Relation of a Simple Cardiac Co-Morbidity Count and Cardiovascular Readmission After a Heart Failure Hospitalization

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Although several risk calculators are available to determine risk for readmission following a heart failure (HF) hospitalization, none provide information on cause-specific readmission. Understanding risk for cause-specific readmission could aid in developing a targeted approach to reducing readmissions. We sought to determine if a simple cardiac co-morbidity count could identify individuals at high risk for a cardiovascular (CV) readmission following a HF hospitalization. Using the Nationwide Readmissions Database, we examined nonfatal hospital discharges with a principal diagnosis of HF. We calculated a 0 to 3 cardiac co-morbidity count based on the presence of coronary artery disease, atrial arrhythmia, and/or ventricular arrhythmia. We used a multinomial logistic regression to determine if the cardiac co-morbidity count was independently associated with CV readmission or non-CV readmission, adjusting for patient- and hospital-level confounders. In 380,075 discharges, 28% had a co-morbidity count of 0, 47% had a count of 1, 23% had a count of 2, and 2% had a count of 3. In a fully adjusted model, cardiac co-morbidity count was independently associated with CV readmission: compared with individuals with a count of 0, the relative risk for those with a count of 1 was 1.27 (95% confidence interval [CI]: 1.23 to 1.31); for those with a count of 2 was 1.40 (95% CI: 1.35 to 1.46); and for those with a count of 3 was 1.36 (95% CI: 1.23 to 1.51). Cardiac co-morbidity count was not independently associated with non-CV readmission. In conclusion, we found that a simple cardiac co-morbidity count was independently associated with increased risk of CV but not non-CV readmission. **(Am J Cardiol 2020;125:1529−1535)**

Despite over a decade of research and health care policy changes in the United States, readmission rates remain high,[1] leading to substantial morbidity and mortality.[2] Part of the challenge with developing and implementing interventions to reduce readmissions following a heart failure (HF) hospitalization is that the HF population is highly heterogeneous[3−8]; relatedly, causes of readmission vary substantially as well—about half of readmissions are for non-CV causes.[9,10] Consequently, a single intervention to reduce readmissions is unlikely to work for everyone, supporting the need to develop phenotype-based approaches for reducing readmissions. To tailor interventions for readmission prevention, 1 potential approach could be to identify individuals at greatest risk for different types of readmission, and subsequently develop targeted therapies based on this risk. For example, individuals at highest risk for a CV readmission may benefit from more aggressive management and monitoring of their CV conditions, perhaps through increased encounters with a CV clinician.[11] To date, there are several risk calculators that can determine a patient's risk for readmission[12−14]; however, none to our knowledge provide information on cause-specific readmission. To fill this gap and aid in the development of a tailored approach to implementing interventions for reducing readmissions, we sought to determine whether a simple count of common cardiac comorbid conditions could identify individuals at the highest risk for a CV readmission.

Methods

The study population was derived from the 2014 Nationwide Readmissions Database (NRD).[15] Briefly, the NRD is part of a family of databases developed for the Healthcare Cost and Utilization Project (HCUP) and sponsored by the Agency for Healthcare Research and Quality. The NRD comprises of a sample of discharges from the State Inpatient Databases. States are chosen based on verifiability of patient linkage numbers, which are needed to track patients. The 2014 NRD was developed from 22 State Inpatient Databases and represents 51.2% of the total US civilian population and 49.3% of US hospitalizations. The 2014 NRD included 14,893,613 discharges from 2,048 hospitals, representing 35 million discharges after weighting to

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provide nationally representative estimates. Discharge-level weights were determined poststratification based on age, sex, and hospital characteristics.

We examined 380,075 adult discharges with a principal diagnosis of HF, as determined by the following International Classification of Diseases, Ninth Edition Clinical Modification (ICD-9-CM) codes: 428.xx, 402.01, 402.11, 402.91, 404.01, 404.11, and 404.91. Using ICD-9-CM codes is a well-accepted and validated approach for identifying HF patients.[16] We excluded 407 patients aged <18 years, and 42,280 patients discharged in December 2014 because they could not be followed for 30 days. Of those remaining in the cohort, 11,878 died during their index hospitalization and were thus excluded. Finally, we excluded 11 discharges with missing data on variables needed to calculate readmission. Supplemental Figure S1 shows the exclusion cascade for this study.

