,215 (59.4) | 6,975 (59.2) | <0.001 |
| Beta-adrenoceptor antagonist | 28,749 (49.4) | 5,203 (52.4) | 7,904 (51.7) | 6,042 (48.6) | 4,171 (47.5) | 5,429 (46.1) | <0.001 |
| Digoxin | 9,654 (16.6) | 1,587 (16.0) | 2,565 (16.8) | 2,024 (16.3) | 1,460 (16.6) | 2,018 (17.1) | 0.160 |
| Furosemide | 30,771 (52.8) | 5,017 (50.5) | 7,904 (51.7) | 6,509 (52.3) | 4,705 (53.6) | 6,636 (56.3) | <0.001 |
| Metolazone | 1,397 (2.4) | 202 (2.0) | 331 (2.2) | 293 (2.4) | 208 (2.4) | 363 (3.1) | <0.001 |
| Spironolactone | 5,172 (8.9) | 832 (8.4) | 1,347 (8.8) | 1,040 (8.4) | 803 (9.1) | 1,150 (9.8) | <0.001 |
| Antiplatelet agent | 6,035 (10.4) | 1,103 (11.1) | 1,671 (10.9) | 1,318 (10.6) | 846 (9.6) | 1,097 (9.3) | <0.001 |
| Warfarin | 16,488 (28.3) | 2,855 (28.7) | 4,469 (29.2) | 3,401 (27.3) | 2,448 (27.9) | 3,315 (28.1) | 0.007 |
| HMG-CoA reductase inhibitor | 27,323 (46.9) | 4,840 (48.7) | 7,360 (48.1) | 5,823 (46.8) | 4,006 (45.6) | 5,294 (44.9) | <0.001 |

Values are n (%).

ACE = angiotensin-converting enzyme; ARB = angiotensin receptor blocker; CABG = coronary artery bypass graft; COPD = chronic obstructive pulmonary disease; GI = gastrointestinal; HF = heart failure; HMG-CoA = 5-hydroxy-3-methylglutaryl-coenzyme A; PCI = percutaneous coronary intervention.

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**TABLE 2 Care Processes by Length of Stay**

