Hospital mortality and thirty day readmission among patients with non-acute myocardial infarction related cardiogenic shock.

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Published In/Presented At

Shah, M., Patel, B., Tripathi, B., Agarwal, M., Patnaik, S., Ram, P., Patil, S., Shin, J., & Jorde, U. P. (2018). Hospital mortality and thirty day readmission among patients with non-acute myocardial infarction related cardiogenic shock. *International journal of cardiology*, *270*, 60–67. https://doi.org/10.1016/j.ijcard.2018.06.036

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International Journal of Cardiology 270 (2018) 60–67

Contents lists available at ScienceDirect

International Journal of Cardiology

journal homepage: www.elsevier.com/locate/ijcard

Hospital mortality and thirty day readmission among patients with non-acute myocardial infarction related cardiogenic shock

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ARTICLE INFO

Article history:
Received 6 August 2017
Received in revised form 2 May 2018
Accepted 8 June 2018
Available online 10 June 2018

Keywords:
Cardiogenic shock
Non acute myocardial infarction
NRD
Readmission
Mortality
Etiologies

ABSTRACT

Background: Cardiogenic shock (CS) in absence of acute myocardial infarction (AMI) has significant morbidity and mortality. This population of patients has been excluded from prior major randomized trials and observational studies.

Methods: We included patients with CS in absence of AMI from the 2013–14 HCUP's National Readmission Database. 30-day readmissions were studied and etiology for readmission was identified by using ICD-9CM codes in primary diagnosis field. Multivariable mixed effect logistic regression models were created to identify predictors of 30-day readmission and in-hospital mortality, respectively.

Results: We studied 38,198 index admissions with non-AMI CS, with an in-hospital mortality of 35.4%. Mean age, length and cost of stay were 63.6 years, 16.9 days and 69,947$, respectively among survivors of index admission. Among those discharged, 22.6% were readmitted within 30 days with >50% readmissions occurring within 11-days. Cardiovascular etiologies (42.3%), especially heart failure (24.0%) comprised the commonest reason for readmission. Among non-cardiac causes were infectious (11.7%) and respiratory (9.2%) etiologies. Older age (50–64 years odds ratio:1.29, 65–79 years, OR:1.59, ≥80 years OR:2.69), ventilator use (OR:4.25), sepsis (OR:1.12), use of short term devices (intra-aortic balloon pump OR:2.67, Impella/TandemHeart OR:4.84, extracorporeal membrane oxygenation OR:3.68) and non-ischemic cardiomyopathy(OR:0.65) were among the predictors of in-hospital mortality. Older age (65–79 years, OR:1.25, ≥80 years OR:1.41), male sex (OR:1.08), and ventilator use (OR:1.21) predicted higher 30-day readmission.

Conclusion: Both, in-hospital mortality and 30-day readmission among those admitted for non-AMI CS were significantly elevated. The majority of readmissions were due to non-cardiovascular causes. Identifying high-risk factors may help devise strategies to improve quality of care and reduce adverse outcome rates.

1. Introduction

Reduction in hospital readmission rates has gained significant momentum as part of policy to alleviate its burden of health care associated costs, due to the fact that a significant proportion of readmissions are preventable. The centers for Medicare and Medicare Services (CMS) consider hospital readmission as a metric for quality of care, and currently penalize hospitals with a high rate of readmissions under the Hospital Readmissions Reduction Program (HRRP) [1, 2]. While several issues have been raised questioning the validity of readmission as an effective metric, recent data suggests that the HRRP has led to a decline in all-cause-30-day-readmission rates [3, 4]. Continued expansive research examining rehospitalization in conditions with a high rate of readmissions such as acute heart failure, or acute myocardial infarction have shown potential in reducing unplanned readmissions and associated expenditures [5, 6].

Cardiogenic shock (CS) represents a high risk population that is at risk for both in-hospital mortality and readmission following discharge. CS typically occurs as a result of cardiac pump failure and reduced cardiac output with evidence of end-organ hypoperfusion. Cardiac pump failure most often occurs in the setting of an acute myocardial infarction (AMI) involving >40% of left ventricular myocardium,

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https://doi.org/10.1016/j.ijcard.2018.06.036
0167-5273/

presence of extensive ischemia or severe right ventricular infarction. CS is the commonest cause of mortality associated with AMI, and affects ST elevation myocardial infarction (STEMI) with a higher frequency compared to a non STEMI [7–9]. Other causes of CS mainly include severe decline in underlying systolic function (from non-ischemic causes such as sepsis, stress, and progression of systolic left ventricular dysfunction among others), arrhythmias, and mechanical cardiac complications. Cardiogenic shock in the absence of AMI (non-AMI CS) is excluded from most studies including randomized trials and remains largely understudied.