For the primary exposure, we created a cardiac co-morbidity count based on the presence of 3 important and easily identifiable cardiac comorbidities (coronary artery disease [CAD], atrial arrhythmias, and ventricular arrhythmias) during the index hospitalization based on validated ICD-9-CM codes (atrial arrhythmia: 427.0, 427.3x; ventricular arrhythmia: 427.41, 427.42, 427.1; CAD: 414.0x, 414, 414.2, 414.3, 414.4, 414.8, and 414.9).[17] We chose these cardiac comorbidities because they are common CV causes of readmission after a HF hospitalization.[9] We included only 3 comorbid conditions in the count because we wanted to create a simple count that clinicians could easily remember and calculate. Each cardiac co-morbidity contributed a count of 1 to the total cardiac co-morbidity count. Thus, values for the cardiac co-morbidity count ranged from 0 (no cardiac comorbidities) to 3 (all cardiac comorbidities present).

The primary study outcome was 30-day cause-specific readmission following a HF hospitalization, categorized into CV cause of readmission (CV-readmission), non-CV cause of readmission (non-CV readmission), and no readmission. We reviewed the principal diagnosis for each readmission and used Clinical Classification Software codes 96-121 to identify whether the readmission was from a CV cause.[18] All other causes of readmission were considered non-CV. To determine readmission, the NRD provides several readmission-specific variables, including a patient linkage number to track patients within a state for a single year, and a time variable to permit calculation of time-to-readmission.

We selected covariates for inclusion in our statistical models based on the Andersen model of healthcare utilization.[19] We included the following variables which HCUP provides as part of the NRD: "predisposing" factors: age at index hospitalization admission and sex; "enabling" factors: annual median household income quartile and payer type; and "need factors": length of stay and Elixhauser Co-morbidity Index. The Elixhauser Co-morbidity Index is a validated weighted measure of 29 selected comorbidities across several organ systems that is associated with 30-day all-cause readmission in several other disease states [20,21] HCUP provided readmission specific weights to permit calculation of the Elixhauser Co-morbidity Index for each patient. For "healthcare utilization" factors, we included the following hospital characteristics: bed size and urban/rural location. Of note, we did not include hospital characteristics such as teaching status or hospital ownership due to significant multicollinearity with hospital bed size and urban/rural location, as determined by variance inflation factors.

All statistical analyses accounted for the complex NRD sample design.[15] We used the provided strata and natural clustering within hospitals to estimate standard errors with the Taylor series (linearization) method.[22] To obtain national estimates, we utilized discharge weights. We presented continuous variables using weighted means and standard deviations and categorical variables using the number of discharges and weighted percentages. We compared patient- and hospital-level characteristics across cardiac co-morbidity counts (0, 1, 2, 3) using a design-corrected Rao-Scott chi-square test for categorical variables and sample design-adjusted univariate linear regression for continuous variables, treating cardiac co-morbidity count as a continuous variable.

We used a multinomial logistic regression model to determine if cardiac co-morbidity count was independently associated with a CV readmission or non-CV readmission (compared to no readmission), adjusting for potential confounders determined a priori using the Anderson model of healthcare utilization. First, we estimated an age-adjusted multinomial logistic regression model examining only the count variable and readmissions. Then we sequentially added predisposing factors and enabling factors (model 1), need factors (model 2), and hospital characteristics (model 3; fully adjusted model). We reported all estimates as relative risk ratios with 95% confidence intervals (CI). We examined trends in relative risk ratio across cardiac co-morbidity count for each model by treating cardiac co-morbidity count as a continuous variable and determining the significance of cardiac co-morbidity count in the model using maximum likelihood estimates.

To ensure that our inferences on the association between cardiac co-morbidity count and cause-specific 30-day readmission were accurate, we repeated the sequential multinomial logistic regression, treating non-CV readmission as the reference group. This allowed us to directly compare risk of CV-readmission to risk of non-CV readmission.

Given the possibility that the influence of cardiac co-morbidity count on 30-day cause-specific readmission might differ in those with advanced age and those with increased co-morbidity burden, we examined interactions with age and with Elixhauser Co-morbidity Index via Wald chi-square test using the logistic regression model's type III analysis of effects. Given statistically significant findings, we subsequently repeated the analyses stratified by age group (<65, 65 to 74, ≥75) and Elixhauser Co-morbidity Index tertiles (<13, 14 to 27, ≥28).

Patients who experience cardiogenic shock during the index hospitalization represent a specific subpopulation for whom the cardiac co-morbidity count may be less relevant, as this population likely needs more intense follow-up and involvement of a cardiologist regardless of their cardiac co-morbidity count. Accordingly, we conducted a sensitivity analysis of individuals who did not experience cardiogenic shock during their index hospitalization.

