Heart Failure Reviews (2021) 26:57–64
https://doi.org/10.1007/s10741-019-09912-z

Readmission-free period and in-hospital mortality at the time of first readmission in acute heart failure patients—NRD-based analysis of 40,000 heart failure readmissions

Ahmed M Altibi[1,2] · George Prousi[3] · Manyoo Agarwal[4] · Mahek Shah[3] · Byomesh Tripathi[5] · Pradhum Ram[6] · Brijesh Patel[7]

Published online: 2 January 2020

Abstract

The 30-day readmission rates, predictors, and outcomes for acute heart failure (AHF) patients are well published, but data beyond 30 days and the association between readmission-free period (RFP) and in-hospital readmission-related mortality remain unknown. We queried the National Readmission Database to analyze comparative outcomes of AHF. Patients were divided into three groups based on their RFP: group 1 (1–30 days), group 2 (31–90 days), and group 3 (91–275 days). AHF cases and clinical variables were identified using ICD-9 codes. The primary outcome was in-hospital mortality at the time of readmission. A total of 39,237 unplanned readmissions occurred within 275 days; 15,181 within group 1, 11,925 within group 2, and 12,131 within group 3. In-hospital mortality in groups 1, 2, and 3 were 7.4%, 5.1%, and 4.1% ($p < 0.001$). Group 1 had higher percentages of patients with cardiogenic shock (1.3% vs. 0.9% vs. 0.9%; $p < 0.001$), acute kidney injury (30.2% vs. 25.9% vs. 24.0%; $p < 0.001$), dialysis use (8.6% vs. 7.5% vs. 6.9%; $p < 0.001$), and non-ST elevation myocardial infarction (4.4% vs. 3.8% vs. 3.6%; $p < 0.001$), but there was no statistical difference among the three groups for ST-elevation myocardial infarction, percutaneous coronary intervention (PCI), or ventricular assist device use at the time of index admission. However, group 3 had higher PCI (1.7%) compared with groups 1 and 2 ($p < 0.001$). In multivariable logistic regression, groups 2 and 3 had odd ratio of 0.70 and 0.55, respectively, for in-hospital mortality compared with group 1. Longer RFP is associated with decreased risk of in-hospital mortality at the time of first readmission.

Keywords Acute heart failure (AHF) · Congestive heart failure (CHF) · Readmission · Mortality · In-hospital mortality

Introduction

Hospital readmissions and their accompanying costs are a significant area of focus for policymakers in the effort to decrease a steadily increasing rate of incidence. Readmissions have historically been associated with poor health outcomes and higher rates of mortality and account for an estimated cost of $17 billion of the $3.3 trillion US health care expenditure in 2016 [1]. To decrease unforeseen hospital readmissions, in 2010, US health reform identified this financially crippling occurrence as a key area for healthcare savings and enacted the Hospital Readmissions Reduction Program (HRRP). In 2012, hospitals began to be penalized for an excess of 30-day readmission rates with heart failure (HF) being one of the most targeted disease states [2]. With an aim on decreasing readmission rates, clinicians and researchers alike have begun to evaluate the potential consequences of emphasizing re-admission reductions in a population associated with significant disease progression [3].

In the USA, heart failure affects approximately 6 million adults and is projected to rise to 8 million by 2030 with associated costs nearing $55 billion [4]. Furthermore, as hospitalizations for heart failure beyond a sentinel event continue to increase, survival is inversely correlated and significantly

✉ Brijesh Patel
Brijesh.patel@wvumedicine.org

1 Harvard T.H. Chan School of Public Health, Harvard University, Boston, MA, USA
2 Henry Ford Allegiance Health, Jackson, MI, USA
3 Lehigh Valley Health Network, Allentown, PA, USA
4 University of Tennessee Health Science Center, Memphis, TN, USA
5 University of Arizona, Banner University Medical Center, Tucson, AZ, USA
6 Albert Einstein Medical Center, Philadelphia, PA, USA
7 Heart and Vascular Institute, West Virginia University, 1 Medical Center Dr., Morgantown, WV 26505, USA

drops with each rehospitalization episode [5]. Although a nationwide emphasis has been placed on reducing readmission rates for acute heart failure (AHF) exacerbations, data suggests that despite these efforts, 30-day mortality and morbidity continue to rise [3].