| | All Patients (N = 58,230) | Length of Stay (Days) 1–2 (n = 9,938) | 3–4 (n = 15,288) | 5–6 (n = 12,439) | 7–8 (n = 8,786) | 9–14 (n = 11,779) | p Value |
|---|---|---|---|---|---|---|---|
| Hospital type | | | | | | | |
| Community | 42,353 (72.7) | 6,935 (69.8) | 11,247 (73.6) | 9,141 (73.5) | 6,413 (73.0) | 8,617 (73.2) | <0.001 |
| Small hospital | 3,348 (5.7) | 657 (6.6) | 912 (6.0) | 676 (5.4) | 485 (5.5) | 618 (5.2) | – |
| Teaching | 12,529 (21.5) | 2,346 (23.6) | 3,129 (20.5) | 2,622 (21.1) | 1,888 (21.5) | 2,544 (21.6) | – |
| Treating physician | | | | | | | |
| Cardiologist | 11,075 (19.0) | 1,482 (14.9) | 2,654 (17.4) | 2,552 (20.5) | 1,827 (20.8) | 2,560 (21.7) | <0.001 |
| Specialist (noncardiologist) | 4,309 (7.4) | 881 (8.9) | 1,087 (7.1) | 863 (6.9) | 616 (7.0) | 862 (7.3) | – |
| Internist | 20,997 (36.1) | 4,105 (41.3) | 5,852 (38.3) | 4,360 (35.1) | 2,960 (33.7) | 3,720 (31.6) | – |
| General practitioner | 21,848 (37.5) | 3,470 (34.9) | 5,695 (37.3) | 4,663 (37.5) | 3,383 (38.5) | 4,637 (39.4) | – |
| Admitting unit | | | | | | | |
| Hospital ward | 49,167 (84.4) | 8,994 (90.5) | 13,058 (85.4) | 10,383 (83.5) | 7,284 (82.9) | 9,448 (80.2) | <0.001 |
| ICU or CCU | 9,063 (15.6) | 944 (9.5) | 2,230 (14.6) | 2,056 (16.5) | 1,502 (17.1) | 2,331 (19.8) | – |
| Admission day | | | | | | | |
| Friday to Sunday | 23,073 (39.6) | 3,367 (33.9) | 6,503 (42.5) | 5,881 (47.3) | 2,424 (27.6) | 4,898 (41.6) | <0.001 |
| Monday to Thursday | 35,157 (60.4) | 6,571 (66.1) | 8,785 (57.5) | 6,558 (52.7) | 6,362 (72.4) | 6,881 (58.4) | – |
| In-hospital procedures | | | | | | | |
| PCI or CABG surgery | 196 (0.3) | ≤18 (≤0.2) | ≤18 (≤0.2) | 38 (0.3) | 40 (0.5) | 100 (0.8) | <0.001 |
| Pacemaker (non-ICD) | 254 (0.4) | ≤26 (≤0.3) | ≤26 (≤0.3) | 38 (0.3) | 64 (0.7) | 126 (1.1) | <0.001 |
| ICD | 42 (0.1) | 0 (0.0) | ≤7 (0.0) | ≤7 (0.0) | ≤7 (0.0) | 35 (0.3) | <0.001 |
| Electrical cardioversion | 403 (0.7) | 33 (0.3) | 71 (0.5) | 79 (0.6) | 78 (0.9) | 142 (1.2) | <0.001 |
| Procedures within 90 days* | | | | | | | |
| PCI or CABG surgery | 946 (1.6) | 172 (1.7) | 263 (1.7) | 223 (1.8) | 109 (1.2) | 179 (1.5) | 0.013 |
| Pacemaker (non-ICD) | 396 (0.7) | 27 (0.3) | 40 (0.3) | 41 (0.3) | 18 (0.2) | 26 (0.2) | 0.394 |
| ICD | 239 (0.4) | 31 (0.3) | 58 (0.4) | 48 (0.4) | 36 (0.4) | 36 (0.3) | 0.624 |
| Electrical cardioversion | 830 (1.4) | 93 (0.9) | 117 (0.8) | 121 (1.0) | 76 (0.9) | 70 (0.6) | 0.010 |
| Discharge medications | | | | | | | |
| ACE inhibitor or ARB | 42,300 (72.6) | 7,193 (72.4) | 11,388 (74.5) | 9,201 (74.0) | 6,307 (71.8) | 8,211 (69.7) | <0.001 |
| Beta-adrenoceptor antagonist | 35,459 (60.9) | 5,971 (60.1) | 9,466 (61.9) | 7,631 (61.3) | 5,360 (61.0) | 7,031 (59.7) | 0.001 |
| Digoxin | 14,875 (25.5) | 2,122 (21.4) | 3,733 (24.4) | 3,256 (26.2) | 2,425 (27.6) | 3,339 (28.3) | <0.001 |
| Furosemide | 51,747 (88.9) | 8,667 (87.2) | 13,671 (89.4) | 11,134 (89.5) | 7,870 (89.6) | 10,405 (88.3) | <0.001 |
| Metolazone | 3,181 (5.5) | 483 (4.9) | 729 (4.8) | 653 (5.2) | 486 (5.5) | 830 (7.0) | <0.001 |
| Spironolactone | 13,077 (22.5) | 1,805 (18.2) | 3,360 (22.0) | 2,797 (22.5) | 2,137 (24.3) | 2,978 (25.3) | <0.001 |
| Antiplatelet agent | 7,341 (12.6) | 1,203 (12.1) | 1,975 (12.9) | 1,625 (13.1) | 1,069 (12.2) | 1,469 (12.5) | 0.103 |
| Warfarin | 21,000 (36.1) | 3,227 (32.5) | 5,323 (34.8) | 4,527 (36.4) | 3,300 (37.6) | 4,623 (39.2) | <0.001 |
| HMG-CoA reductase inhibitor | 29,788 (51.2) | 5,118 (51.5) | 7,907 (51.7) | 6,427 (51.7) | 4,419 (50.3) | 5,917 (50.2) | 0.035 |