To account for missing covariates, we used the traditional Markov Chain Monte Carlo multiple imputation method, as is recommended for HCUP data. We used 5 iterations of the imputation technique and pooled together estimates for 1.4% discharges with missing data on income quartile and 0.1% discharges with missing data on Primary Payer Type. All other variables had complete data with no missingness.

We conducted all analyses using SAS Version 9.4 (SAS Institute, Cary, North Carolina), and we used a p <0.05 to indicate statistical significance.

Results

We examined 380,075 unique discharges from 1,972 unique hospitals in the United States, which represented 831,929 discharges after weighting. The mean (standard deviation) age of the cohort at index hospitalization was 72.0 (0.2) years and included a balance of men and women (Table 1). The mean (standard deviation) length of stay for HF hospitalization was 5.3 (0.04) days. Most discharges occurred at hospitals that were large (>400 beds), teaching, owned privately as a nonprofit, and located in a large metropolitan area. The prevalence of CAD was 51%, atrial arrhythmias was 43%, and ventricular arrhythmia was 5%.

In 380,075 discharges, 28% had a cardiac co-morbidity count of 0, 47% had a cardiac co-morbidity count of 1, 23% had a count of 2, and 2% had a count of 3. In individuals

Table 1
Baseline characteristics of heart failure patients by cardiac co-morbidity count, N (%) unless otherwise noted