To date, despite a focus on 30-day readmissions for heart failure, data on days beyond that cutoff and how time between admissions could potentially provide insight into a patient's state of disease remain unknown. Equipped with data to suggest that readmissions within 30 days of initial discharge are unfavorable, assumptions can be made regarding the length between admissions and their correlation with stability. For this reason, a more thorough evaluation of readmissions beyond 30 days is essential in determining disease severity and its progression. We aimed to analyze HF morbidity and mortality among patients admitted within these time frames in hopes of expanding on literature pertaining to current metrics used for rewarding or penalizing hospitals regarding readmission rates. Furthermore, our study wishes to provide insight into how readmissions as they relate to sentinel events can provide insight into the severity of one's disease by analyzing intervals between exacerbations requiring hospitalization.

We aimed to analyze HF morbidity and mortality through evaluation of readmissions beyond the 30-day frame in hopes of expanding on literature pertaining to current metrics used for rewarding or penalizing hospitals regarding readmission rates.

Methods

National Readmission Database

We conducted our study using the National Readmission Database (NRD) 2014. The database contains nearly 49.3% of in-hospital admissions/readmissions with de-identified patient data from across the USA [6]. The database provides International Classification of Diseases, 9th revision (ICD-9) for diagnoses and procedure codes, as well as patient demographics and hospital-related information. The NRD also includes meaningful clusters of similar conditions called the Clinical Classifications Software (CCS) for diagnoses and procedures and Elixhauser comorbidities and reliably tracks patients for readmissions. However, the database only contains discharge information from January 2014–December 2014; hence, longitudinal follow-up beyond this period is not provided. To maintain patient confidentiality, NRD provides numerical values instead of dates. The method of calculating time between admissions has been published previously [7].

Patient selection

The objective of the study is to assess the outcomes at the time of first readmission of patients who presented with AHF as a principle diagnosis at the time of index admission and its relationship to time between the two admissions. Our predefined follow-up period was 9 months (275 days). Thus, we included patients who had an Index AHF admission between January 1, 2014 and March 31, 2014. Since follow-up beyond December 31, 2014 is not possible, we decided to exclude index admissions after March 31, 2014 so that there is enough time to follow patients for 275 days.

We included patients who had at least one readmission with AHF within 9 months, but only first readmissions and respective index admissions were included in the final analysis. We did not include index admissions that did not result in readmissions or patients that died during an index admission. Patients with missing length of stay, age < 18 years, same-day readmissions, and elective (planned) readmissions and those who were transferred out were excluded from the study. We used the same ICD-9 codes (shown in Table 1) for "acute heart failure" to identify index AHF admissions and readmissions. Table 1 provides all ICD-9 and CCS codes that were used to identify clinical variables in the study.

Variables

We analyzed several variables at the time of first readmission as potential predictors for in-hospital mortality. The analyzed data include patient demographics (age and gender), clinical variables (acute kidney injury, cardiogenic shock, chronic pulmonary diseases, dialysis use, non-ST and ST elevation myocardial infarctions, percutaneous coronary intervention, and ventricular assist device use), presence of implanted devices (single-chamber pacemaker, dual-chamber pacemaker, implantable cardioverter defibrillator, biventricular pacemaker with and without defibrillator), hospital characteristics (bed size and teaching status of hospitals), median household income quartiles, primary insurance payer, and readmission-free days (group 1, 1–30; group 2, 31–90; and group 3, 91–275).

Outcomes

We were primarily interested in assessing the relationship between readmission-free period (RFP) between an index admission and readmission, in addition to in-patient mortality at the time of first readmission. We hypothesized that the patients with shorter RFP are more likely to be more ill and have worse outcomes. Secondary outcomes were to assess length of stay of the readmissions.