We sought to examine specific etiologies, trends and predictors for hospital mortality and 30-day readmission in patients admitted with non-AMI CS from one of the largest available nationwide databases.

2. Methods

The study cohort was derived from HCUP's National Readmission Database (NRD) of 2013 and 2014, sponsored by the Agency for Healthcare Research and Quality (AHRQ). NRD is one of the largest publicly available all-payer inpatient database in the US, including data on approximately 28 million discharges in years 2013–14, estimating >50 million discharges from 21 states with reliable, verified linkage numbers. NRD represents 49.1% of total US hospitalizations. Patients were tracked using variable "NRD_visitlink" and time between two admissions was calculated by subtracting variable "NRD_DaysToEvent". Time to readmission was calculated by subtracting length of stay (LOS) of index admission from the time between two admissions. The details regarding the NRD data are available online [10].

We queried the NRD database using ICD-9CM diagnosis codes to identify patients with a diagnosis of cardiogenic shock during hospitalization (ICD-9CM code: 785.51). We excluded patients under the age of 16 years, those with an associated acute coronary syndrome or missing data for age, sex and mortality. If patients had more than one admission with non-AMI CS during the year, the discharge record for the subsequent admission was excluded from index cases. December discharges were excluded due to an inability to obtain 30-day readmission data for patients. We identified a total of 38,198 unweighted index admissions. Similar methods were utilized previously by Chen J, et al. [6]. Patients who were readmitted within one month in the same calendar year were further evaluated (n = 5570).

NRD variables were used to identify patients' demographic characteristics including age, gender; hospital characteristics such as bed size and teaching status; other patient specific characteristics, primary payer information, admission type, admission day and discharge disposition. "CM_" variables identified different co-morbidities by using ICD-9CM diagnoses and the diagnosis-related group in effect on the discharge date. These co-morbidities are not directly related to the principal diagnosis or the main reason for admission and are likely to have originated before the hospital stay [11]. International Classification of Diseases, Ninth Edition, Clinical Modification (ICD-9CM) or Clinical Classifications Software (CCS) codes used to define comorbidities and additional variables as listed in Supplementary Table A. Severity of co-morbid conditions defined using Deyo modification of Charlson comorbidity index (CCI), which contains 17 co-morbid conditions with differential weights and the Elixhauser comorbidity index which is a sum of the 29 Elixhauser comorbidity variables within database. The score ranges from 0 to 33, with higher scores corresponding to greater burden of co-morbid diseases [12].

The primary outcomes were all cause 30-day readmission and in-hospital mortality. Additional outcomes analyzed were the economic impact of readmissions, evaluation of predictors for in-hospital mortality or 30-day readmission, and elaboration of etiology for 30-day readmissions. Readmission causes were identified by using ICD-9CM codes in primary diagnosis field and represented based on underlying etiology or organ system involvement. We identified and combined the ICD-9CM codes with similar diagnoses to make clinically important groups. Two authors (M.S. and B.P.) independently reviewed the primary diagnosis of each readmission record and grouped them into clinically meaningful categories to determine the main cause of readmission. Discrepancies were resolved by mutual agreement.

2.1. Statistical analysis

All analyses were performed using the IBM SPSS Statistics for Windows, Version 23.0 (Armonk, NY) statistics software. Categorical variables were expressed as percentages and continuous variables as mean ± SD and/or median. Differences between categorical variables were tested using the chi-square test and continuous variables by using student's *t*-test. An exploratory multivariable analysis was performed using mixed effect logistic regression modeling to assess which variables predicted 30-day readmission with hospital identity as random effect. The multivariate models for readmission included - hospital level variables like bed size, teaching status; patient level variables like age groups, sex, CCI, admission type, admission day, primary payer; income quartile, length of stay of index admission; calendar year; type of cardiomyopathy, co-morbidities and disposition post index admission. Patients who died at the end of index admission were excluded from the regression model. A separate regression model was created to evaluate predictors of in-hospital mortality among all index admissions followed by among those with either an ischemic or mixed ischemic (ICM) and non-ischemic cardiomyopathy (NICM).