Variable	Entire cohort	Cardiac co-morbidity count				p Value
		0	1	2	3	
Number	380,075	107,290 (28%)	178,649 (47%)	88,870 (23%)	5,266 (2%)	
Age, mean (SD) (Years)	72.0 (0.2)	65.8 (0.2)	73.1 (0.1)	76.7 (0.1)	74.0 (0.3)	<0.001
Men	196,370 (48.8%)	48,909 (44.8%)	90,468 (50.1%)	52,987 (59.1%)	4,006 (75.3%)	<0.001
Co-morbidity						
Elixhauser Co-morbidity Index, mean (SD)	21.2 (0.1)	20.5 (0.1)	21.1 (0.1)	22.0 (0.1)	23.7 (0.3)	<0.001
AIDS	809 (0.2%)	456 (0.4%)	283 (0.1%)	67 (0.06%)	3 (0.04%)	<0.001
Alcohol Abuse	13,083 (3.3%)	5,230 (4.7%)	5,600 (3.0%)	2,087 (2.3%)	166 (3.0%)	<0.001
Chronic pulmonary disease	142,826 (38.1%)	37,412 (35.5%)	67,650 (38.4%)	35,663 (40.4%)	2,101 (40.6%)	<0.001
Coagulopathy	23,119 (5.9%)	5,302 (4.8%)	10,527 (5.7%)	6,714 (7.1%)	576 (10.9%)	<0.001
Depression	37,460 (10.5%)	10,159 (10.1%)	17,894 (10.6%)	8,909 (10.6%)	498 (9.6%)	0.007
Diabetes, uncomplicated	129,105 (33.9%)	33,848 (31.7%)	62,262 (34.8%)	31,256 (35.0%)	1,739 (32.6%)	<0.001
Diabetes with chronic complications	45,515 (11.8%)	13,052 (11.8%)	22,281 (12.3%)	9,607 (10.8%)	575 (11.4%)	<0.001
Drug abuse	14,612 (3.4%)	7,585 (6.3%)	5,487 (2.8%)	1,420 (1.4%)	120 (2.0%)	<0.001
Hypertension (combined uncomplicated and complicated)	282,650 (74.3%)	76,013 (70.7%)	134,637 (75.4%)	68,105 (76.9%)	3,895 (73.8%)	<0.001
Hypothyroidism	63,519 (16.9%)	14,383 (13.6%)	30,684 (17.4%)	1,778 (20.0%)	874 (17.3%)	<0.001
Fluid and electrolyte disorders	122,725 (32.4%)	34,149 (31.9%)	57,012 (32.0%)	29,434 (33.3%)	2,130 (40.5%)	<0.001
Obesity	82,498 (21.8%)	28,078 (26.4%)	37,403 (21.1%)	16,052 (18.1%)	965 (18.3%)	<0.001
Peripheral vascular disorders	48,322 (12.5%)	7,850 (7.0%)	24,299 (13.2%)	15,218 (17.0%)	955 (17.5%)	<0.001
Renal failure	162,891 (42.9%)	42,056 (38.9%)	76,641 (42.8%)	41,547 (47.2%)	2,647 (51.5%)	<0.001
Cardiogenic shock	4,420 (1.2%)	803 (0.8%)	1,825 (1.0%)	1,474 (1.7%)	318 (6.4%)	<0.001
Median household income quartile						<0.001
0-25th	126,783 (33.7%)	41,521 (39.7%)	58,281 (32.8%)	25,510 (28.5%)	1,471 (27.7%)	
26-50th	100,878 (27.0%)	28,343 (26.6%)	47,790 (27.25)	23,457 (26.9%)	1,288 (25.3%)	
51-75th	81,714 (21.4%)	21,495 (19.6%)	38,872 (21.7%)	20,141 (22.8%)	1,206 (22.5%)	
76-100th	70,700 (18.0%)	15,931 (14.1%)	33,706 (18.2%)	19,762 (21.8%)	1,301 (24.5%)	
Primary Payer Type						<0.001
Medicare	282,730 (75.4%)	65,690 (62.5%)	137,188 (77.8%)	75,515 (85.6%)	4,337 (82.8%)	
Medicaid	40,168 (9.7%)	18,710 (16.1%)	16,667 (8.6%)	4,479 (4.6%)	312 (5.6%)	
Private	38,662 (10.1%)	14,192 (13.3%)	17,477 (9.6%)	6,533 (7.3%)	460 (8.9%)	
Other	18,515 (4.8%)	8,698 (8.2%)	7,317 (4.1%)	2,343 (2.6%)	157 (2.8%)	
Length of Stay, median days (IQR)	3.4 (2.1-5.9)	3.0 (1.7-5.1)	3.4 (2.0-5.7)	3.8 (2.2-6.5)	5.6 (3.1-9.9)	<0.001
Hospital Bed Size						<0.001
Small	58,086 (17.8%)	17,405 (18.9%)	27,374 (17.9%)	12,707 (16.8%)	600 (13.8%)	
Medium	112,878 (28.1%)	30,813 (27.0%)	53,523 (28.3%)	27,060 (28.9%)	1,482 (26.6%)	
Large	209,111 (54.1%)	59,072 (54.1%)	97,752 (53.8%)	49,103 (54.3%)	3,184 (59.6%)	
Hospital Location						<0.001
Large Metropolitan	218,857 (53.6%)	61,124 (52.5%)	102,323 (53.1%)	51,981 (55.2%)	3,429 (63.6%)	
Small Metropolitan	126,402 (33.5%)	35,379 (33.3%)	59,723 (33.7%)	29,680 (33.5%)	1,620 (30.6%)	
Micropolitan/Nonurban	34,816 (12.9%)	10,889 (14.1%)	16,603 (13.1%)	7,109 (11.3%)	217 (5.8%)	
Hospital Type						<0.001
Nonteaching Metropolitan	122,113 (28.6%)	33,745 (28.0%)	58,094 (28.9%)	28,847 (28.8%)	1,427 (23.2%)	
Teaching Metropolitan	223,146 (58.5%)	62,758 (57.8%)	103,952 (57.9%)	52,814 (59.8%)	3,622 (70.9%)	
Nonmetropolitan Hospital	34,816 (12.9%)	10,787 (14.2%)	16,603 (13.2%)	7,209 (11.4%)	217 (5.9%)	
Hospital Control						<0.001
Government, nonfederal	47,340 (11.6%)	16,101 (13.9%)	21,696 (11.3%)	9,013 (9.4%)	530 (8.6%)	
Private, Notprofit	269,000 (73.4%)	72,554 (70.2%)	126,664 (73.5%)	65,640 (76.6%)	4,142 (81.3%)	
Private, Invest-Own	63,735 (15.0%)	18,635 (15.8%)	30,289 (15.1%)	14,217 (14.0%)	594 (10.1%)	

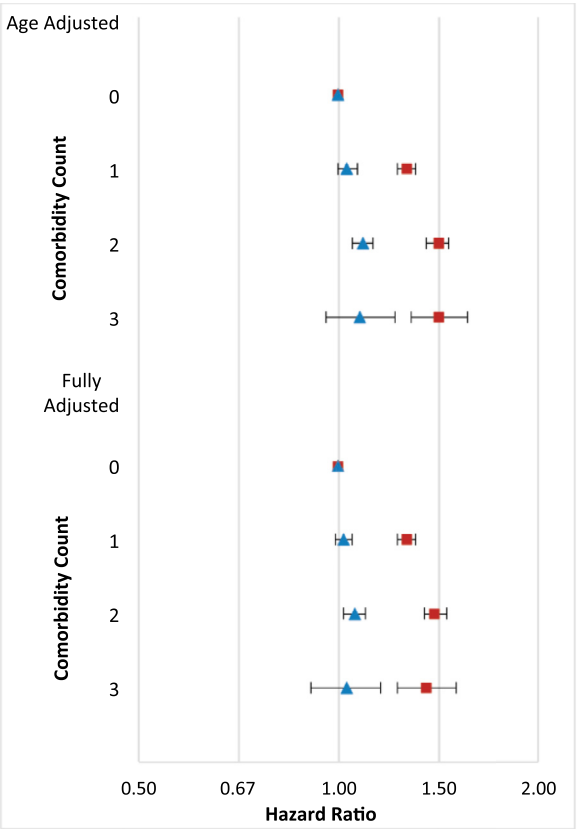
IR = interquartile range; SD = standard deviation.