Statistical analysis

The data was analyzed with SPSS version 23 (IBM, NewYork). The continuous variables were analyzed using Kruskill-Wallis test and reported as median and interquartile range (IQR). The categorical variables were analyzed using

Table 1 International Classifications of Diseases, 9th revision codes

Variables	Codes
Acute heart failure	428.21, 428.23, 428.31, 428.33, 428.41, and 428.43
Acute kidney injury	584.5-584.9
Cardiogenic shock	785.51
Chronic pulmonary disease	Elixhauser comorbidity provided in the database
Dialysis	39.95, 54.98
Non-ST elevation myocardial infarction	410.7, 410.71, 410.71, 410.72, and 411.1
Percutaneous coronary intervention	00.66, 17.55, 36.01, 36.02, 36.05, 36.06, and 36.07
ST elevation myocardial infarction	410.X1 (410.01-410.91)
Ventricular assist device	37.52, 37.60, 37.62, 37.65, 37.66, 37.68, 39.65
Single-chamber pacemaker	37.80-37.82
Dual-chamber pacemaker	37.83
Implantable cardioverter defibrillator	37.94
Biventricular pacemaker without defibrillator	00.50
Biventricular pacemaker with defibrillator	00.51

chi square test and reported in percentages. A p value < 0.05 was considered statistically significant for any compared variables. The final cohort was analyzed into three groups based on RFP, group 1, 1–30 days; group 2, 31–90 days; and group 3, 91–275 days. We also created multivariate, hierarchical logistic regression model which nested patient level data into the hospital-related variable to identify independent predictors of in-hospital mortality at the time of first readmission. The values for the predictive variables included in the logistic regression model are those recorded at the time of first readmission, rather than the index admission.

Results

NRD provides 14,894,913 unweighted cases to analyze, out of which 75,410 cases of acute heart failure (AHF) as primary a diagnosis were identified after applying exclusion criteria. An additional 2910 (2.9%) patients were excluded due to in-hospital mortality during their initial hospitalization. Only 39,248 patients were included in the final analysis as remaining index admissions (33,252 or 44.1%) did not result in at least one readmission during April 1, 2014 to December 31, 2018. The cases were then divided into three groups: group 1, 15,181 patients; group 2, 11,925 patients; and group 3, 12,131 patients.

Readmission cohort

For groups 1, 2, and 3, the median age in years (IQR) were 74 (63–84), 75 (63–84), and 75 (63–85), respectively ($p < 0.001$). About 47.7%, 49.2%, and 48.7% of patients were females in groups 1, 2, and 3 respectively. Group 1 had more patients with cardiogenic shock (2.4%), acute kidney injury (35.8%), need for dialysis (8.6%), and more ventricular assist device use (0.4%) than the other two groups. p values were less than 0.001 for each variable. Percutaneous coronary intervention was significantly higher performed in the group 1 (Table 2), $p = 0.009$. There was no significant difference among groups for ST elevation and non-ST elevation myocardial infarction. Also, there was no statistical difference among groups for the presence of implanted devices (e.g., chamber pacemaker, biventricular pacemaker, or implantable defibrillators) at index readmission (Table 4). Admitting hospital size and teaching status, primary insurance payers, and median household income by quartiles were not significantly different among three groups (Table 2).

Index admission cohort

When we assessed the baseline characteristics of readmitted patients, those who were admitted within 30 days have significantly higher proportions of cardiogenic shock (1.3%), chronic pulmonary disease (41.7%), dialysis use (6.5%), acute kidney injury (30.2%), and non-ST elevation myocardial infarction (4.4%) at the time of index admission compared with the other two groups (Table 3). Percutaneous coronary interventions, ventricular assist device use, or ST elevation myocardial infarction were not significantly different among three groups.

Outcomes

The primary outcome of in-hospital mortality upon readmission was higher in patients (7.4% in group 1 vs. 5.1% in group 2 vs. 4.1% in group 3) who were admitted within 30 days. Additionally, the group 1 cohort had significantly higher median length of stay of 5 days (IQR: 3–8), then 4 days (IQR: 3–7) in Group 2, and 4 days (IQR2–6) in group 3; $p < 0.001$

