Early Unplanned Readmissions After Admission to Hospital With Heart Failure

Chun Shing Kwok, MBBS, MSc, BSc[a,b,*], Petar M Seferovic, MD, PhD[c], Harriette GC Van Spall, MD[d], Toby Helliwell, MBChB, PhD[e], Lorna Clarson, MBChB, PhD[e], Claire Lawson, PhD[f], Evangelos Kontopantelis, PhD[g], Ashish Patwala, MD[b], Simon Duckett, MD[b], Erik Fung, MBChB, PhD[h], Christian D Mallen, BMBS, PhD[e], and Mamas A Mamas, BMBCh, DPhil[a,b]

Hospital readmissions remain a continued challenge in the care of patients with heart failure (HF). This study aims to examine the rates, temporal trends, predictors and causes of 30-day unplanned readmissions after admission with HF. Patients hospitalized with a primary or secondary diagnosis of HF in the U.S. Nationwide Readmission Database were included. We examined the incidence, trends, predictors and causes of unplanned all-cause readmissions at 30-days. A total of 2,635,673 and 8,342,383 patients were included in the analyses for primary and secondary diagnoses of HF, respectively. The 30-day unplanned readmission rate was 15.1% for primary HF and 14.6% for secondary HF. Predictors of readmission in primary HF included renal failure (OR 1.27 (1.25 to 1.28)), cancer (OR 1.26 (1.22 to 1.29)), receipt of circulatory support (OR 2.81 (1.64 to 4.81)) and discharge against medical advice (OR 2.29 (2.20 to 2.39)). In secondary HF, the major predictors were receipt of circulatory support (OR 1.43 (1.12 to 1.84)) and discharge against medical advice (OR 2.01 95%CI (1.95 to 2.07)). In primary HF 52.4% of patients were readmitted for a noncardiac cause while for secondary HF 73.9% were readmitted for a noncardiac cause. For secondary HF, the strongest predictor of readmission was discharge against medical advice (OR 2.06 95%CI 2.01 to 2.12, p < 0.001). Early unplanned readmissions are common among patients hospitalized with HF, and a majority of readmissions are due to causes other than HF. Our results highlight the need to better manage comorbidities in patients with HF. **(Am J Cardiol 2019;124:736−745)**

Hospital readmissions remain a continued challenge in the care of patients with heart failure (HF)[1] as approximately 1 in 5 patients are readmitted within 30-day of hospitalization.[2−5] Readmissions are considered an adverse outcome for patients which is also associated with a poor prognosis.[6] They further have important health economic implications, both from a direct costs perspective as well as through the Hospital Readmission Reduction Program in the Affordable Care Act, which financially penalizes hospitals that have higher than expected risk-standardized 30-day readmission rates for HF.[7] While previous studies have examined readmissions in HF they are limited because the data are derived from distinct healthcare providers (Medicare or Veterans Health Administration beneficiaries),[8,9] are limited to 1 year of national data or do not consider secondary diagnosis of HF.[5] In this study, we aimed to examine the rates of 30-day readmission, temporal trends in rates of 30-day readmission, predictors of 30-day readmissions, attributable causes of 30-day readmission and outcomes for both index admission and readmission among patients with primary and secondary diagnosis of HF in the Nationwide Readmission Database (NRD) in the United States.

Methods

The NRD is a nationally representative sample of all-age, all-payer discharges from US nonfederal hospitals that is produced by the Healthcare Cost and Utilization Project of the Agency for Healthcare Research and Quality.[10] Readmissions were determined using a deidentified unique patient linkage number assigned to each patient, which allows for patient tracking across hospitals within a state during a given calendar year.

Individual patients in the NRD dataset are assigned up to 25 *International Classification of Disease, Ninth Revision* (ICD-9) codes (there are 30 rather than 25 for 2014) for each hospitalization. We defined patients with primary

[a]Keele Cardiovascular Research Group, Keele University, Stoke-on-Trent, UK; [b]Royal Stoke University Hospital, Stoke-on-Trent, UK; [c]Department of Cardiology, Belgrade University Medical Centre, Belgrade, Serbia; [d]Department of Medicine, McMaster University, Hamilton, Canada; [e]Primary Care & Health Sciences, Keele University, Stoke-on-Trent, UK; [f]Leicester Real World Evidence Unit, University of Leicester, Leicester, UK; [g]Faculty of Biology, Medicine and Health, University of Manchester, Manchester, UK; and [h]Division of Cardiology and Gerald Choa Cardiac Research Centre, Department of Medicine & Therapeutics, Faculty of Medicine, The Chinese University of Hong Kong, Hong Kong, Hong Kong SAR. Manuscript received April 16, 2019; revised manuscript received and accepted May 21, 2019.

Funding: The study was supported by a grant from the Research and Development Department at the Royal Stoke Hospital. This work is conducted as a part of PhD for CSK which is supported by Biosensors International.

See page 744 for disclosure information.

*Corresponding author: Tel: +44 1782 732911; fax: +44 1782 734719.
E-mail address: shingkwok@doctors.org.uk (C.S. Kwok).

0002-9149/
https://doi.org/10.1016/j.amjcard.2019.05.053

diagnosis of HF as those having at least one of the following as their first ICD-9 code of 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, and 428.* HF as a secondary diagnosis was defined as any of the ICD-9 codes specifying HF as a diagnosis other than as a primary diagnosis for the hospital admission. We included the first admission for each patient with primary or secondary diagnosis of HF within a calendar year. Only patients who were not admitted to hospital with an admission that was classified as elective and alive at discharge were considered. Planned readmissions were excluded, which were defined as readmissions within 30 days that were classified as elective.

The primary outcome was the unplanned readmissions within 30 days of nonelective readmission for primary and secondary HF. We included patients with a diagnosis of HF between 2010 and 2014 with 30-days of follow-up. Patients admitted in December of each year were excluded because they would not have 30-days of follow-up. The cost of index hospitalization and hospital readmissions were determined by multiplying the hospital charges by the Agency for Healthcare Research and Quality's all-payer cost-to-charge ratios for each hospital.

Data on patient demographics, comorbidities, clinical variables, procedural variables, and causes of readmissions were collected as defined in Supplementary Data 1.

Statistical analysis was performed using Stata version 14.0 (StataCorp, College Station, TX). Full description of statistical methods is described in Supplementary Data 1. The sample was split into patients with HF as primary and secondary diagnoses, and their unplanned 30-day all-cause and HF readmission were determined along with descriptive statistics. Multiple logistic regressions were used to identify independent predictors of 30-day readmissions and we evaluated the proportion of 30-day unplanned readmissions for secondary diagnosis of HF according to the primary cause of admission.