with 1 cardiac co-morbidity, 57% had CAD, 40% had an atrial arrhythmia, and 3% had a ventricular arrhythmia. Of those with 2 cardiac comorbidities, 89% had both CAD and atrial arrhythmia (but no ventricular arrhythmia), 7% had both CAD and ventricular arrhythmia (but no atrial arrhythmia), and 4% had both atrial and ventricular arrhythmia (but no CAD). Approximately 2% had all 3 cardiac comorbidities.

A higher cardiac co-morbidity score tracked with several important patient and hospital characteristics. For example, individuals with higher cardiac co-morbidity scores were increasingly more likely to be male and in the highest median household income quartile. Those with higher cardiac co-morbidity scores were also more likely to experience cardiogenic shock during the index hospitalization, had higher Elixhauser co-morbidity index scores, and were more likely to have chronic pulmonary disease, fluid and electrolyte disorders, peripheral vascular disorders, and renal failure during the index hospitalization. In addition, those with higher cardiac co-morbidity scores experienced longer lengths of stay and were more likely to be hospitalized in large hospitals, in teaching hospitals, and in private non-profit hospitals.

Overall, the 30-day all-cause readmission rate was 20%. Of these readmissions, 55% were for CV causes, and 45% were for non-CV causes. The 30-day all-cause readmission rate for a co-morbidity count of 0 was 19.2%, count of 1 was 20.4%, count of 2 was 21.2%, and count of 3 was 21.6%. The 30-day CV-readmission rates for a co-morbidity count of 0 was 10.3%, count 1 was 11.5%, count of 2 was 12%, and count of 3 was 12.4%. Table 2 shows that the relative risk of a CV readmission compared to no readmission for CAD, atrial arrhythmias, and ventricular arrhythmias in an age-adjusted model were relatively comparable to each other. Compared to the relative risks for a CV readmission, non-CV readmission were lower for CAD, atrial arrhythmia, and ventricular arrhythmia.

In the age-adjusted model, we found that the relative risk of a CV-readmission was 1.27 (95%CI: 1.23 to 1.31) for a cardiac co-morbidity count of 1, 1.42 (95%CI: 1.36 to 1.47) for a count of 2, and 1.42 (95%CI: 1.29 to 1.57) for a count of 3 (compared to a count of 0; Figure 1). In a fully-adjusted model, which accounted for potential patient- and hospital-level confounders, we found that cardiac co-morbidity count remained independently associated with CV-readmission, with a relative risk of 1.27 (95%CI: 1.23 to 1.31) for a count of 1, 1.40 (95%CI: 1.35 to 1.46) for a count of 2, and 1.36 (95%CI: 1.23 to 1.51) for a count of 3. The relative risks of a non-CV readmission in an age-adjusted and fully-adjusted model were close to 1 irrespective of cardiac co-morbidity count. In a secondary analysis that used non-CV readmission (instead of no readmission) as the reference, we confirmed that the cardiac co-morbidity count was indeed more strongly associated with CV-readmission compared to non-CV readmission (Figures S2 to S4).



Count	Total N	Non-CV	CV
0	107,290	9,571	11,201
1	178,649	15,791	20,902
2	88,870	8,207	10,936
3	5,266	488	669