Table 2 Clinical variables at the time of first readmission

Variables	Readmission-free period 1–30 $n = 15{,}181$ %	31–90 $n = 11{,}925$ %	≥ 91 $n = 12{,}131$ %	p value
Age	74 (63–84)	75 (63–84)	75 (63–85)	< 0.001
Female	47.7	49.2	48.7	0.05
Acute kidney injury	35.8	30.8	31.7	< 0.001
Cardiogenic shock	2.4	1.8	1.5	< 0.001
Chronic pulmonary disease	38.1	36.3	34.6	< 0.001
Dialysis	8.6	7.5	6.9	< 0.001
Non-ST elevation myocardial infarction	5.9	5.6	6.3	0.06
Percutaneous coronary intervention	1.3	1.2	1.7	0.009
ST elevation myocardial infarction	0.5	0.5	0.6	0.94
Ventricular assist device	0.4	0.3	0.1	< 0.001
Bed size of hospital				
Small	12.6	12.9	13.2	0.24
Medium	29.4	28.9	29.4	
Large	58.0	58.2	57.4	
Median household income quartile				
$ 1–39,999	32.6	32.7	31.6	0.23
$ 40,000–50,999	26.5	26.1	27.0	
$ 51,000–65,999	21.7	22.1	21.9	
$ 66,000 or more	19.2	19.1	19.5	
Primary payer				
Medicare	76.6	76.8	76.8	0.83
Medicaid	11.3	11.3	10.0	
Private insurance	8.2	8.0	9.3	
Self-pay	1.8	2.0	2.0	
No charge	0.2	0.3	0.3	
Other	2.0	1.8	1.6	
Teaching status of urban hospitals				
Metropolitan non-teaching	30.5	30.9	31.2	0.83
Metropolitan teaching	63.4	61.8	61.8	
Non-metropolitan	6.1	7.3	6.9	
Outcomes				
Died during hospitalization	7.4	5.1	4.1	< 0.001
Length of stay	5 (3–8)	4 (3–7)	4 (2–6)	< 0.001

(Table 2). In-hospital mortality was higher in the shorter readmission-free period and eventually decreased disproportionately as readmission-free period increased. Nearly 50% of all in-hospital mortality occurred during the first 30 days (Fig. 1).

Predictors of in-hospital mortality

The multivariable analysis showed that cardiogenic shock (OR 8.47; 95% CI7.02–10.2; $p < 0.001$) was the most significant predictor of mortality. ST elevation myocardial infarction (OR 7.69; 95% CI 5.30–11.0; $p < 0.001$), age > 75 years (OR 2.12; 95% CI 1.90–2.37; $p < 0.001$), acute kidney injury (OR 2.21; 95% CI 2.01–2.42; $p < 0.001$), and dialysis use (OR 1.91; 95% CI 1.64–2.21; $p < 0.001$) were among predictors of in-hospital mortality. Percutaneous coronary intervention (OR 0.28; 95% CI 0.17–0.45; $p < 0.001$) was a negative predictor of mortality. Ventricular assist device use (OR 1.43; 95% CI 0.79–2.57; $p = 0.24$) and device implanted at index admission (Table 4) were not predictors of in-hospital mortality.

The most common insurance categories (Medicare, Medicaid, or private insurances) and teaching status of hospitals were not predictors of in-hospital mortality. The

Table 3 Clinical, procedure and hospital-related variables at the time of index admission

Variables	Readmission-free days 1–30 $n = 15,181$ %	31–90 $n = 11,925$ %	≥ 91 $n = 12,131$ %	p value
Acute kidney injury	30.2	25.9	24.0	< 0.001
Cardiogenic shock	1.3	0.9	0.9	0.002
Dialysis	6.5	5.9	5.4	0.001
Non-ST elevation myocardial infarction	4.4	3.8	3.6	0.001
Percutaneous coronary intervention	1.0	0.8	1.0	0.34
ST elevation myocardial infarction	0.2	0.2	0.2	0.96
Ventricular assist device	0.3	0.3	0.3	0.48
Bed size of hospital				
Small	13.4	13.4	13.7	0.70
Medium	29.7	29.2	29.8	
Large	57.0	57.4	56.5	
Teaching status of urban hospitals				
Metropolitan non-teaching	31.4	31.5	31.6	0.48
Metropolitan teaching	61.7	61.1	61.4	
Non-metropolitan	6.9	7.4	7.1	
Devices implanted				
Single-chamber pacemaker	0.2	0.1	0.1	0.64
Dual-chamber pacemaker	0.2	0.3	0.2	0.90
Implantable cardioverter defibrillator	0.6	0.8	0.8	0.53
Biventricular pacemaker without defibrillator	0.1	0.1	0.1	0.94
Biventricular pacemaker with defibrillator	0.5	0.5	0.5	0.99

higher income quartile (OR 1.32; 95% CI 1.15–1.50; $p < 0.001$) was associated with increased mortality. Compared with group 1 RFP, group 2 RFP (OR 0.70; 95% CI 0.63–0.77; $p < 0.001$) and group 3 RFP (OR 0.55; 95% CI 0.49–0.62; $p < 0.001$) were significant negative predictors of mortality.