Values are n (%). *Procedures within 90 days post-discharge.
CCU = coronary care unit; ICD = implantable cardioverter-defibrillator; ICU = intensive care unit; other abbreviations as in Table 1.

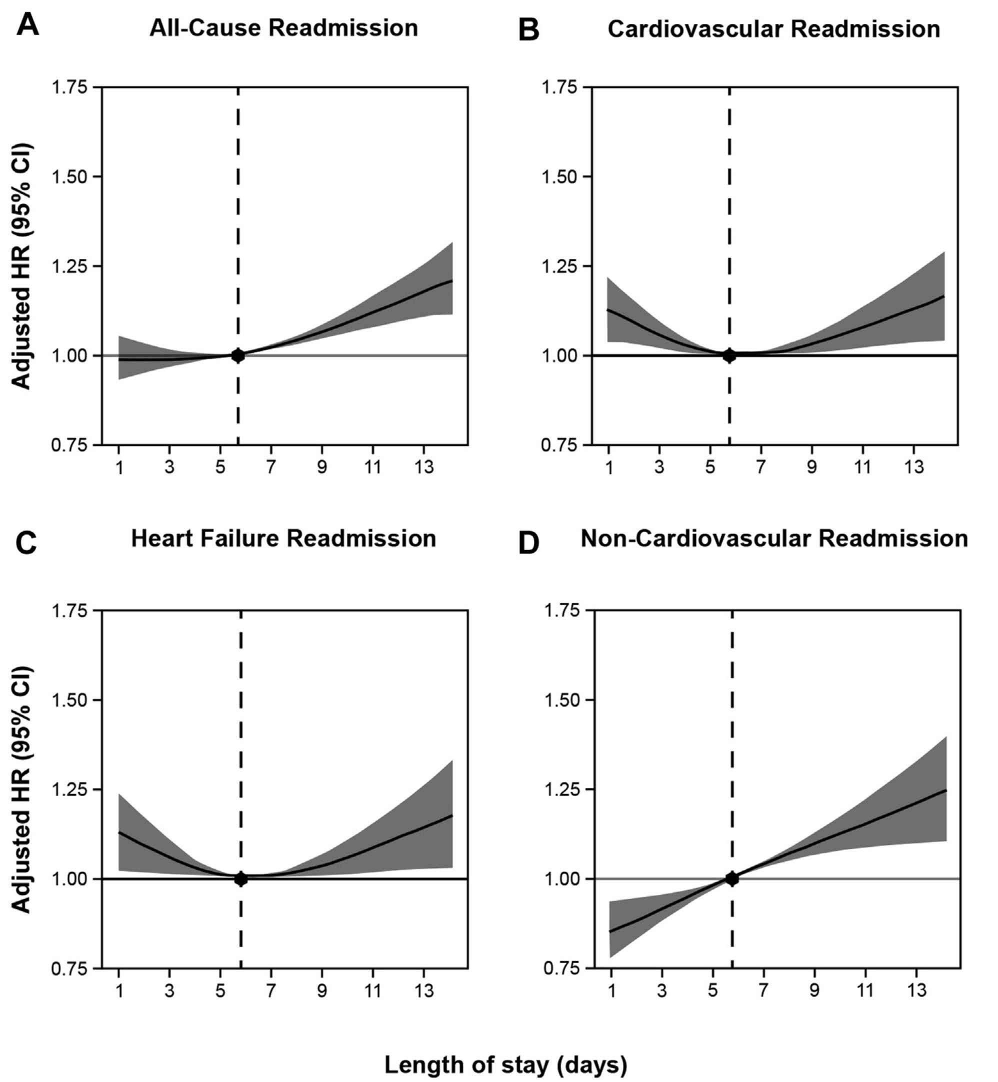
Admission to intensive care increased the odds of a long LOS. Finally, belonging to the highest income quintile increased the odds of a short LOS.