Results

A total of 10,978,056 patients were included in the analysis after the exclusion criteria were applied (Supplementary Figure 1). A total of 2,635,673 patients had a primary diagnosis of HF while 8,342,383 patients had a secondary diagnosis of HF. The rate of in-hospital mortality for the total cohort was 5.8%. The 30-day unplanned readmission rate was 15.1% for primary HF and 14.6% for secondary HF. The rates of all-cause unplanned readmissions decreased over time from 15.7% to 14.4% for primary HF and from 15.0% to 14.2% for secondary HF between 2010 to 2014 (Figure 1). A similar decrease was observed for 30-day HF readmissions. The rate of death during the unplanned readmission was 6.8% and 7.7% for primary and secondary HF respectively.

The characteristics of the patients according to primary and secondary diagnosis of HF are shown in Table 1. Large absolute differences were observed for renal failure (38.4% in primary HF, 29.3% in secondary HF), pulmonary vascular disorder (0.4% in primary HF, 7.7% in secondary HF) and fluid and electrolyte disorders (29.4% in primary HF and 37.5% in secondary HF). Patients with primary HF were more likely to be discharged home (57.6% vs 47.5%) and their length of stay for index admission was shorter (5.2 vs 7.3 days). The mean cost of hospitalization for primary HF was less than that for secondary HF ($11,213 vs $17,098). The mean time to readmission was approximately 16 days for both groups and the mean readmission length of stay and direct in-hospital costs were 6.2 days and $13,488 and 6.5 days and $13,947 for primary and secondary HF, respectively.

Table 2 shows the baseline characteristics of participants according to readmission status. Compared with nonreadmitted patients, those requiring hospital readmission were more likely to have renal failure (44.9% vs 37.2% in primary HF, 34.1% vs 28.5% in secondary HF), anemia (32.6% vs

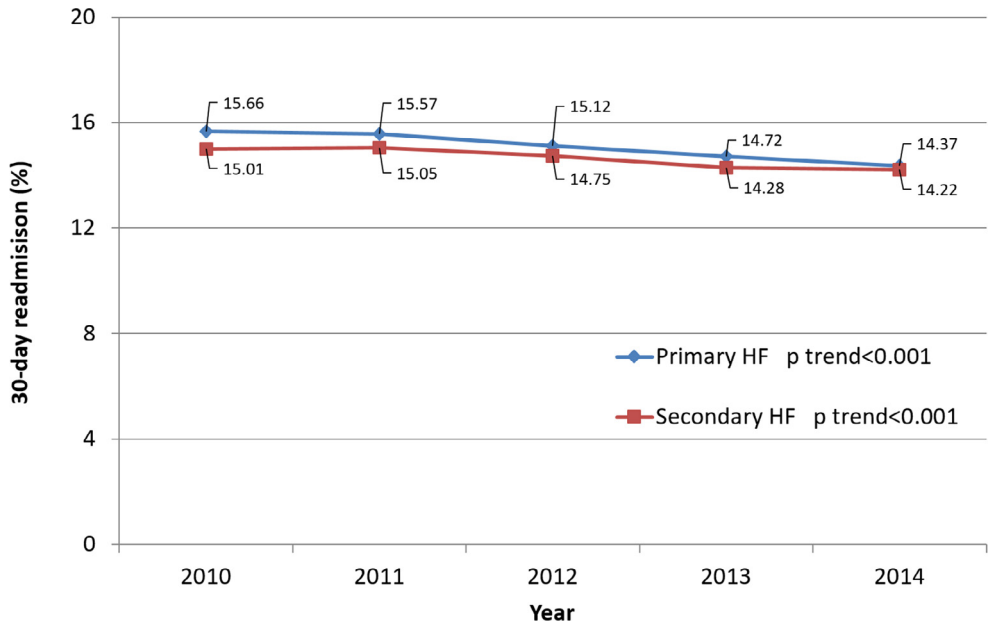

Figure 1. Trends in 30-day all-cause readmissions over time among patients hospitalized with a primary or secondary diagnosis of heart failure.

Table 1
Characteristics of participants by primary or secondary diagnosis of heart failure

Variable	Primary heart failure (n = 2,635,673)	Secondary heart failure (n = 8,342,383)	p Value
Demographics			
Age (years)	72.5 ± 14.5	73.1 ± 13.7	<0.001
Female	49.5%	52.5%	<0.001
Weekend admission	23.6%	24.3%	<0.001
Year			<0.001
2010	19.7%	18.7%	
2011	19.2%	19.1%	
2012	18.4%	18.9%	
2013	20.6%	21.0%	
2014	22.2%	22.3%	
Primary expected payer			<0.001
Medicare	73.8%	77.5%	
Medicaid	8.3%	7.6%	
Private	11.4%	10.5%	
Uninsured	3.7%	2.1%	
No charge	0.4%	0.2%	
Other	2.4%	2.1%	
Median household income (percentile)			<0.001
0-25th	31.6%	30.8%	
26-50th	25.0%	25.0%	
51-75th	23.3%	23.4%	
76-100th	20.2%	20.8%	
Cardiovascular comorbidities			
Hypertension	70.5%	71.3%	<0.001
Coronary artery disease	44.5%	44.9%	<0.001
Previous myocardial infarction	12.6%	12.1%	<0.001
Previous PCI	9.9%	9.4%	<0.001
Previous CABG	14.5%	11.4%	<0.001
Previous heart failure	1.5%	75.7%	<0.001
Atrial fibrillation	36.8%	35.8%	<0.001
Valvular heart disease	0.4%	11.8%	<0.001
Previous stroke or TIA	10.7%	13.1%	<0.001
Peripheral vascular disease	11.5%	12.5%	<0.001
Pulmonary circulatory disorder	0.4%	7.7%	<0.001
Noncardiovascular comorbidities			
Smoker	27.3%	26.6%	<0.001
Alcohol misuse	3.4%	3.5%	<0.001
Dyslipidemia	45.0%	43.7%	<0.001
Obesity	19.1%	16.8%	<0.001
Diabetes mellitus	43.1%	40.4%	<0.001
Chronic lung disease	33.9%	31.0%	<0.001
Hypothyroidism	15.9%	16.6%	<0.001
Renal failure	38.4%	29.3%	<0.001
Liver disease	2.7%	3.1%	<0.001
Fluid and electrolyte disorders	29.4%	37.5%	<0.001
Peptic ulcer disease	0.03%	0.04%	<0.001
Anemia	28.3%	27.8%	<0.001
Bleeding	0.7%	2.8%	<0.001
Cancer	3.6%	4.8%	<0.001
Depression	8.6%	11.2%	<0.001
Dementia	9.2%	13.5%	<0.001
Charlson Comorbidity Index	2.2 ± 1.7	2.9 ± 1.8	<0.001
Hospital characteristics			
Bed size			<0.001
Small	11.8%	10.8%	
Medium	26.4%	25.5%	
Large	61.9%	63.7%	
Teaching hospital	55.6%	56.7%	<0.001
Urban hospital	89.8%	90.3%	<0.001
In-hospital outcomes and treatment			
Cardiogenic shock	0.8%	1.3%	<0.001
Cardiac arrest	0.3%	0.9%	<0.001