3. Results

3.1. Baseline characteristics

As shown in Supplementary Table B, our analysis included 38,198 index admissions for non AMI associated CS. The mean age for patients included within the study was 65.1 ± 16.8 years and 39.9% of the patients were females. In-hospital mortality within the studied population was 35.4%. Exploration of the underlying cause for cardiac dysfunction revealed an ischemic cardiomyopathy in 34.8%, non-ischemic etiology in 26.7%, mixed ischemic and non-ischemic etiology in 3.7%, and an unspecified type in 34.8% of the index admissions. Table 1 demonstrates the baseline characteristics among patients who survived their index hospitalization and compares those readmitted within 30-days to those who were not. The patients that were readmitted (mean age = 63.4 years, 38.7% female) had significant comorbidity burden (64.5% with CCI ≥3, mean Elixhauser comorbidity index = 4.3), were mostly under Medicare (62.0%) and discharged from predominantly Urban teaching hospitals (75.2%). Readmitted patients had a longer length of stay (19.2 vs. 16.2 days; $p < 0.01$), and higher mean cost of hospital stay (77,213$ vs. 67,841$; $p < 0.01$) compared to non-readmitted patients. A majority of the patients that were readmitted were discharged to either home or home with home health care (64.4%).

3.2. 30-day readmission characteristics and cost-impact

There were a total of 6433 readmission among 5570 patients (14.3% of total; 22.6% of those who survived to discharge) within 30-days of discharge from hospital. Among those readmitted within 30-days, 4801 (86.2%) patients had one readmission, 675 (12.1%) patients had two readmissions and 94 (1.7%) of the patients had three or more readmissions. The trends in readmission show a higher early burden of readmissions post discharge, with 25% of readmission occurring within 5 days and >50% of readmissions occurring within 11 days of discharge. The mean time to first readmission for patients was 12.2 days (median = 11 days, interquartile range 5–19 days) (Supplementary Fig. A). Among the 6433 readmission, mean length of stay was 8.56 ± 11.67 days (median 5 days, interquartile range 3–10 days) and cost of stay was 27,018$ (median 11,172$, interquartile range 5979–24,378$). Readmission hospitalization costs amounted to 6.5% of total costs (readmission costs / readmission + index costs) for the readmitted patients. In-hospital mortality was reported at 10.5% among patients that were rehospitalized within 30-days. Roughly 10% of the readmitted patients had an associated diagnosis of cardiogenic shock, with low rates of overall mechanical support device use among readmitted patients (IABP 1.3%, Impella/TandemHeart 0.2%, ECMO 0.3%, long term ventricular assist device placement in 1.8%).

3.3. Etiology for 30-day readmission

Among the 6433 readmissions, 2722 (42.3%) were for cardiovascular reasons and 3711 (57.7%) readmission were for non-cardiovascular etiologies (Fig. 1 and Supplementary Table C). Heart failure (24.0%), atrial or supraventricular arrhythmias (3.4%), hypertensive disorders (3.1%), ventricular arrhythmias (2.2%), acute coronary syndrome (1.5%), and hypotension (1.1%) were the commonest causes for cardiovascular readmissions. Infectious (11.7%), respiratory (9.2%), injury/burns/toxicity/poisoning related conditions (7.8%), gastrointestinal/hepatobiliary/pancreatic (6.9%) and genitourinary system disorders (4.6%) were among the commonest non-cardiovascular etiologies for readmission.

Table 1
Baseline characteristics of patients with non-acute myocardial infarction related cardiogenic shock during index admission, among those who survived to discharge.