**SENSITIVITY ANALYSIS.** There were 64,165 patients with LOS up to 35 days, and rates of readmission (Online Figure 3) and mortality (Online Figure 4) increased further as the hospital stay extended to 35 days. There were 71,586 patients ≥18 years of age with an index HF-related hospitalization. In this sensitivity analysis cohort, the associations between LOS and readmission (Online Figure 5) and LOS and mortality (Online Figure 6) remained similar to those observed in older patients ≥65 years of age. When repeat hospital admissions were included (85,885 HF-related hospitalizations), the associations between LOS and rates of readmission (Online Figure 7) and LOS and mortality (Online Figure 8) remained similar to those of the main analysis.

## DISCUSSION

In this large, provincial cohort of older patients, we found that the index hospital LOS was associated with 30-day mortality risk and rates of cause-specific readmission, depending on whether the duration of stay was short or long. Although all-cause readmissions increased as LOS extended beyond

**FIGURE 1** Associations Between LOS and Rates of 30-Day Readmission




Association between length of stay (LOS) and rate of 30-day **(A)** all-cause, **(B)** cardiovascular, **(C)** heart failure HF, and **(D)** noncardiovascular readmissions. Length of stay was modeled with the use of restricted cubic splines and adjusted for the covariates shown in the Online Appendix. The **solid line** indicates adjusted hazard ratio (HR) for any length of stay, with corresponding 95% confidence intervals (CIs) indicated by the **shaded area.** The reference is indicated by the intersection of the underlying reasons (hazard ratio: 1), above which there is an increased readmission rate, and the **dashed line** indicating the mean length of stay.

5 to 6 days, examination of cause-specific readmissions identified a U-shaped association for cardiovascular and HF readmissions. The rate of 30-day readmissions for HF or cardiovascular causes was highest in patients with the shortest and longest LOS, but noncardiovascular readmissions increased linearly as LOS increased. All-cause, cardiovascular, and noncardiovascular mortality rates uniformly increased when index hospital LOS exceeded 8 days.

Our study findings are concordant with those of the Efficacy of Vasopressin Antagonism in Heart Failure Outcome Study with Tolvaptan trial (16) and a large retrospective analysis from Kaiser Permanente (28). In these studies, a long LOS for HF was associated with higher 30-day all-cause readmission risk, but differential risks of cardiovascular and noncardiovascular admissions were not identified. Adding to these previous studies, we were able to uncover an at-risk group of patients with a short