(*continued*)

Table 1 (***Continued***)

Variable	Primary heart failure (n = 2,635,673)	Secondary heart failure (n = 8,342,383)	p Value
Ventilation	1.4%	6.8%	<0.001
Circulatory support	0.3%	0.8%	<0.001
Intra-aortic balloon pump	0.2%	0.8%	<0.001
Vasopressor	0.3%	0.6%	<0.001
Coronary angiogram	8.9%	10.6%	<0.001
Current admission PCI	1.1%	3.9%	<0.001
Current CABG	0.3%	1.7%	<0.001
Pacemaker or ICD implantation	1.5%	2.1%	<0.001
Cardiac resynchronization therapy	0.9%	0.4%	<0.001
Left ventricular assist device	0.14%	0.09%	<0.001
Heart transplant	0.08%	0.02%	<0.001
Discharge disposition			<0.001
Home	57.6%	47.5%	
Transfer to other hospital	18.2%	30.3%	
Care home	23.0%	21.3%	
Discharge against medical advice	1.2%	0.9%	
Court/law enforcement	<0.1%	<0.1%	
Length of stay (days)	5.2 ± 6.1	7.3 ± 9.0	<0.001
Cost (USD)	$11,213 ± 19,499	$17,098 ± 25,287	<0.001
Time to readmission	16.3 ± 7.6	16.6 ± 7.5	<0.001
Readmission length of stay (days)	6.2 ± 7.2	6.5 ± 7.5	<0.001
Death during readmission	6.8%	7.7%	<0.001
Cost of readmission (USD)	$13,488 ± 22,758	$13,947 ± 20,125	<0.001

CABG = coronary artery bypass graft; ICD = implantable defibrillator device; PCI = percutaneous coronary intervention; TIA = transient ischemic attack.

27.5% in primary HF, 31.8% vs 27.1% in secondary HF) and cancer (4.3% vs 3.4% for primary HF, 5.8% vs 4.7% in secondary HF). The most common primary cause for admission in secondary HF was infections (20.5%).

The independent predictors of readmissions in primary and secondary HF are shown in Table 3. For primary HF, diabetes (odds ratio (OR) 1.11 95% confidence interval (CI) 1.09 to 1.12, $p < 0.001$), coronary artery disease (OR 1.10 95%CI 1.08 to 1.11, $p < 0.001$), chronic lung disease (OR 1.16 95% CI 1.15 to 1.17, $p < 0.001$), renal failure (OR 1.27 95%CI 1.25 to 1.28, $p < 0.001$), liver failure (OR 1.21 95%CI 1.18 to 1.25, $p < 0.001$), anemia (OR 1.13 95%CI 1.12 to 1.14, $p < 0.001$) and cancer (OR 1.26 95%CI 1.22 to 1.29, $p < 0.001$) were associated with greater odds of readmission. Receipt of circulatory support was associated with greater odds of readmission (OR 2.81 95%CI 1.64 to 4.81, $p < 0.001$). Status or place of discharge were associated with greater odds of readmission as rates were high for patients transferred to other hospitals (OR 1.23 95%CI 1.21 to 1.25, $p < 0.001$), care homes (OR 1.21 95%CI 1.19 to 1.22, $p < 0.001$) and those who were discharged against medical advice (OR 2.29 95%CI 2.20 to 2.39, $p < 0.001$) compared with those were discharge home. For secondary HF, the strongest predictor of readmission was discharge against medical advice (OR 2.06 95%CI 2.01 to 2.12, $p < 0.001$). The impact of causes for admissions as predictors of readmission in patients with secondary HF is shown in Supplementary Table 2.

The causes of unplanned readmissions are shown in Figure 2. For primary HF, 32.3% of patients were readmitted for HF while 15.4% were readmitted for non-HF cardiac reasons and 52.4% for noncardiac reasons. The rates of HF, non-HF cardiac and noncardiac readmissions for secondary HF were 12.6%, 13.5%, and 73.9%, respectively. For noncardiac reasons of unplanned readmissions, the top 5 categories were infections, respiratory disorders, gastrointestinal disorders, renal failure, and hematological disorders/neoplasms for both a primary or secondary diagnosis of HF during the index hospital admission (Supplementary Figure 2). For cardiac reasons of unplanned readmissions, HF was dominant followed by arrhythmias. The single most common reason for readmission was HF after admission with primary HF (32.3%) and infection for secondary HF (18.4%). Compared with primary HF, secondary HF was associated with lower rates of HF readmissions (12.6% vs 32.3%).

Supplementary Figure 3 shows rates of 30-day unplanned readmissions according to the primary cause of the readmission for patients with an index admission with secondary HF. Patients with a primary noncardiac diagnosis that was hematological/oncological (17.1%), renal (16.7%), respiratory (16.2%), and endocrine/metabolic (16.2%) had the most readmissions. Readmissions were least among patients with obstetrical diagnoses (8.2%), TIA/stroke (10.8%) and syncope (11.4%). For cardiac causes, a secondary diagnosis of HF in the context of acute myocardial infarction (15.4%) and arrhythmia (14.1%) had the highest rates of readmission.