Characteristics	Overall ($n = 24,665$)	30-day readmission		p value
		Yes (5570)	No ($n = 19,095$)	
Age (categories-%)				0.002
≤ 49 years	17.0	16.7	17.0	
50–64 years	29.8	31.5	29.3	
65–79 years	36.2	36.1	36.2	
≥ 80 years	17.0	15.7	17.4	
Female sex (%)	38.8	38.7	38.8	0.86
Weekend admission (%)	20.1	19.9	20.2	0.58
Elective admission (%)	17.9	17.4	18.1	0.29
Payer information (%)				<0.001
Medicare	59.4	62.0	58.7	
Medicaid	12.2	13.9	11.7	
Private	21.7	18.6	22.6	
Self-pay	3.0	2.3	3.2	
No charge	0.3	0.3	0.3	
Other	3.3	2.8	3.5	
Cost of hospitalization in USD (Mean)	69,947	77,213	67,841	<0.001
Length of stay categories				<0.001
≤ 7 days	30.5	24.6	32.2	
≥ 8 days	69.5	75.4	67.8	
Median household income category for patient's zip code[b] (percentile)				0.16
0–25th	27.8	29.0	27.5	
26–50th	26.1	25.8	26.2	
51–75th	24.7	24.2	24.8	
76–100th	21.5	21.0	21.6	
Elixhauser comorbidity index (Mean ± SD)	4.1 ± 2.1	4.3 ± 2.1	4.0 ± 2.1	<0.001
Charlson comorbidity index[a]				<0.001
≤ 1	22.1	16.9	23.7	
2	20.6	18.3	21.3	
≥ 3	57.2	64.8	55.0	
Hospital bedsize[c] (%)				0.08
Small	6.9	6.6	7.0	
Medium	19.1	18.3	19.3	
Large	74.0	75.2	73.7	
Location/Teaching status of hospital (%)				0.003
Urban Non-teaching	23.6	22.3	24.0	
Urban Teaching	73.5	75.2	73.0	
Rural	2.9	2.5	3.0	
Year (%)				0.76
2013	46.2	46.4	46.2	
2014	53.8	53.6	53.8	
Cardiomyopathy (%)				<0.001
Ischemic	35.1	37.0	34.6	
Non Ischemic	30.6	31.9	30.3	
Mixed	4.2	4.9	4.0	
Unspecified	30.0	26.2	31.2	
Valvular heart disease (%)	36.8	37.9	36.4	0.04
Hypertension with and without complications (%)	55.8	55.8	55.8	0.95
Diabetes with and without complications (%)	32.7	35.4	31.9	<0.001
Dyslipidemia (%)	38.1	38.2	38.0	0.85
Chronic pulmonary disease (%)	26.0	29.2	25.1	<0.001
Pulmonary circulation disorders (%)	7.2	7.7	7.1	0.12
Current or past smoker (%)	27.4	27.1	27.5	0.56
History of stroke or TIA (%)	8.5	8.9	8.5	0.32
History of myocardial infarction (%)	11.7	12.8	11.3	0.002
Drug abuse (%)	5.4	6.2	5.2	0.003
Alcohol abuse (%)	6.3	6.2	6.3	0.71
Peripheral vascular disorders (%)	12.6	13.3	12.3	0.06
Coagulopathy (%)	24.8	24.7	24.8	0.81
Deficiency anemia (%)	26.9	29.4	26.2	<0.001
Chronic blood loss anemia (%)	1.6	1.6	1.6	0.98
Collagen vascular disease or rheumatoid arthritis (%)	2.9	3.1	2.8	0.27
Hypothyroidism (%)	13.1	13.4	12.9	0.34
Liver disease (%)	5.4	6.2	5.2	0.007
Fluid and electrolytes disorders (%)	63.4	63.9	63.3	0.40
Obesity (%)	17.4	17.8	17.3	0.41
Obstructive sleep apnea (%)	10.1	12.2	9.5	<0.001
Sepsis (%)	12.8	14.0	12.4	0.002
Cardiac conduction disease (%)	28.4	30.6	27.8	<0.001
Atrial fibrillation or flutter (%)	46.1	48.0	45.6	0.002
Ventricular tachycardia or fibrillation (%)	20.9	22.1	20.6	0.01
Acute kidney injury (%)	55.6	60.2	54.3	<0.001
Chronic kidney disease (%)	36.6	44.5	34.3	<0.001
Depression (%)	9.2	10.3	8.9	0.003
Psychoses (%)	4.4	4.8	4.2	0.05
Valvular heart disease (%)	8.2	9.2	7.9	0.002
Vasopressor or inotrope use (%)	9.4	8.9	9.6	0.09
Ventilator use (%)	37.6	34.6	38.4	<0.001
Ischemic stroke (%)	3.0	2.8	3.0	0.46
Systemic thromboembolic event excluding AMI and stroke (%)	3.5	3.8	3.4	0.09
Gastrointestinal bleeding (%)	3.3	3.8	3.1	0.01
Prior venous thromboembolic event (%)	4.0	4.3	4.0	0.28
Acute deep venous thrombosis (%)	5.8	5.5	5.9	0.25
Acute pulmonary embolism (%)	4.8	3.7	5.1	<0.001
Blood product transfusion (%)	24.1	26.1	23.5	<0.001
Right heart catheterization (%)	22.7	25.3	22.0	<0.001
Percutaneous coronary intervention (%)	2.4	2.3	2.4	0.54
Coronary artery bypass grafting (%)	9.5	8.8	9.7	0.03
Other cardiac surgery[d] (%)	30.6	31.1	30.4	0.32
Intra-aortic balloon pump (%)	10.0	10.1	10.0	0.84
Ventricular assist device (%)	4.2	6.2	3.7	<0.001
Vascular complications (%)	3.8	3.8	3.8	0.89
Major bleeding event (%)	14.0	14.5	13.9	0.20
Discharge disposition (%)				<0.001
Home	34.8	31.4	35.8	
Short-term hospital	4.4	3.5	4.7	
SNF	29.8	30.8	29.5	
Home with HHC	29.9	33.0	29.0	

Variables involving <2% of population have been represented in Supplementary Table F.
SD: standard deviation, USD: United States Dollar, IQR: Interquartile range, TIA: transient ischemic attack, SNF: skilled nursing facility, HHC: home health care.