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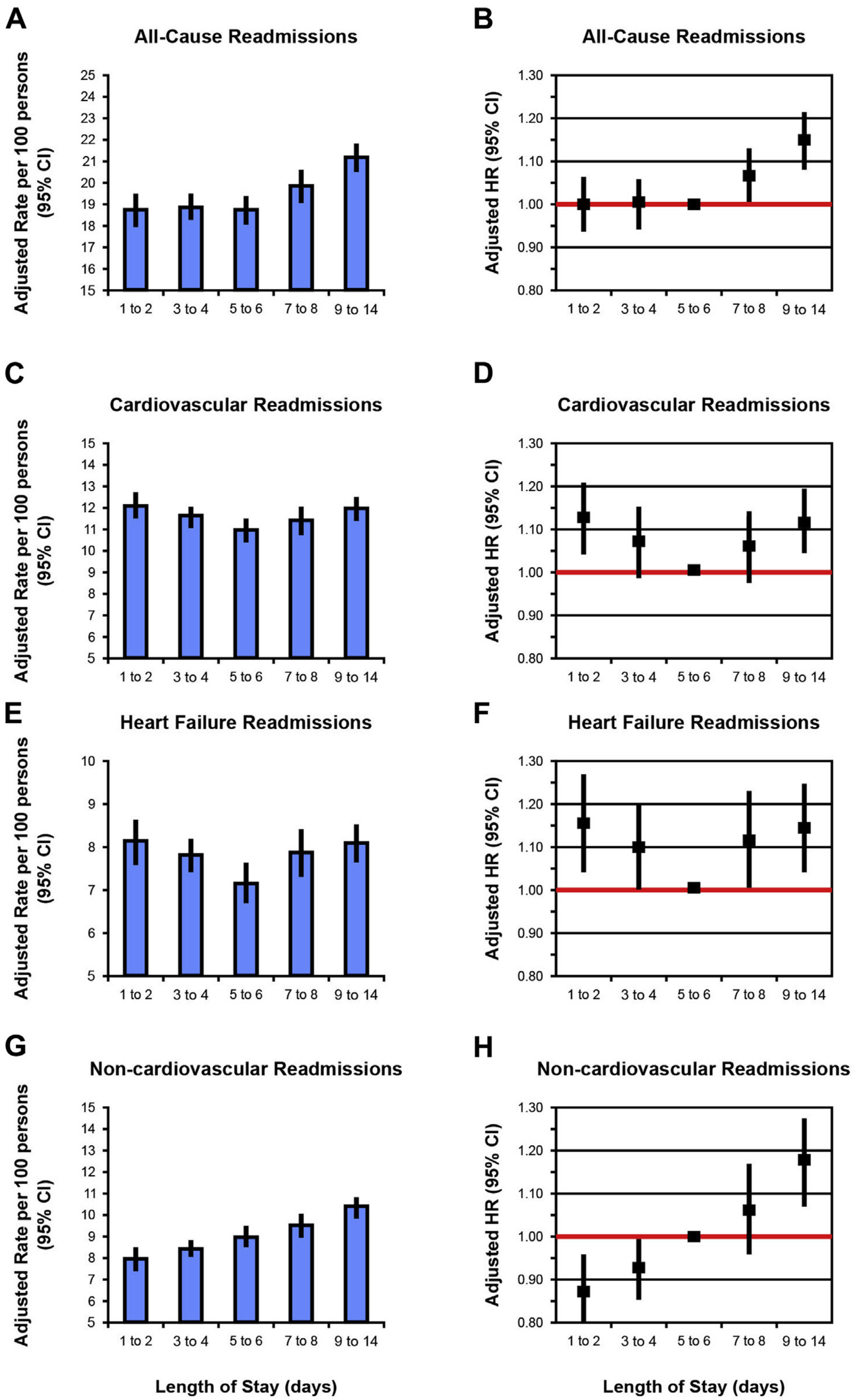
**FIGURE 2** Adjusted Rates and HRs of 30-Day Readmissions




Adjusted rates and hazard ratios (HRs) of 30-day **(A, B)** all-cause, **(C, D)** cardiovascular, **(E, F)** heart failure, and **(G, H)** noncardiovascular readmissions stratified by heart failure length of stay categories. CI = confidence interval.

LOS who exhibited a higher cardiovascular and HF readmission risk. The short LOS group represented a substantial proportion (17%) of our study cohort, with clinical equipoise in the impact of LOS on readmission and mortality outcomes.

Our results differ from those of a between-country analysis of the Acute Study of Clinical Effectiveness of Nesiritide in Decompensated Heart Failure trial (29), in which longer LOS was associated with lower adjusted risk of all-cause and HF readmissions. However, the aforementioned study was an ecological analysis in which the wide variations in LOS and readmission rates were affected by large between-country differences in both these measures (29).