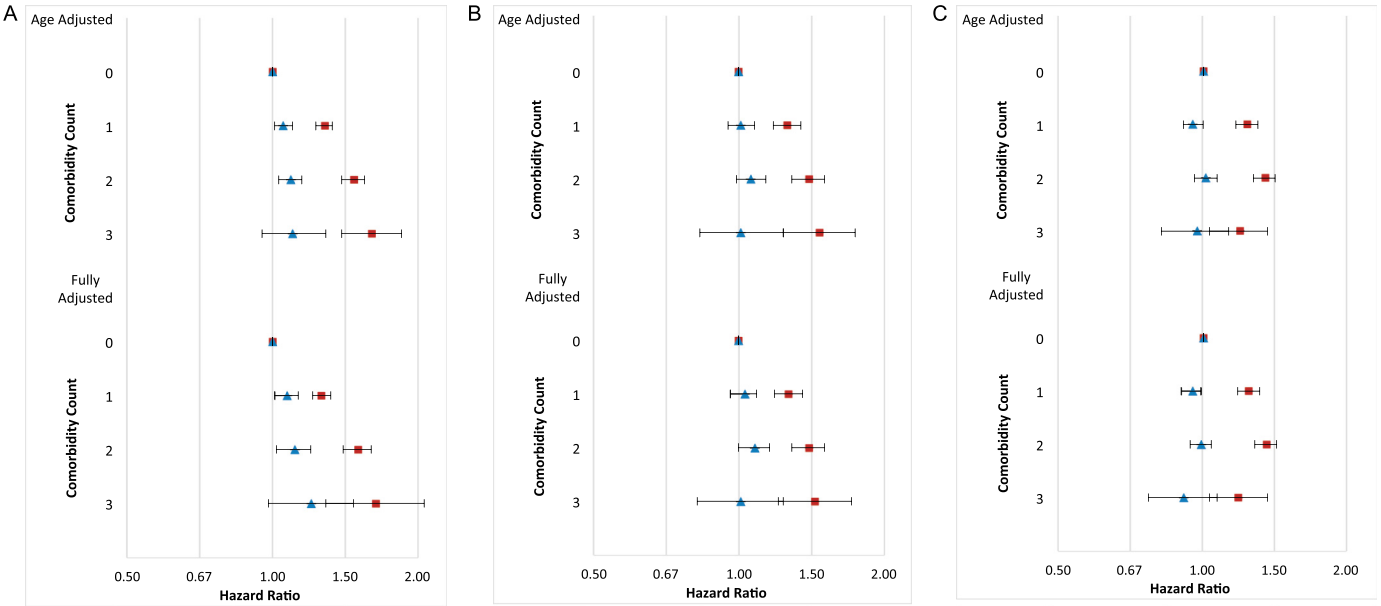
Figure 1. Association between cardiac co-morbidity count and cause-specific readmission. Age-adjusted and fully-adjusted relative risk ratios of cardiac co-morbidity counts (0 to 3) for cardiovascular readmission (red square) and noncardiovascular readmissions (blue triangle) compared to no readmission (referent). Table shows unweighted N.

The Wald test revealed statistically significant interactions with age ($p < 0.001$) and co-morbidity burden

Table 2
Age-adjusted association between individual cardiac comorbidities and 30-day cause-specific readmissions (reference: no readmission)

Univariate associations		Overall (95% confidence interval)
Coronary Artery Disease	CV-Readmission	1.25 (1.22-1.28)
	Non-CV Readmission	1.07 (1.04-1.09)
Atrial Arrhythmia	CV-Readmission	1.13 (1.10-1.16)
	Non-CV Readmission	1.06 (1.03-1.09)
Ventricular Arrhythmia	CV-Readmission	1.12 (1.06-1.18)
	Non-CV Readmission	0.87 (0.81-0.93)

CV = cardiovascular.



Count	Total N	Non-CV	CV
0	50,821	4,372	6,176
1	47,701	4,292	6,869
2	13,476	1,216	2,225
3	1,105	105	192

Count	Total N	Non-CV	CV
0	20,220	1,973	1,980
1	39,700	3,816	4,826
2	19,525	1,964	2,612
3	1,371	131	182

Count	Total N	Non-CV	CV
0	36,249	3,226	3,045
1	91,248	7,683	9,207
2	55,869	5,027	6,099
3	2,790	252	295

Figure 2. Association between cardiac co-morbidity counts for cause-specific readmission stratified by age. Age-adjusted and fully-adjusted relative risk ratios for cardiovascular readmission readmission (red square) and noncardiovascular readmissions (blue triangle) compared to no readmission (referent) among adults aged <65 years (A), aged 65 to 74 years (B), and aged ≥75 years (C). Tables show unweighted N.