[a] Charlson/Deyo co-morbidity index (CCI) was calculated as per Deyo classification.

[b] Represents a quartile classification of the estimated median household income of residents in the patient's ZIP Code, derived from ZIP Code-demographic data obtained from Claritas. The quartiles are identified by values of 1 to 4, indicating the poorest to wealthiest populations. Because these estimates are updated annually, the value ranges vary by year.

[c] The bed size cutoff points divided into small, medium, and large have been done so that approximately one-third of the hospitals in a given region, location, and teaching status combination would fall within each bed size category. *State and County QuickFacts*. Washington, DC: US Census Bureau; 2012.

[d] Cardiac surgery excluding coronary artery bypass grafting.

3.4. Predictors of in-hospital mortality

Predictors of higher in-hospital mortality (Table 2 and Supplementary Table E) were older age (50-64 years adjusted odds ratio 1.29; 65–79 years aOR 1.59, and ≥80 years aOR 2.69), self-pay (aOR 1.41), and comorbidities such as ventilator use (aOR 4.25), sepsis (aOR 1.12), metastatic cancer (1.91), acute kidney injury (aOR 1.21), liver disease (aOR 1.43), ventricular tachycardia or fibrillation (aOR 1.17), chronic kidney disease (aOR 1.15), and peripheral vascular disorders (aOR 1.12) among others. Use of intra-aortic balloon pump (aOR 2.67), Impella/TandemHeart (aOR 4.84) and extracorporeal membrane oxygenation (aOR 3.68) were predictive of higher in-hospital mortality. On the other hand, presence of an underlying non-ischemic cardiomyopathy (aOR 0.65), mixed ischemic and non-ischemic cardiomyopathy (aOR 0.69), or acute myocarditis (aOR 0.37) was associated with lower