Discussion

Heart failure is a primary diagnosis responsible for more than one million hospitalizations annually in the USA, with an aggregated annual cost of more than 10 billion dollars [8]. In an analysis conducted by the Healthcare Cost and Utilization

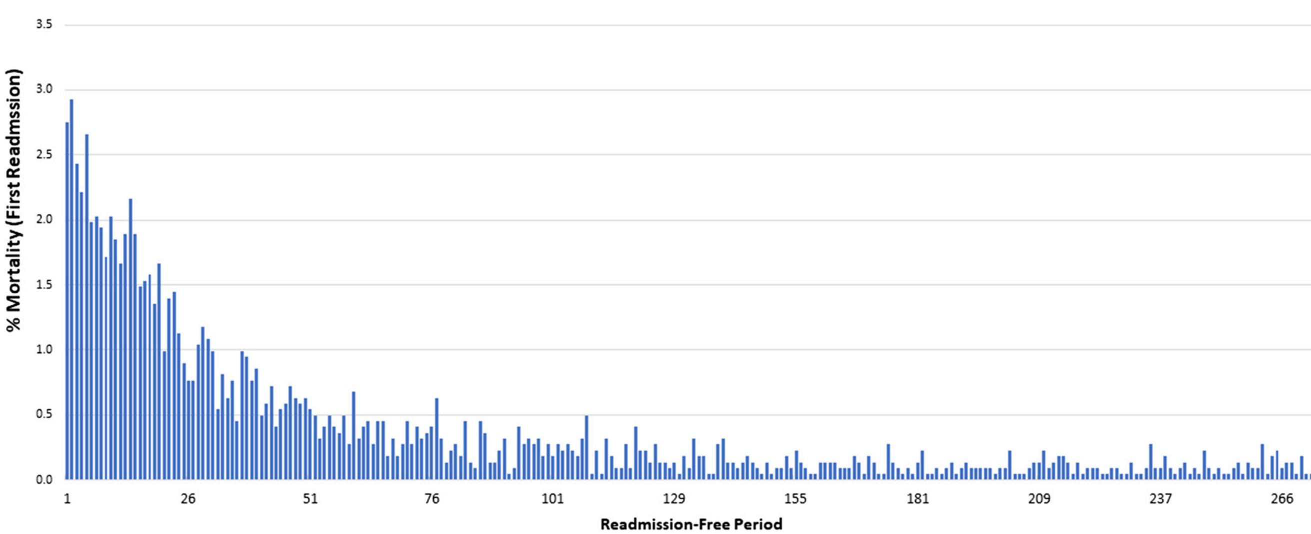

Figure 1 Mortality trends upon readmission following AHF admission and the correlation with RFP