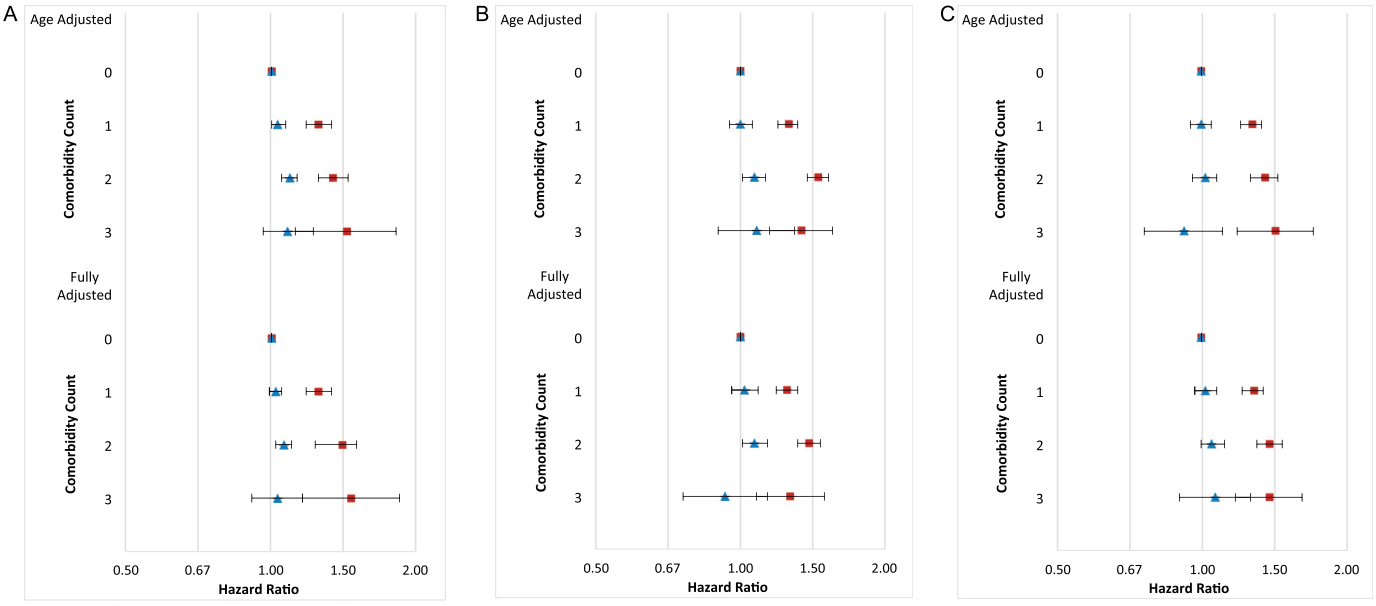
($p = 0.01$). We accordingly repeated the primary analyses stratified by age, and stratified by co-morbidity burden (Elixhauser co-morbidity index tertiles). As shown in Figure 2, the fully adjusted relative risk of CV-readmission for patients <65 years and those aged 65 to 74 years increased in a graded fashion with increasing cardiac co-morbidity count. Meanwhile, for those aged ≥75 years, the relative risk of CV-readmission peaked at a cardiac co-morbidity count of 2, and then showed a slight decrease (albeit with wider confidence intervals related to a small number of events). When stratified by Elixhauser weighted index tertiles, we found that the fully-adjusted relative risk of CV-readmission were similar across all 3 tertiles (Figure 3). Across all 3 tertiles, there was no significant trend or association between cardiac co-morbidity count and non-CV readmission.

We also conducted a sensitivity analysis excluding those who experienced cardiogenic shock during their index hospitalization, which revealed similar findings as the main results (Figure S5).

Discussion

In this nationally representative study of adults hospitalized with HF, we found that a simple cardiac co-morbidity count comprised of CAD, atrial arrhythmia, and ventricular arrhythmia was independently associated with CV readmissions. In particular, having at least 2 of these conditions increased the risk for a CV-readmission by 40%. This finding has important implications as it could lead to better interventions for readmission prevention in the future, which have been largely ineffective to date.[1,23] Accordingly, although the observed absolute differences were small, the potential impact on the 7 million people with HF across the United States and the costs associated with readmission are likely to be substantial. For example, even a 1% decrease in 30-day readmission rate would save millions of dollars. To our knowledge, this is the first study to identify patients at risk for cause-specific readmission following a HF hospitalization. Previous studies have developed calculators to identify individuals at highest risk for readmission[12–14]; but none to our knowledge have specifically attempted to risk stratify based on the specific cause for readmission. This is important because strategies designed to prevent a CV-related readmission are likely to differ from strategies designed to prevent a non-CV readmission. Accordingly, our simple count has the potential to provide clinicians a tool for risk stratification that can aid in implementing readmission-reducing strategies. HF readmission risk scores are often complex, requiring a computer for calculation. For example, the Yale Center for Outcome Research and Evaluation HF readmission score includes 20 variables and incorporates a weighting scheme.[24] We constructed a count that includes a parsimonious number (3) of easily-identifiable cardiac comorbid conditions that can be determined at the bedside by the clinical team or through cursory review of the medical chart by nonclinicians that may be part of a disease management team, making it broadly useful.