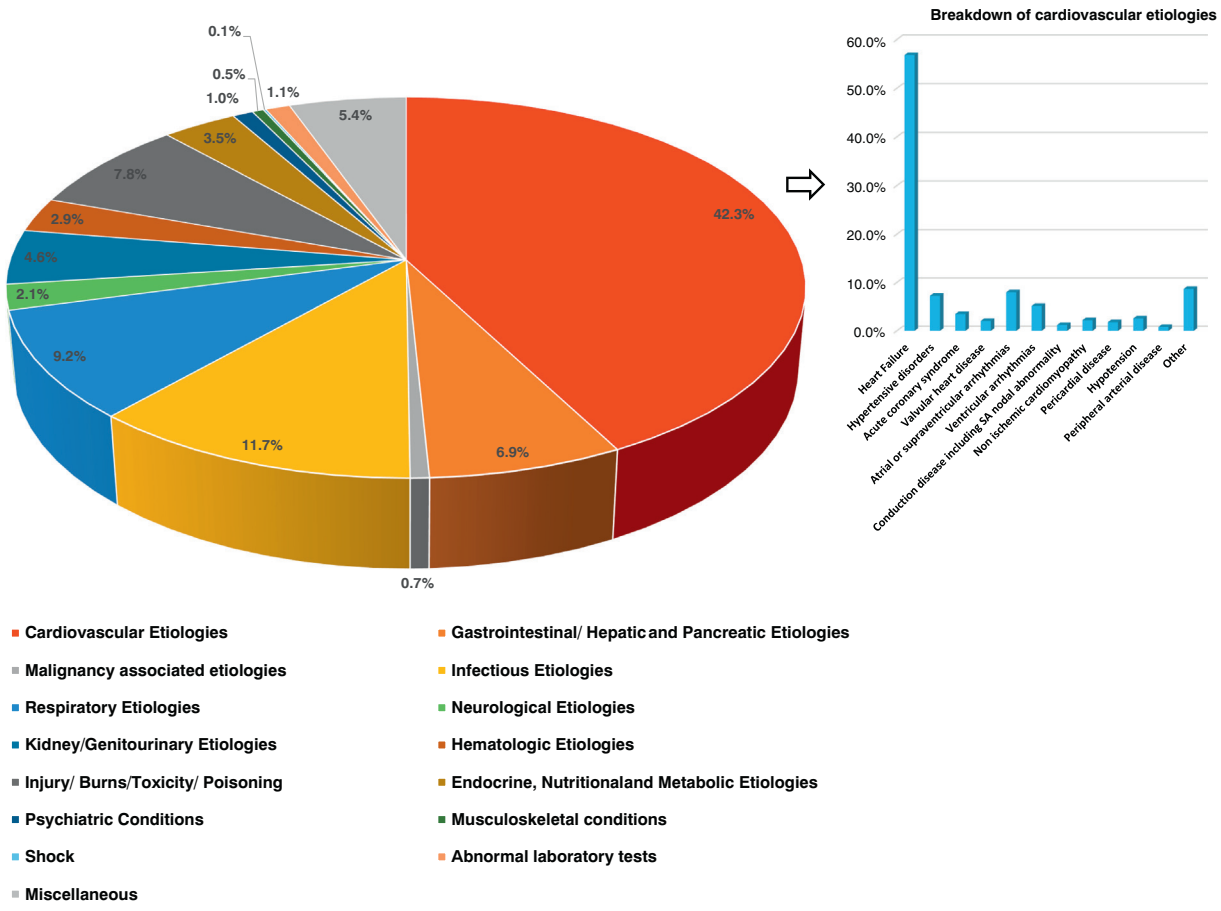

Fig. 1. Etiologies for 30-day readmission among non-acute myocardial infarction related cardiogenic shock.

in-hospital mortality. Use of revascularization techniques such as percutaneous coronary intervention (PCI aOR 0.55) and coronary artery bypass grafting (CABG aOR 0.43) were associated with lower in-hospital mortality.

A subset analysis among patients with either ICM or mixed ICM and NICM revealed a lower adjusted in-hospital mortality seen with CABG (aOR 0.59) but not PCI within this patient subgroup. Rate of revascularization was low among such patients (CABG 2.5% and PCI 1.1%).

Table 2
Significant predictors of in-hospital mortality.

Variable	AOR (95% CI)	Variable	AOR (95% CI)
Elective admission	0.74 (0.68–0.81)	Age 50–64 (vs. 16–49 years)	1.29 (1.19–1.41)
Medicaid insurance (vs. Medicare)	0.87 (0.79–0.96)	Age 65–79 (vs. 16–49 years)	1.59 (1.45–1.75)
Private insurance payer (vs. Medicare)	0.80 (0.74–0.87)	Age ≥ 80 (vs. 16–49 years)	2.69 (2.42–3.00)
Charlson comorbidity index 2 (vs. ≤1)	0.91 (0.84–0.98)	Self-pay (vs. Medicare)	1.41 (1.23–1.62)
Urban teaching hospital (vs. urban non-teaching)	0.93 (0.88–0.98)	Peripheral vascular disorders	1.12 (1.04–1.21)
Non ischemic cardiomyopathy	0.65 (0.61–0.70)	Coagulopathy	1.16 (1.09–1.24)
Mixed Ischemic and non-ischemic cardiomyopathy	0.69 (0.60–0.80)	Hypothyroidism	1.10 (1.01–1.20)
Acute myocarditis	0.37 (0.25–0.53)	Liver disease	1.43 (1.28–1.58)
Dyslipidemia	0.91 (0.86–0.97)	Sepsis	1.12 (1.04–1.20)
Drug abuse	0.77 (0.68–0.87)	Ventricular tachycardia or fibrillation	1.17 (1.10–1.24)
Alcohol abuse	0.83 (0.74–0.92)	Acute kidney injury	1.21 (1.15–1.27)
Deficiency anemia	0.71 (0.67–0.76)	Chronic kidney disease	1.15 (1.07–1.23)
Chronic blood loss anemia	0.61 (0.49–0.77)	Vasopressor use	1.36 (1.26–1.47)
Obesity	0.86 (0.80–0.93)	Ventilator use	4.25 (4.04–4.49)
Obstructive sleep apnea	0.84 (0.76–0.92)	Metastatic cancer	1.91 (1.62–2.25)
Cardiac conduction disorder	0.81 (0.77–0.86)	Solid tumor without metastasis	1.28 (1.08–1.50)
Atrial fibrillation or flutter	0.78 (0.74–0.82)	Acute pulmonary embolism	1.15 (1.02–1.29)
Depression	0.90 (0.82–0.98)	Intra-aortic balloon pump	2.67 (2.36–3.03)
Percutaneous coronary intervention	0.55 (0.45–0.67)	Impella/TandemHeart	4.84 (3.82–6.13)
Coronary artery bypass grafting	0.43 (0.37–0.49)	Extracorporeal membrane oxygenation	3.68 (2.97–4.55)
Other cardiac surgery	0.36 (0.33–0.40)		
Ventricular assist device	0.60 (0.48–0.75)		
Vascular complications	0.77 (0.66–0.91)		
Major bleeding event	0.70 (0.63–0.77)		

AOR: adjusted odds ratio, CI: confidence interval.
p-value for all variables <0.05.