Discussion

Our results suggest that approximately 1 in 6 patients with either a primary or secondary diagnosis of HF have an unplanned readmission within 30-days of hospitalization. The important predictors of readmission after an index admission with a primary or secondary diagnosis of HF are comorbidities as well as discharge to care homes, or choosing to self-discharge against medical advice. Our

Table 2
Characteristics of participants by 30-day unplanned readmission and primary or secondary diagnosis of heart failure

Variable	Primary heart failure (n = 2,635,673)			Secondary heart failure (n = 8,342,383)		
	Not readmitted	Readmitted	p Value	Not readmitted	Readmitted	p Value
Demographics						
Age (years)	72.3 ± 14.5	73.1 ± 14.1	<0.001	73.1 ± 13.7	73.1 ± 13.6	0.15
Female	49.5%	49.7%	0.12	52.5%	52.3%	0.006
Weekend admission	23.5%	24.1%	<0.001	24.3%	24.6%	<0.001
Year			<0.001			<0.001
2010	19.5%	20.5%		18.7%	19.2%	
2011	19.1%	19.8%		19.0%	19.7%	
2012	18.4%	18.5%		18.9%	19.1%	
2013	20.6%	20.1%		21.1%	20.4%	
2014	22.4%	21.2%		22.4%	21.6%	
Primary expected payer			<0.001			<0.001
Medicare	73.1%	77.6%		77.1%	79.9%	
Medicaid	8.1%	9.2%		7.4%	8.2%	
Private	11.9%	8.5%		10.8%	8.4%	
Uninsured	4.0%	2.4%		2.2%	1.6%	
No charge	0.4%	0.2%		0.3%	0.2%	
Other	2.5%	2.0%		2.2%	1.7%	
Median household income (percentile)			<0.001			<0.001
0-25th	31.5%	32.5%		30.7%	31.0%	
26-50th	25.0%	24.8%		25.1%	25.0%	
51-75th	23.3%	22.9%		23.4%	23.3%	
76-100th	20.2%	19.8%		20.8%	20.6%	
Cardiovascular comorbidities						
Hypertension	70.4%	71.0%	<0.001	71.4%	71.2%	0.001
Coronary artery disease	44.0%	46.9%	<0.001	44.7%	46.4%	<0.001
Previous myocardial infarction	12.5%	13.2%	<0.001	12.0%	12.4%	<0.001
Previous PCI	9.8%	10.5%	<0.001	9.3%	9.7%	<0.001
Previous CABG	14.3%	15.4%	<0.001	11.4%	12.0%	<0.001
Previous heart failure	1.6%	1.3%	<0.001	75.5%	76.9%	<0.001
Atrial fibrillation	36.6%	38.4%	<0.001	35.6%	36.7%	<0.001
Valvular heart disease	0.5%	0.4%	0.001	11.8%	12.2%	<0.001
Previous stroke or TIA	10.5%	11.6%	<0.001	13.0%	13.4%	<0.001
Peripheral vascular disease	11.2%	12.9%	<0.001	12.3%	13.8%	<0.001
Pulmonary circulatory disorder	0.4%	0.3%	0.001	7.7%	8.0%	<0.001
Noncardiovascular comorbidities						
Smoker	27.4%	26.6%	<0.001	26.5%	26.8%	<0.001
Alcohol misuse	3.5%	3.1%	<0.001	3.6%	3.5%	0.076
Dyslipidemia	45.1%	44.1%	<0.001	43.9%	42.5%	<0.001
Obesity	19.5%	16.9%	<0.001	17.0%	15.7%	<0.001
Diabetes mellitus	42.7%	45.9%	<0.001	39.9%	43.0%	<0.001
Chronic lung disease	33.3%	37.2%	<0.001	30.6%	33.4%	<0.001
Hypothyroidism	15.7%	16.8%	<0.001	16.5%	16.8%	<0.001
Renal failure	37.2%	44.9%	<0.001	28.5%	34.1%	<0.001
Liver disease	2.6%	3.3%	<0.001	2.9%	3.7%	<0.001
Fluid and electrolyte disorders	29.0%	31.5%	<0.001	37.2%	39.0%	<0.001
Peptic ulcer disease	0.03%	0.04%	0.003	0.04%	0.04%	0.59
Anemia	27.5%	32.6%	<0.001	27.1%	31.8%	<0.001
Bleeding	0.7%	0.8%	<0.001	2.8%	2.7%	0.18
Cancer	3.4%	4.3%	<0.001	4.7%	5.8%	<0.001
Depression	8.5%	9.4%	<0.001	11.1%	11.7%	<0.001
Dementia	9.1%	9.8%	<0.001	13.5%	13.4%	0.011
Charlson Comorbidity Index	2.2 ± 1.6	2.5 ± 1.7	<0.001	2.9 ± 1.8	3.1±1.8	<0.001
Hospital characteristics						
Bed size			<0.001			<0.001
Small	11.8%	11.5%		10.8%	10.7%	
Medium	26.4%	26.6%		25.5%	25.8%	
Large	61.8%	62.0%		63.8%	63.5%	
Teaching hospital	55.9%	54.1%	<0.001	56.9%	55.6%	<0.001
Urban hospital	89.7%	90.0%	<0.001	90.2%	90.9%	<0.001

(*continued*)

Table 2 (***Continued***)

Variable	Primary heart failure (n = 2,635,673)			Secondary heart failure (n = 8,342,383)		
	Not readmitted	Readmitted	p Value	Not readmitted	Readmitted	p Value
In-hospital outcomes and treatments						
Cardiogenic shock	0.9%	0.7%	<0.001	1.4%	1.0%	<0.001
Cardiac arrest	0.3%	0.2%	<0.001	1.0%	0.6%	<0.001
Ventilation	1.5%	1.0%	<0.001	7.0%	5.5%	<0.001
Circulatory support	0.3%	0.1%	<0.001	0.9%	0.7%	<0.001
Intra-aortic balloon pump	0.3%	0.1%	<0.001	0.8%	0.6%	<0.001
Vasopressor	0.3%	0.2%	0.027	0.6%	0.5%	<0.001
Coronary angiogram	9.3%	6.4%	<0.001	10.8%	9.2%	<0.001
Current admission PCI	1.1%	1.0%	0.002	4.0%	3.7%	<0.001
Current CABG	0.3%	0.2%	<0.001	1.7%	1.2%	<0.001
Pacemaker or ICD implantation	1.5%	1.1%	<0.001	2.1%	1.6%	<0.001
Cardiac resynchronization therapy	1.0%	0.7%	<0.001	0.4%	0.3%	<0.001
Left ventricular assist device	0.16%	0.03%	<0.001	0.09%	0.05%	<0.001
Heart transplant	0.09%	0.02%	<0.001	0.02%	0.01%	<0.001
Discharge location			<0.001			<0.001
Home	58.6%	51.9%		48.1%	43.9%	
Transfer to other hospital	17.8%	20.5%		30.2%	31.4%	
Care home	22.6%	25.5%		21.0%	23.2%	
Discharge against medical advice	1.0%	2.1%		0.8%	1.6%	
Court/law enforcement	<0.1%	<0.1%		<0.1%	<0.1%	
Length of stay (days)	5.3 ± 6.5	5.0 ± 3.7	<0.001	7.4 ± 9.6	6.2 ± 4.7	<0.001
Cost (USD)	$11,410 ± 20,707	$10,105 ± 10,274	<0.001	$17,561 ± 26,666	$14,394 ± 14,579	<0.001
Time to readmission	–	16.3 ± 7.5	–	–	16.6 ± 7.5	–
Readmission length of stay (days)	–	6.2 ± 7.2	–	–	6.5 ± 7.5	–
Death during readmission	–	6.8%	–	–	7.7%	–
Cost of readmission (USD)	–	$13,488 ± 22,758	–	–	$13,947 ± 20,124	–