Table 4 Predictors of in-hospital mortality at time of first readmission

Clinical variables	Odd ratio (95% CI)	*p* value
Age > 75 years	2.12 (1.90–2.37)	< 0.001
Female	0.99 (0.91–1.09)	0.93
Acute kidney injury	2.21 (2.01–2.42)	< 0.001
Cardiogenic shock	8.47 (7.02–10.2)	< 0.001
Chronic pulmonary disease	1.03 (0.93–1.13)	0.60
Dialysis	1.91 (1.64–2.21)	< 0.001
Non-ST elevation myocardial infarction	1.90 (1.63–2.22)	< 0.001
Percutaneous coronary intervention	0.28 (0.17–0.45)	< 0.001
ST elevation myocardial infarction	7.69 (5.32–11.1)	< 0.001
Ventricular assist device	1.43 (0.80–2.58)	0.23
Device implanted		
Single-chamber pacemaker	0.58 (0.16–2.06)	0.40
Dual-chamber pacemaker	0.86 (0.37–2.05)	0.74
Implantable cardioverter defibrillator	0.89 (0.52–1.53)	0.68
Biventricular pacemaker without defibrillator	1.21 (0.32–4.53)	0.78
Biventricular pacemaker with defibrillator	0.85 (0.44–1.62)	0.61
Bed size of hospital		
Small	Reference	
Medium	0.81 (0.70–0.94)	0.005
Large	0.82 (0.72–0.94)	0.004
Median household income quartile		
$ 1–39,999	Reference	
$ 40,000–50,999	1.16 (1.02–1.31)	0.02
$ 51,000–65,999	1.13 (0.99–1.29)	0.06
$ 66,000 or more	1.32 (1.15–1.50)	< 0.001
Primary payer		
Medicare	Reference	
Medicaid	0.83 (0.68–1.00)	0.06
Private insurance	1.27 (1.07–1.51)	0.008
Self-pay	0.94 (0.62–1.45)	0.79
No charge	0.67 (0.16–2.85)	0.59
Other	2.97 (2.32–3.81)	< 0.001
Teaching status of urban hospitals		
Metropolitan non-teaching	Reference	
Metropolitan teaching	0.64 (1.02–0.93-1.13)	0.64
Non-metropolitan	1.21 (1.00–1.47)	0.054
Readmission-free period		
1–30	Reference	
31–90	0.70 (0.63–0.77)	< 0.001
91 or more	0.55 (0.49–0.62)	< 0.001

Project (HCUP), heart failure was the most common cause for hospital readmission in 2011 among Medicare patients with the readmission costs alone exceeding 1.7 billion USD in that year [9]. Reducing hospital readmissions has been pinpointed as a national priority and a key area of improvement in the past decade—with many campaigns targeting > 20% reduction in the readmission rates. However, recent analyses have shown that only very few hospitals (1.4%) managed to achieve the goal of 20% reduction in readmission rates [10].

In this observational study, we aimed to describe the relationship between readmission-free period following hospitalization for AHF and the clinical outcomes upon the subsequent admission, including in-hospital mortality rate. We also investigated the factors predictive for in-hospital mortality upon readmission. Our analysis of this large nationally representative data from the USA demonstrates that a shorter RFP correlates with higher mortality rates and longer LOS upon readmission.

Based on our analysis, in-hospital mortality was significantly higher in patients readmitted within a 30-day period (7.4%) as compared with those readmitted within 31–90 days (5.1%) or those readmitted after 90 days (4.1%) from their index heart failure admission. Of note, this correlation between RFP and mortality decreases disproportionately, and nearly terminates as the RFP increases (shown in Fig. 1). For example, about 50% of mortality at the time of first readmission occurred in those who were admitted within 30 days of initial hospitalization. In our analysis, patients who had cardiogenic shock at the time of index admission were more likely to readmit within 30 days, and group 1 had higher risk of in-hospital mortality at readmission. This suggests that patients who were sicker at the time of index admission more likely experience short-term morbidity and mortality. The probable reason for lesser in-hospital mortality in groups 2 and 3 is likely due to presence of lesser comorbidities and severity at the time of index admissions. Patients who were readmitted within 30 days of the initial hospitalization had higher prevalence for several comorbidities—compared with those readmitted after 30 days. Specifically, group 1 had a statistically significantly higher percentage of patients with cardiogenic shock, dialysis use, chronic pulmonary disease, acute kidney injury, and ventricular assist devices. This partially explains the higher mortality in the 30-day group knowing the fatality of many of these conditions. For example, cardiogenic shock is a highly morbid condition with a fatality rate approaching 50% in the literature [11–13]. Shorter RFP entails that patients had less chance to be evaluated outpatient and further optimization. Prompt outpatient follow-up within 14 days has been shown to improve mortality and emergency room visits [14]. Groups 2 and 3 might have had opportunity to be further medically optimized on outpatient basis than group 1, which could be an important reason for our findings.

Additionally, our analysis demonstrates that a shorter RFP correlates with a longer LOS upon readmission—and hence a higher cost of care. Specifically, the difference in LOS was significant upon comparing patients readmitted within 30 days (median LOS of 5 days) with readmissions after 30 days (median LOS of 4 days). Again, such a difference is anticipated in lieu of the higher prevalence of comorbid conditions in the 30-day readmission group. This also goes along with the analysis by Sud and colleagues that demonstrated that greater noncardiac morbidity burden increased the odds for LOS in hospitalized patients with AHF [15]. LOS is directly proportional to the costs of care during hospitalization, and hence, hospitals and healthcare providers are always incentivized to reduce the LOS. In a recent study by Samsky and colleagues evaluating the trends in LOS between 2005 and 2015, the LOS for AHF hospitalizations remained stable for a decade in US hospitals (mean of 4.9 days) despite the decline in the 30-day all-cause readmissions during the same interval [16]. This clearly tells that the efforts invested in reducing readmission rates did not necessarily translate into a reduction in the LOS among heart failure patients in the USA.