3.5. Predictors of 30-day readmission

On multivariable analysis (Fig. 2 and Supplementary Table D), older age (65–79 years aOR 1.25; ≥80 years aOR 1.41), insurance payer (private aOR 1.32 and self-pay aOR 1.41), and the presence of underlying NICM (aOR 1.11) were independent predictors of higher 30-day readmission. The presence of comorbidities such as acute myocarditis (aOR 1.43), acute pulmonary embolism (aOR 1.27) ventilator use (aOR 1.21), obesity (aOR 1.09) and fluid or electrolyte disorders (aOR 1.07). Longer length of hospital stay (≥3 days), female sex, and the presence of comorbidities such as chronic pulmonary disease, and obstructive sleep apnea among others predicted lower 30-day readmission. The use of Impella/TandemHeart (aOR 0.66) or long term ventricular assist device (aOR 0.69) during index admission also predicted lower 30-day readmission. Discharge to either a skilled nursing facility (aOR 0.88) or home with home health care (HHC aOR 0.88) was predictive of a lower 30-day readmission rate.

4. Discussion

To the best of our knowledge, our study has reported the largest and most comprehensive analysis for both index admissions and 30-day readmissions following non AMI associated cardiogenic shock within the United States. The major findings of our study were as follows: 1) 22.6% of the discharged patients were readmitted within 30 days of discharge, 2) in-hospital mortality was significantly elevated among

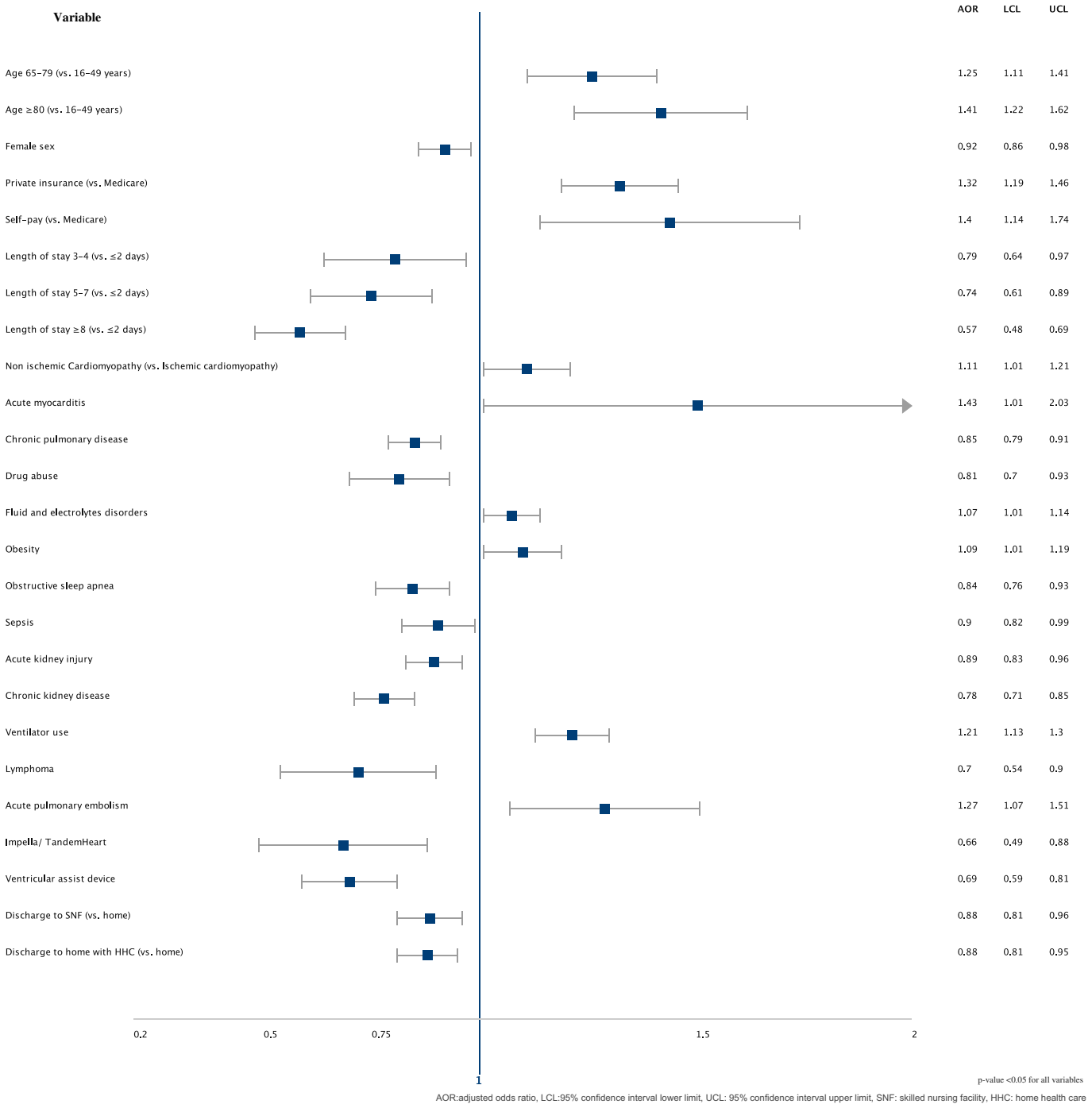

Fig. 2. Multivariate predictors of 30-day readmission among non-acute myocardial infarction related cardiogenic shock.