CABG = coronary artery bypass graft; ICD = implantable defibrillator device; NS = nonsignificant; PCI = percutaneous coronary intervention; TIA = transient ischemic attack.

evaluation of reasons for admission and rate of readmission among patients with secondary diagnosis of HF suggests that variation in readmission propensity depends on the reason(s) for the index hospital admission. While overall, causes of readmission were primarily noncardiac (52.8% and 73.0% for primary and secondary HF, respectively), HF only accounted for 32% of unplanned readmission in patients admitted with an index primary diagnosis of HF and a significant number (13%) of patients with other causes for admissions have an unplanned readmission for HF. The findings from this study support the need for HF care to focus on the integrated patient health burden and better management of co-morbidities in HF in addition to the details of HF medications and specific follow-up in HF clinics.

Our analysis is important for several reasons. First, we include all patients admitted to hospitals in the United States with diagnoses of HF. Both clinical trials and registries of HF are selective in patient inclusion. For example, the PARADIGM-HF exclude patients with hypotension, estimated glomerular filtration rate <30 and side effects to angiotensin receptor blockers or angiotensin receptor antagonists[11] and in particular renal impairment in commonly observed in patients with HF especially those on diuretics. In terms of registries, the Get With The Guidelines-HF study only included a subset of hospitals in the United States which volunteer to take part and there is only linkage to Medicare inpatient data.[12] For the readmissions study, there were only 130,146 patients eligible from 339 sites between 2005 and 2013 and 70% were excluded leaving 37,457 patients from 132 sites in the analysis.[13] Our analysis represents complete national data which has advantages because of its size, representativeness and inclusion of all types of patients that present to hospital such as those with Medicaid, private and no health insurance. Secondly, because of the completeness of the NRD dataset across the years, we were able to examine trends over time and show that readmission rates are decreasing. Third, our analysis was able to consider primary and secondary HF separately which is important as patients with secondary HF have a greater burden of comorbidities and there are differences in causes for readmissions for these patients. For secondary diagnosis of HF, we further explored the rates of 30-day unplanned readmissions according to the primary diagnosis which is novel. We show that there is considerable variation in rates which vary from 8.2% for patients with primary diagnosis of obstetric or pregnancy problems and highest for hematological/oncological problems (17.1%) Finally, we were able to consider the financial implications of readmissions which adds an additional level of significance of readmissions. Readmissions were associated with on average more than $13,000 for both primary and secondary diagnosis of HF which was greater than the cost of the index admission for patients with a primary diagnosis of HF.

HF services should be optimally structured to prevent or reduce readmissions after hospitalizations for HF. Strategies to improve outcomes and reduce hospitalizations include optimization of medical therapy for HF and early follow-up

Table 3
Predictors of readmission with primary heart failure and secondary heart failure