The underlying reasons for the associations between LOS and readmission and LOS and mortality are complex. As reported previously (30-32), we found that patients with a longer LOS were older and had more noncardiovascular comorbidities, such as diabetes and chronic respiratory disease. These comorbidities could predispose to nosocomial infections, in-hospital complications, and further deconditioning, ultimately contributing to higher noncardiovascular readmission and mortality risk (10). Patients with longer LOS may also exhibit greater HF severity, as indicated by more use of diuretics and spironolactone before admission and a higher rate of intensive or coronary care unit admission. Increased risk of cardiovascular and HF readmission with a short LOS may be explained by persistent congestion that may not have been apparent before discharge, as well as insufficient opportunity to optimize medications or ensure optimal transitional care (33).

Although our findings cannot infer a causal link between LOS and readmission, they have some important implications for policy. There exist concerns that adoption of bundled fixed payments may have the unintended effect of incentivizing shorter hospital stays to improve efficiency and reduce costs, albeit at the expense of higher readmission rates (5). Over a 9-year period, encompassing >50,000 patients in a health care environment that was uninfluenced by these financial pressures, our data suggest that shorter LOS for HF did not adversely affect early all-cause mortality outcomes. Despite the increased cardiovascular and HF readmission risk in patients with short LOS, our data do not challenge strategies aimed at reducing LOS. Indeed, in the current environment where cardiologists and generalists provide HF care, our data highlight potential strategies that may improve efficiency and outcomes. Because there was an increase in cardiovascular readmissions after early hospital discharge, it is conceivable that rapid cardiology-specific follow-up may be effective in reducing repeat hospitalizations in this group (34,35). In contrast, because longer LOS was an indicator of broadly increased readmission and death, peri-discharge strategies that address both general medical and cardiac-specific issues, and other multidisciplinary strategies (4), may mitigate risk among patients with long hospital stays.

**TABLE 3 Mortality Outcomes at 30 Days**

| Outcome | Length of Stay (Days) | Deaths/Patients | Adjusted Rate/100 Persons (95% CI)* | Adjusted HR (95% CI)* |
|---|---|---|---|---|
| All-cause mortality | 1-2 | 323/9,938 | 3.40 (3.03-3.77) | 0.96 (0.83-1.11) |
| | 3-4 | 424/15,288 | 2.81 (2.52-3.10) | 0.79 (0.68-0.91) |
| | 5-6 | 441/12,439 | 3.52 (3.20-3.85) | Referent |
| | 7-8 | 344/8,786 | 3.93 (3.54-4.32) | 1.12 (0.97-1.29) |
| | 9-14 | 551/11,779 | 4.46 (4.13-4.78) | 1.28 (1.14-1.43)† |
| Cardiovascular mortality | 1-2 | 198/9,938 | 2.09 (1.79-2.38) | 0.91 (0.76-1.09) |
| | 3-4 | 270/15,288 | 1.76 (1.53-1.99) | 0.77 (0.65-0.91) |
| | 5-6 | 282/12,439 | 2.27 (2.01-2.52) | Referent |
| | 7-8 | 208/8,786 | 2.40 (2.09-2.71) | 1.06 (0.89-1.27) |
| | 9-14 | 340/11,779 | 2.77 (2.51-3.03) | 1.23 (1.06-1.44) |
| Noncardiovascular mortality | 1-2 | 125/9,938 | 1.31 (1.08-1.54) | 1.03 (0.81-1.32) |
| | 3-4 | 154/15,288 | 1.05 (0.87-1.24) | 0.82 (0.64-1.06) |
| | 5-6 | 159/12,439 | 1.26 (1.06-1.46) | Referent |
| | 7-8 | 136/8,786 | 1.53 (1.29-1.77) | 1.22 (0.99-1.51) |
| | 9-14 | 211/11,779 | 1.69 (1.49-1.89) | 1.35 (1.09-1.67) |