Our simple cardiac co-morbidity score could have utility in devising targeted postdischarge ambulatory plans. We did not have data on healthcare utilization patterns



Count	Total N	Non-CV	CV
0	37,796	2,215	3,407
1	58,942	3,657	5,913
2	26,576	1,812	2,907
3	1,384	99	154

Count	Total N	Non-CV	CV
0	34,575	3,009	3,607
1	60,184	5,232	7,082
2	31,069	2,798	3,780
3	1,817	143	220

Count	Total N	Non-CV	CV
0	34,919	4,347	4,187
1	59,523	6,902	7,907
2	31,225	3,597	4,249
3	2,065	246	295

Figure 3. Association between cardiac co-morbidity counts for cause-specific readmission stratified by Elixhauser co-morbidity weighted index. Age-adjusted and fully-adjusted relative risk ratios for cardiovascular readmission readmission (red square) and noncardiovascular readmissions (blue triangle) compared to no readmission (referent) among adults with Elixhauser weighted index <13 (A), 14 to 27 (B), and ≥28 (C). Tables show unweighted N.

posthospitalization. However, based on our observations, it may be reasonable to test whether this score can assist with triaging patients to different postdischarge follow-up strategies. For example, individuals with a high cardiac co-morbidity score are at highest risk for a CV-specific readmission, and thus may benefit from seeing a cardiologist early during the postdischarge period; whereas those with a cardiac co-morbidity score of 0 (over a quarter of this cohort) may be optimally managed by seeing a primary care physician in the early postdischarge period. While early postdischarge follow-up is important following a hospitalization for HF,[25] it remains unknown as to which specialty is best suited to see the patient during the early postdischarge period. This issue is complicated by challenges with appointment availability of subspecialty services like cardiology, for which shortages have been described.[26] Accordingly, a tool that could help triage patients based on risk of a CV-readmission warrants prospective investigation.

One might expect that advanced age or high co-morbidity burden would attenuate associations between a cardiac co-morbidity count and a CV-readmission. Importantly, we found that the simple count was effective for both younger and older adults, and in those with lower and higher co-morbidity burden. This observation suggests that our simple strategy is applicable to a broad population, supporting its potential use for population management.

Major strengths of this study are that we examined a geographically-diverse nationally-representative all-payer cohort in the United States. There are also several limitations. The NRD does not track mortality, which is a competing risk for readmission. While mortality rates in the 30-day postdischarge period are not substantial (7% in a Medicare population), this still could have influenced our findings, especially in older individuals where we observed a dip in relative risk at a cardiac co-morbidity score of 3 in those aged 75 years and older. We also did not have information on the type of follow-up care that patients received after discharge. Although most postdischarge strategies to date have failed to reduce readmissions in a consistent way,[23] it is possible that strategies, which may have differed according to various clinical characteristics including acuity of illness and co-morbidity burden, could have had differential effects on cause-specific readmission patterns. The influence of follow-up strategies on cause-specific readmission patterns is unknown, and represents an important area that warrants further investigation. Another limitation is that diagnoses were based on ICD-9 codes, similar to any other administrative database. Despite its shortcomings, examining administrative databases has become a widely accepted method for assessing patterns of readmission in HF.[1,9] Although we examined the association between a simple co-morbidity count and cause-specific readmission in a broadly generalizable cohort, prospectively examining the utility of this count as a prediction tool in other cohorts with a focus on examining receiver operating characteristics will be necessary before implementation.

In conclusion, we found that a simple cardiac co-morbidity count was independently associated with CV but not with non-CV readmissions. Accordingly, a simple cardiac co-morbidity count could provide a convenient bedside tool to aid clinicians and disease management teams in

identifying patients who may benefit from more aggressive CV-specific follow-up.

Author Contribution

Aayush Visaria: Methodology, Software, Formal Analysis, Data Curation, Writing − Original Draft; Lauren Balkan: Investigation, Writing − Review & Editing, Visualization; Laura Pinheiro: Conceptualization, Investigation, Writing − Review & Editing; Joanna Bryan: Methodology, Visualization; Samprit Banerjee: Methodology, Software, Formal Analysis, Validation; Madeline Sterling: Conceptualization, Writing- Reviewing and Editing; Uday Krishnan: Conceptualization, Writing- Reviewing and Editing; Evelyn Horn: Conceptualization, Writing- Reviewing and Editing; Monika Safford: Conceptualization, Writing-Reviewing and Editing, Validation; Parag Goyal: Conceptualization, Methodology, Data Curation, Investigation, Writing − Original Draft, Supervision

Disclosures

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Supplementary materials

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