Variable	Primary heart failure		Secondary heart failure*	
	Odds ratio (95% CI)	p Value	Odds ratio (95% CI)	p Value
Age (per year)	0.99 (0.99-0.99)	<0.001	0.99 (0.99-0.99)	<0.001
Female	NS	0.063	NS	0.28
Weekend admission	1.02 (1.01-1.04)	<0.001	1.02 (1.01-1.03)	<0.001
Year vs 2010				
2011	NS	0.22	NS	0.74
2012	0.95 (0.93-0.97)	<0.001	0.97 (0.96-0.98)	<0.001
2013	0.92 (0.91-0.94)	<0.001	0.93 (0.92-0.94)	<0.001
2014	0.89 (0.88-0.91)	<0.001	0.92 (0.91-0.93)	<0.001
Primary expected payer vs Medicare				
Medicaid	1.11 (1.09-1.14)	<0.001	1.05 (1.04-1.06)	<0.001
Private	0.75 (0.74-0.77)	<0.001	0.77 (0.76-0.78)	<0.001
Uninsured	0.65 (0.63-0.68)	<0.001	0.70 (0.68-0.72)	<0.001
No charge	0.64 (0.58-0.71)	<0.001	0.77 (0.72-0.82)	<0.001
Other	0.82 (0.79-0.85)	<0.001	0.79 (0.77-0.81)	<0.001
Median household income (percentile) vs 0-25th				
26-50th	0.96 (0.94-0.97)	<0.001	NS	0.32
51-75th	0.94 (0.93-0.96)	<0.001	0.99 (0.98-0.99)	0.001
76-100th	0.93 (0.92-0.95)	<0.001	0.99 (0.98-1.00)	0.003
Hypertension	NS	0.066	0.97 (0.96-0.98)	<0.001
Dyslipidemia	0.93 (0.92-0.94)	<0.001	0.93 (0.93-0.94)	<0.001
Obesity	0.83 (0.82-0.84)	<0.001	0.88 (0.87-0.89)	<0.001
Diabetes mellitus	1.11 (1.09-1.12)	<0.001	1.10 (1.10-1.11)	<0.001
Smoker	0.96 (0.95-0.98)	<0.001	0.99 (0.99-1.00)	0.048
Alcohol misuse	0.95 (0.92-0.98)	0.002	NS	0.87
Coronary artery disease	1.10 (1.08-1.11)	<0.001	1.08 (1.07-1.08)	<0.001
Previous myocardial infarction	NS	0.12	1.01 (1.00-1.02)	0.048
Previous PCI	1.03 (1.01-1.05)	0.003	1.03 (1.01-1.04)	<0.001
Previous CABG	NS	0.38	NS	0.52
Previous heart failure	0.72 (0.69-0.76)	<0.001	NS	0.27
Atrial fibrillation	1.08 (1.07-1.09)	<0.001	1.08 (1.08-1.09)	<0.001
Valvular heart disease	NS	0.50	1.01 (1.00-1.02)	<0.001
Previous stroke or TIA	1.05 (1.03-1.07)	<0.001	1.03 (1.02-1.04)	<0.001
Peripheral vascular disease	1.07 (1.06-1.09)	<0.001	1.07 (1.06-1.08)	<0.001
Pulmonary circulatory disorder	NS	0.72	NS	0.29
Chronic lung disease	1.16 (1.15-1.17)	<0.001	1.14 (1.13-1.14)	<0.001
Hypothyroidism	1.04 (1.03-1.06)	<0.001	NS	0.14
Renal failure	1.27 (1.25-1.28)	<0.001	1.24 (1.23-1.25)	<0.001
Liver disease	1.21 (1.18-1.25)	<0.001	1.20 (1.18-1.22)	<0.001
Fluid and electrolyte disorders	1.08 (1.07-1.09)	<0.001	1.04 (1.03-1.05)	<0.001
Peptic ulcer disease	1.46 (1.11-1.92)	0.007	NS	0.89
Anaemia	1.13 (1.12-1.14)	<0.001	1.15 (1.15-1.16)	<0.001
Bleeding	NS	0.25	0.97 (0.96-0.99)	0.12
Cancer	1.26 (1.22-1.29)	<0.001	1.22 (1.20-1.24)	<0.001
Depression	1.08 (1.07-1.11)	<0.001	1.04 (1.03-1.05)	<0.001
Dementia	NS	0.15	0.97 (0.96-0.98)	<0.001
Bed size vs small				
Medium	NS	0.067	1.01 (1.00-1.02)	0.035
Large	1.02 (1.00-1.03)	0.049	NS	0.81
Teaching hospital	0.96 (0.95-0.97)	<0.001	0.98 (0.98-0.99)	<0.001
Urban hospital	1.03 (1.01-1.05)	0.001	1.09 (1.08-1.10)	<0.001
Cardiogenic shock	NS	0.071	0.88 (0.85-0.91)	<0.001
Cardiac arrest	0.83 (0.73-0.94)	0.004	0.84 (0.81-0.87)	<0.001
Ventilation	0.74 (0.70-0.78)	<0.001	0.72 (0.71-0.73)	<0.001
Circulatory support	2.81 (1.64-4.81)	<0.001	NS	0.46
Intra-aortic balloon pump	0.30 (0.18-0.52)	<0.001	NS	0.73
Vasopressor	NS	0.86	0.94 (0.90-0.98)	0.003
Coronary angiogram	0.74 (0.72-0.75)	<0.001	0.84 (0.83-0.86)	<0.001
Current admission PCI	1.26 (1.19-1.33)	<0.001	1.08 (1.05-1.10)	<0.001
Current CABG	NS	0.55	0.74 (0.72-0.76)	<0.001
Pacemaker or ICD implantation	0.84 (0.80-0.88)	<0.001	0.82 (0.80-0.84)	<0.001

(*continued*)

Table 3 (***Continued***)

Variable	Primary heart failure		Secondary heart failure*	
	Odds ratio (95% CI)	p Value	Odds ratio (95% CI)	p Value
Cardiac resynchronization therapy	0.77 (0.73-0.82)	<0.001	0.82 (0.68-0.76)	<0.001
Left ventricular assist device	0.18 (0.12-0.25)	<0.001	0.60 (0.49-0.74)	<0.001
Heart transplant	0.34 (0.24-0.48)	<0.001	0.32 (0.22-0.47)	<0.001
Discharge location vs home				
Transfer to other hospital	1.23 (1.21-1.25)	<0.001	1.19 (1.18-1.20)	<0.001
Care home	1.21 (1.19-1.22)	<0.001	1.20 (1.19-1.21)	<0.001
Discharge against medical advice	2.29 (2.20-2.39)	<0.001	2.06 (2.01-2.12)	<0.001
Court/law enforcement	NS	-	NS	0.51

* Also adjusted for causes of admission but shown in detail in Supplementary Table 2; NS = not significant where $p > 0.05$.

postdischarge. An important challenge in managing patients with HF is that of medication adherence as a review of 57 studies suggests that interventions to improve medication adherence reduces risk of mortality by 11% and odds of readmission by 21%.[14] In addition, nonpharmacological measures may also be implemented to reduce readmissions which include programs such as Hospital-to-Home Readmission Intervention Program,[15] ModelHeart,[16] Patient-Centered Care Transitions,[17] and other interventions such as telemedical care[18] and use of grand-aides nurse extenders.[19]

Our finding that noncardiac factors are the commonest reasons for unplanned readmissions in both primary and secondary HF raises the question about whether resources should be directed at management of co-morbidities. Opportunities to manage co-morbidities can take place during the index hospitalization or in the postdischarge period. Strategies can be employed to target the management of co-morbidities such as continuous positive airway pressure for sleep disordered breathing, cardiopulmonary rehabilitation, immunization, inhalational drug therapies for chronic obstructive pulmonary disease and counselling patients on the consequences of failure to properly manage these multimorbidities may influence future hospitalization and progression of HF.[20]

A major concern has been raised regarding an active promotion for shortening length of hospital stay and reducing readmissions in HF that could result in increased mortality rates.[21,22] It has been suggested that readmissions rates and mortality for congestive HF are inversely related.[23–25] Analysis of the Get With The Guidelines-Heart Failure Registry (GWTG-HF) reported that among Medicare beneficiaries the rate of mortality in HF increased from 7.2% to 8.6% after the introduction of the Hospital Readmissions Reduction Program.[26] It has been suggested that the increase in mortality may be related to hospitals attempting to delay admissions beyond day 30, increase observational stays or shift inpatient care to emergency departments.[27] In the current study, mortality rates for patients with primary HF admission declined in the Medicare (3.2 % to 2.9%), and Medicaid (1.5% to 1.3%) patients but increased among uninsured patients (2.5% to 2.3%) with overall mortality rates declining over time from 3.0% to 2.7%. The divergence in findings between the Medicare cohorts and NRD may be related to generalizability of the cohort as