Data from the American Heart Association (AHA) Heart Failure registry between 2009 and 2012 reported a 30-day all-cause readmission rates of 20.0% and 19.0% in 2009 and 2012, respectively [10]. Nonetheless, these readmission rates are noticeably lower than the rates published by the Heart Failure Network (HFN) trials (30-day readmission rate 26%) [17] and the analysis of national Medicare data from US hospitals between 2006 and 2008 (30-day readmission rate of 27%) [18]. Reviewing the trends from these statistics leaves us with the impression that there has been slight but steady decrease in the 30-day all-cause readmission rates over the past decade in patients with heart failure. Despite these "little gains" towards reducing all-cause readmission rates in heart failure patients, only very few hospitals have achieved the preset goal of 20% reduction [10]. Since HRRP has been implemented, the 30-day readmission rate has declined, but there was an increase in mortality among heart failure patients [3]. Whether HRRP delivers the intended outcomes is subject of ongoing debate.

To our knowledge, this is the first study that analyzed national sample with intermediate term followed to assess the link between RFP and in-hospital mortality at the time of first readmission. There are many unmeasured variables such as medication compliance, prompt and routine hospital follow-ups after index admission, and availability of resources. From our data, we believe that acuity of illness and the presence of other cardiovascular co-morbidities at the time of index admission are likely to predict early readmission and portents poorer prognosis.

Our study has several important limitations. First, when re-evaluating criteria for penalizing criteria for readmission these findings should be taken into consideration. One of the drawbacks of the database is that it may not capture patients who returned to hospitals (i.e., emergency rooms or short-stay units) but were not admitted to the hospital. The study is based on retrospective analysis of the NRD administrative data—which can only draw associative rather than causative relationship. Second, ICD-9 coding system was utilized to identify heart failure patients and the variables of interest. Usage of ICD-9 codes in the setting of administrative data analysis is prone to inaccurate coding and behavioral errors. Nevertheless, in the case of heart failure, the validity of ICD-9 codes was previously evaluated in the literature [19]. Further, we utilized data with a short time period (i.e., 2014 only) to minimize the impact of coding behavior. Moreover, the NRD does not include data on patients who were hospitalized at a different state; hence, some of the readmissions might have been uncaptured by NRD, resulting into underreporting. Nonetheless, the relatively short follow-up duration in our analysis should help minimizing the impact of this factor. Another inherent limitation to NRD, and other administrative database, is the lack of depth in clinical details (i.e., vital signs, laboratory data, outpatient care, etc.). Importantly, the NRD does not provide sufficient data on the duration or severity of heart failure (e.g., ejection fraction and the NYHA class) at the time of admission or readmission. Also, it is not feasible using the NRD to distinguish between "de novo" heart failure and end-stage heart failure patients using the NRD; those are two very contrasting subcategories with variable readmission and mortality rates. This might raise concern on the generalizability of our conclusions onto certain subset of AHF patient with an advance disease. Similarly, the NRD fails to capture the impact of atrial fibrillation on AHF readmissions as the ICD-9 codes do not distinguish between paroxysmal, persistent, or permanent atrial fibrillation. Hence, we opted not to include atrial fibrillation in our regression model as a predictor for mortality, as this might provide distorted conclusions. Therefore, only a limited number of variables and their impacts on the outcome of interest could be assessed.