Values are n/N. *Models adjusted for the following covariates: age, sex, socioeconomic status, heart failure history (no history, heart failure with no previous hospitalizations, 1 previous heart failure hospitalization, and ≥2 previous heart failure hospitalizations), myocardial infarction, angina, unstable angina, chronic atherosclerosis, coronary revascularization (coronary artery bypass grafting vs. percutaneous coronary intervention), implantable cardiac defibrillator, permanent pacemaker, hypertension, cerebrovascular disease, peripheral vascular disease, valvular and rheumatic heart disease, arrhythmias, cardiopulmonary-respiratory failure and shock, diabetes, cancer, pneumonia, trauma, major psychiatric disorders, decubitus skin ulcers, chronic obstructive pulmonary disease, rheumatologic disease, renal disease, gastrointestinal disorders, year and day of admission, hospital type (community, urban, teaching), admission to hospital ward or intensive or coronary care unit, and previous use of beta-adrenergic receptor blockers, angiotensin-converting enzyme inhibitors or angiotensin receptor blockers, digoxin, furosemide, metolazone, spironolactone, antiplatelet agents, warfarin, or 5-hydroxy-3-methylglutaryl-coenzyme A reductase inhibitors. †$p < 0.001$.

CI = confidence interval; HR = hazard ratio.

The strengths of our analysis include its large sample size and complete population capture in a diverse array of patients. Our study was unlikely to be influenced by financial penalties that could result in distortion of 30-day readmission rates (36).

**STUDY LIMITATIONS.** We relied on administrative coding for the index HF admission and subsequent cardiovascular admissions. However, these algorithms have demonstrated high accuracy with a positive predictive value of 94% when compared with the Framingham criteria (11,13,15,37). Without clinical data, we could not characterize the severity of disease at presentation; however, we adjusted for validated administrative models for HF readmission and mortality (17-19), as well as care setting (intensive care unit), which are proxies for HF acuity (20). We were unable to subdivide HF by the presence or absence of reduced left ventricular ejection fraction; however, at the population level there is comparable prognosis in these subtypes (38). Our study was observational and used administrative data as its basis; therefore, unmeasured confounding is a risk for the presence and magnitude of the association between LOS and 30-day outcomes detected in this study. Finally, our results may not be generalizable to jurisdictions in which LOS, hospital care, and post-discharge care for patients with HF differ substantially. As such, these results require confirmation in additional population-based registries.

## CONCLUSIONS

The LOS during the index HF-related hospitalization differentially predicts 30-day cardiovascular and noncardiovascular readmissions. Patients with either a short or long LOS have increased rates of 30-day readmission. Our data underscore the need for further examination of patients with short and long LOS with the aim of developing targeted approaches to mitigate readmission risk.

**ADDRESS FOR CORRESPONDENCE:** Dr. Douglas S. Lee, Institute for Clinical Evaluative Sciences, Division of Cardiology, University Health Network-Toronto General Hospital, NU 4-482, 200 Elizabeth Street, Toronto, Ontario M5G 2C4, Canada. E-mail: dlee@ices.on.ca.

## PERSPECTIVES

**COMPETENCY IN PATIENT CARE:** In older patients hospitalized with acute HF, LOS is an important metric that demonstrates a U-shaped relationship with 30-day cardiovascular and HF readmissions but a linear relationship with 30-day noncardiovascular readmissions. Furthermore, a shorter LOS (1 to 2 days) was associated with a reduced risk of 30-day noncardiovascular readmissions, at the expense of an increased risk of 30-day cardiovascular and HF readmissions.

**TRANSLATIONAL OUTLOOK:** Future studies should evaluate the impact of post-discharge strategies such as early physician follow-up and transitional care in reducing cardiovascular and HF readmissions after a short LOS.

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**KEY WORDS** heart failure, length of stay, mortality, readmissions

**APPENDIX** For supplemental tables, figures, and a description of variables, please see the online version of this paper.