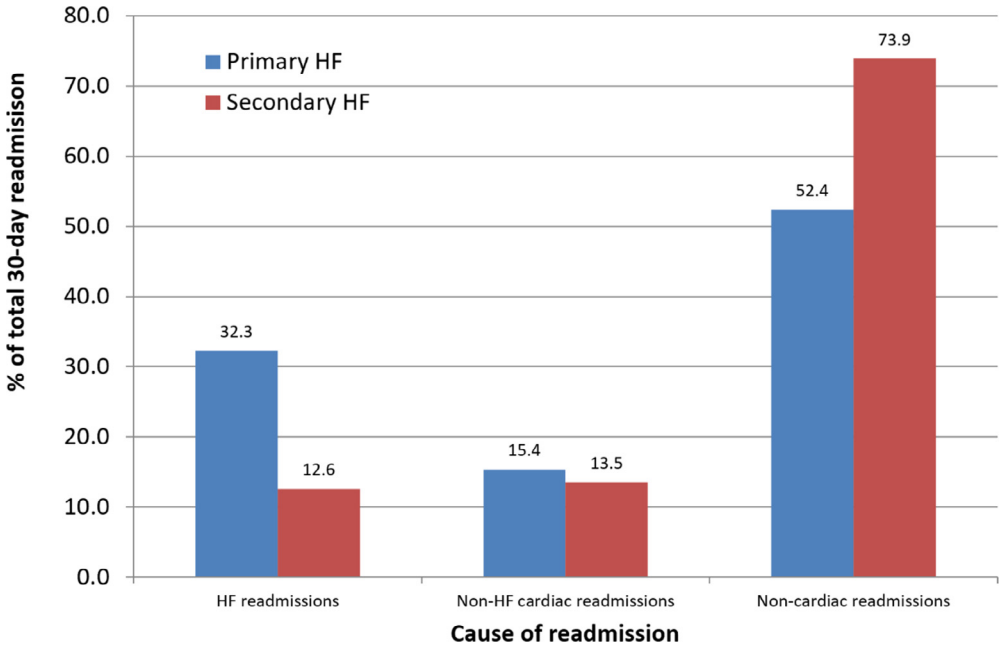

Figure 2. Causes of readmission among patients hospitalized with a primary and secondary diagnosis of heart failure.

participation in the Get With The Guidelines-Heart Failure Registry registry is voluntary whereas the NRD includes all payers and is designed to be nationally representative.

Important considerations in determining predictors of rehospitalization include patient-level nonclinical factors. Some of these factors not captured in the current dataset include the local healthcare infrastructure, patient preferences, access to care, caregiver situation, financial incentives for hospitals or physicians and medicolegal liability climate. In the current study, we were able to capture the primary expected payer, median household income, hospital bed size, teaching status, discharge location, but they are unlikely to account for the propensity to be readmitted based on the nonclinical factors. The inability of the research community to capture these nonclinical factors may be an explanation why there are difficulties in robustly predicting HF rehospitalizations.

Our study has several limitations. The NRD is also limited in its ability to explore regional differences and link outcomes across calendar years; as such, patients may appear in multiple years. In addition, in the current study we do not have information left ventricular systolic function, left ventricular diastolic function, New York Heart Association class, volume status, etiology of HF or prescription of pharmacological therapies such as angiotensin converting enzyme inhibitors that have been shown to reduce mortality and readmission.[11,12] Furthermore, there is evidence that specialist management in hospital reduces readmissions in HF[28] and the NRD does not capture data around whether patients had been managed or reviewed by HF specialists or cardiologists during their index admission. Also, once discharged there is no information regarding outpatient HF clinic follow-up which has been shown to reduce 30-day readmission and mortality.[29] As being inherent in any observational study, there is the risk of confounding and it would be incorrect to make causal inferences. Finally, the nature of the dataset is such that we are unable to determine deaths outside of hospital after discharge, so there is an issue of survivor bias.

In conclusion, 30-day unplanned readmission after admission with primary and secondary diagnosis is common. We report that noncardiac causes are the most common causes of unplanned readmissions in both primary and secondary diagnoses of HF. The single most common cause for readmission in primary HF was HF whereas for secondary diagnosis of HF it was infection. Findings from this study highlight and confirm the importance of managing comorbidities, including respiratory, metabolic/endocrine disorders and renal failure, as targets to prevent readmission and warrant special attention to medical handover when discharging patients to destinations other than home.

Disclosures

The authors have no conflicts of interest to declare.

Acknowledgment

We are grateful to the Healthcare Cost and Utilization Project (HCUP) and the HCUP Data Partners for providing the data used in the analysis.

Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.amjcard.2019.05.053.