Conclusion

In conclusion, the length between index heart failure admission and the first readmission inversely correlates with in-hospital mortality and LOS upon readmission. About 50% of mortality at the time of first readmission occurred in those who were admitted within 30 days. Readmission-free period might be utilized as a marker to identify the subset of heart failure patients at higher mortality risk upon readmission. Developing cardiogenic shock was the single most predictive factor for in-hospital mortality upon readmission.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Jencks SF, Williams MV, Coleman EA (2009) Rehospitalizations among patients in the medicare fee-for-service program. N Engl J Med. https://doi.org/10.1056/NEJMsa0803563
2. Zuckerman RB, Sheingold SH, Orav EJ et al (2016) Readmissions, observation, and the hospital readmissions reduction program. N Engl J Med. https://doi.org/10.1056/NEJMsa1513024
3. Gupta A, Allen LA, Bhatt DL et al (2018) Association of the hospital readmissions reduction program implementation with readmission and mortality outcomes in heart failure. JAMA Cardiol. https://doi.org/10.1001/jamacardio.2017.4265
4. Heidenreich PA, Albert NM, Allen LA et al (2013) Forecasting the impact of heart failure in the United States a policy statement from the american heart association. Circ Heart Fail. https://doi.org/10.1161/HHF.0b013e318291329a
5. Setoguchi S, Stevenson LW, Schneeweiss S (2007) Repeated hospitalizations predict mortality in the community population with heart failure. Am Heart J. https://doi.org/10.1016/j.ahj.2007.01.041
6. Healthcare Cost and Utilization Project (HCUP) (2014) HCUP National Readmissions Database (NRD). In: Agency Healthc. Res. Qual. Rockville, MD. www.hcup-us.ahrq.gov/nrdoverview.jsp. Accessed 15 Jun 2019
7. Patel B, Prousi G, Shah M et al (2018) Thirty-day readmission rate in acute heart failure patients discharged against medical advice in a matched cohort study. Mayo Clin Proc. https://doi.org/10.1016/j.mayocp.2018.04.023
8. Blecker S, Paul M, Taksler G et al (2013) Heart failure-associated hospitalizations in the United States. J Am Coll Cardiol. https://doi.org/10.1016/j.jacc.2012.12.038
9. Hines AL, Barrett ML, Jiang HJ, Steiner CA (2014) Conditions with the largest number of adult hospital readmissions by payer, 2011
10. Bergethon KE, Ju C, DeVore AD et al (2016) Trends in 30-day readmission rates for patients hospitalized with heart failure: findings from the get with the guidelines-heart failure registry. Circ Heart Fail. https://doi.org/10.1161/CIRCHEARTFAILURE.115.002594
11. Shaefi S, O'Gara B, Kociol RD et al (2015) Effect of cardiogenic shock hospital volume on mortality in patients with cardiogenic shock. J Am Heart Assoc. https://doi.org/10.1161/JAHA.114.001462
12. Shah P, Cowger JA (2014) Cardiogenic shock. Crit Care Clin
13. Yandrapalli S, Sanaani A, Harikrishnan P et al (2019) Cardiogenic shock during heart failure hospitalizations: age-, sex-, and race-stratified trends in incidence and outcomes. Am Heart J. https://doi.org/10.1016/j.ahj.2019.03.015
14. McAlister FA, Youngson E, Kaul P, Ezekowitz JA (2016) Early follow-up after a heart failure exacerbation: the importance of continuity. Circ Heart Fail. https://doi.org/10.1161/CIRCHEARTFAILURE.116.003194
15. Sud M, Yu B, Wijeysundera HC et al (2017) Associations between short or long length of stay and 30-day readmission and mortality in hospitalized patients with heart failure. JACC Hear Fail. https://doi.org/10.1016/j.jchf.2017.03.012
16. Samsky MD, Ambrosy AP, Youngson E et al (2019) Trends in readmissions and length of stay for patients hospitalized with heart failure in Canada and the United States. JAMA Cardiol. https://doi.org/10.1001/jamacardio.2019.0766
17. Vader JM, LaRue SJ, Stevens SR et al (2016) Timing and causes of readmission after acute heart failure hospitalization—insights from the heart failure network trials. J Card Fail. https://doi.org/10.1016/j.cardfail.2016.04.014
18. Joynt KE, Orav EJ, Jha AK (2011) Thirty-day readmission rates for medicare beneficiaries by race and site of care. JAMA - J Am Med Assoc. https://doi.org/10.1001/jama.2011.123
19. McCormick N, Lacaille D, Bhole V, Avina-Zubieta JA (2014) Validity of heart failure diagnoses in administrative databases: a systematic review and meta-analysis. PLoS One