1. O'Connor CM. High heart failure readmission rates. *JACC Heart Failure* 2017;5:393.
2. Fernandez-Gasso L, Hernando-Arizaleta L, Palomar-Rodriguez JA, Abellan-Perez MV, Pascual-Figal DA. Trends, causes and timing of 30-day readmissions after hospitalization for heart failure: 11-year population-based analysis with linked data. *Int J Cardiol* 2017;246:251.
3. Goyal P, Loop M, Chen L, Brown TM, Durant RW, Safford MM, Levitan EB. Causes and temporal patterns of 30-day readmissions among older adults hospitalized with heart failure with preserved or reduced ejection fraction. *J Am Heart Assoc* 2018;7:e007785.
4. Gupta A, Allen LA, Bhatt DL, Cox M, Devore AD, Heidenreich PA, Hernandez AF, Peterson ED, Matsouaka RA, Yancy CW, Fonarow GC. Association of the hospital readmission reduction program implementation with readmission and mortality outcomes in heart failure. *JAMA Cardiol* 2018;3:44–53.
5. Arora S, Patel P, Lahewala S, Patel N, Patel NJ, Thakore K, Amin A, Tripathi B, Kumar V, Shah H, Shah M, Panaich S, Deshmukh A, Badheka A, Gidwani U, Gopalan R. Etiologies, trends, predictors of 30-day readmission in patients with heart failure. *Am J Cardiol* 2017;119:760–769.
6. Tung YC, Chou SH, Liu KL, Hsieh IC, Wu LS, Lin CP, Wen MS, Chu PH. Worse prognosis in heart failure patients with 30-day readmission. *Acta Cardiol Sin* 2016;32:698–707.
7. McIlvennan CK, Eapen ZJ, Allen LA. Hospital readmissions reduction program. *Circulation* 2015;131:1796–1803.
8. Bergethon KE, Ju C, DeVore AD, Hardy NC, Fonarow GC, Yancy CW, Heidenreich PA, Bhatt DL, Peterson ED, Hernandez AF. Trends in 30-day readmission rates for patients hospitalized with heart failure: findings from the GWTG-HF registry. *Circ Heart Fail* 2016;9. https://doi.org/10.1161/CIRCHEARTFAILURE.115.002594e002594.
9. Suter LG, Li SX, Grady JN, Lin Z, Wang Y, Bhat KR, Turkmani D, Spivack SB, Lindernauer PK, Merrill AR, Drye EE, Krumholz HM, Bernheim SM. National patterns of risk-standardized mortality readmission after hospitalization for acute myocardial infarction, heart failure, and pneumonia: update on publicly reported outcome measures based on the 2013 release. *J Gen Intern Med* 2014;29:1333–1340.
10. Healthcare Cost and Utilization Project (HCUP). Available at:https://www.ahrq.gov/research/data/hcup/index.html. Last searched July 30, 2018.
11. McMurray JJV, Packer M, Desai AS, Gong J, Lefkowtiz MP, Rizkala AR, Rouleau JL, Shi VC, Solomon SD, Swedberg K, Zile MR. Angiotensin-neprilysin inhibition versus enalapril in heart failure. *N Engl J Med* 2014;371:993–1004.
12. Kumbhani DJ, Fonarow GC, Heidenreich PA, Schulte PJ, Hernandez A, Yancy C, Bhatt DL. Association between hospital volume processes of care, and outcomes in patients admitted with heart failure. *Circulation* 2018;137:1661–1670.
13. Jalnapurkar S, Zhao X, Heidenriech PA, Bhatt DL, Smith EE, DeVore AD, Hernandez AF, Matsouaka R, Yancy CW, Fonarow GC. A hospital level analysis of 30-day readmission performance for heart failure patients and long-term survival: findings from the get with the guidelines-heart failure. *Am Heart J* 2018;200:127–133.
14. Ruppar TM, Cooper PS, Mehr DR, Delgado JM, Dunbar-Jacob JM. Medication adherence interventions improve heart failure mortality and readmission rates: systematic review and meta-analysis of controlled trials. *J Am Heart Assoc* 2016;5. pii: e002606.
15. Bilchick K, Moss T, Welch T, Levy W, Stukenborg G, Lawlor BT, Reigle J, Thomas SC, Brady C, Bergin JD, Kennedy JLW, Abuannadi M, Scully K, Mazimba S. Improving heart failure readmission costs and outcome with a Hospital-to-Home Readmission Intervention Program. *Am J Med Qual* 2018;1:1062860618788436.
16. Kachur S, Kachur P, Akhtar T, Collado E, Espinosa-Friedman M, Asher C, Hernandez M. ModelHeart: a resident-led implementation of metrics to reduce 30-day heart failure readmissions. *Postgrad Med J* 2018. https://doi.org/10.1136/postgradmedj-2018-135745. pii: postgradmedj-2018-135745.

17. Van Spall HGC, Lee SF, Xie F, Ko DT, Thabane L, Ibrahim Q, Mitoff PR, Heffernan M, Maingi M, Tjandrawidjaja MC, Zia MI, Panju M, Perez R, Simek KD, Porepa L, Graham ID, Haynes RB, Haughton D, Connolly SJ. Rationale and design of the patient-centered care transitions in Heart Failure pragmatic stepped wedge cluster randomized trial. *Am Heart J* 2018;199:75–82.
18. Frederix I, Vanderlinden L, Verbown AS, Welten M, Wouters D, De Keulenaer G, Ector B, Elegeert I, Troisfontaines P, Weytjens C, Mullens W, Dendale P. Long-term impact of a six-month telemedical care programme on mortality, heart failure readmissions and healthcare cost in patients with chronic heart failure. *J Telemed Telecare* 2018;1. 1357633 × 18774632. doi: 10.1177/1357633 × 18774632.
19. Thomas GC, Greevy RA Jr, Garson A Jr. Effect of grand-aides nurse extenders on readmissions and emergency department visits in medicare patients with heart failure. *Am J Cardiol* 2018;1212:1336–1342.
20. Chong VH, Singh J, Parry H, Saunders J, Chowdhury F, Mancini DM, Lang CC. Management of noncardiac comorbidities in chronic heart failure. *Cardiovasc Ther* 2015;33:300–315.
21. Fonarow GC, Konstam MA, Yancy CW. The hospital readmission program is associated with fewer readmissions more deaths. *J Am Cardiol* 2017;70:1931–1934.
22. Shakir M, Wasfy JH. Heart failure and readmissions: research in the public eye. *Am Heart J* 2018;203:1–3.
23. Krumholz HM, Lin Z, Keenan PS, Chen J, Ross JS, Drye EE, Bernheim SM, Wang Y, Bradley EH, Han LF, Normand SL. Relationship between hospital readmission and mortality rates for patients hospitalized with acute myocardial infarction, heart failure, or pneumonia. *JAMA* 2013;309:587–593.
24. Pandey A, Golwala H, Xu H, DeVore AD, Matsouaka R, Pencina M, Kumbhani DJ, Hernandez AF, Bhatt DL, Heidenreich PA, Yancy CW, de Lemos JA, Fonarow GC. Association of 30-day readmission metric for heart failure under the Hospital Readmissions Reduction Program with quality of care and outcomes. *JACC Heart Fail* 2016;4:935–946.
25. Heidenreich PA, Sahay A, Kapoor JR, Pham MX, Massie B. Divergent trends in survival and readmission following a hospitalization for heart failure in the Veterans Affairs health care system 2002 to 2006. *J Am Coll Cardiol* 2010;56:362–368.
26. Gupta A, Allen LA, Bhatt DL, Cox M, DeVore AD, Heidenreich PA, Hernandez AF, Peterson ED, Matsouaka RA, Yancy CW, Fonarow GC. Association of the Hospital Readmissions Reduction Program implementation with readmissions and mortality outcomes in heart failure. *JAMA Cardiol* 2018;3:44–53.
27. Woolhandler S, Himmelstein DU. The Hospital Readmissions Reduction Program. *N Engl J Med* 2016;375:493.
28. Frizzell JD, Liang L, Schulte PJ, Yancy CW, Heidenreich PA, Hernandez AF, Bhatt DL, Fonarow GC, Laskey WK. Prediction of 30-day all-cause readmissions in patients hospitalized for heart failure. *JAMA Cardiol* 2017;2:204–209.
29. Kalhan R, Mutharasan RK. Reducing readmissions in patients with both heart failure and COPD. *Chest* 2018. https://doi.org/10.1016/j.chest.2018.06.001. pii: S0012-3692(18)30891-2.