index admissions at 35.4%, 3) cardiovascular disorders were responsible for roughly 42% of all 30-day readmissions, 4) age ≥50 years, ventilator use, sepsis, underlying metastatic cancer, acute kidney injury, liver disease, coagulopathy, and use of short term MCS devices (IABP, Impella/TandemHeart and ECMO) were predictors of higher mortality, 5) underlying NICM and revascularization in from of either PCI or CABG was independently associated with lower mortality, 6) age ≥65 years, presence of NICM, acute myocarditis, acute pulmonary embolism, ventilator use, Impella/TandemHeart use, permanent VAD implantation, and discharge to either SNF or home with HHC were predictors of 30-day readmission, and 7) 30-day readmissions accounted for significant economic burden accounting to 6.5% of total hospitalization related costs.

Reduction in unplanned rehospitalization and associated costs is no longer limited to CMS, with increasing initiatives from large commercial insurers promoting similar policies. An increasing amount of research, time and resources is being directed towards understanding various factors contributing to this phenomenon [12–15]. Jencks et al. in their analysis of >11 million Medicare beneficiaries reported a 19.6% thirty-day and 34% ninety-day readmission rate across all admissions [16]. Heart failure and AMI are the two most commonly studied cardiovascular disorders when it comes to readmissions [6]. Previous reports on readmission rates have varied widely secondary to methodological differences, diverse study populations, and inclusion criteria among others [17, 18]. These studies highlight the need for a multidisciplinary approach to tackle rehospitalization, taking into account patient and hospital characteristics, quality of inpatient care, transition of care and outpatient interventions. Readmission rates following AMI were typically lower than those seen after discharge for heart failure (19.1% vs. 24.8%, respectively according to one study) [6], however temporal improvements in AMI associated readmission rate have lagged improvements in mortality despite improved access to revascularization, and higher rate of use of evidence based treatments [17, 19, 20]. Readmission following cardiogenic shock has not been well studied. Furthermore, outcomes on non AMI associated CS have never been studied in trials or large scale observational studies. Jerger et al. examined data from the SHould we emergently revascularize Occluded Coronaries in cardiogenic shocK? trial and found that 45% of the survivors were readmitted, mainly for either heart failure or AMI in 74% of the cases [21]. Shah et al. retrospectively analyzed 112,668 survivors of AMI, and found a 33.9% rate of all cause death or hospitalization at 60 days post discharge [22]. Heart failure-specific readmissions comprised 23.8% of all readmissions. A comparison to our findings may be inappropriate, as these studies studied smaller samples of patients with CS, and more importantly excluded non AMI related CS from their analyses. We noted that the overall rate of readmission was 14.2% across all patients hospitalized with non AMI related CS. The in-hospital mortality of 35.4% causes significant underestimatation of the actual impact of this finding on the affected population. Prior studies have repeatedly noted the influence of mortality on readmission rates, as lowering mortality rates leave presumably sicker patients alive with higher likelihood for readmission and vice versa [19, 23]. Three-fifths of all readmissions were secondary to cardiovascular etiologies, and a quarter were attributed to heart failure in our study, however the rate of acute coronary syndrome (1.5%) related readmission was a small fraction of what has been noted before.

Historically mortality in CS complicating AMI was in the range of 75–80% but has improved to just a third of all patients on analysis of real world data from the National Inpatient Sample within the last decade, likely secondary to early revascularization and mechanical circulatory support (MCS) device use [24, 25]. The in-hospital mortality rate of 35.4% with non AMI CS is comparable to that seen with AMI according to recent estimates, however the role of revascularization and MCS in this population has only had a theoretical basis. A recent analysis by Shah et al. has also demonstrated that the proportion of patients with non AMI related CS has been steadily increasing in recent years, with patients in this category actually having a slightly worse mortality compared to AMI associated CS [26].

Our study showed that revascularization by either PCI or CABG predicted lower hospital mortality, especially among those with an ischemic cardiomyopathy. An analysis from the GUSTO-1 database found that increasing age, prior AMI, and oliguria were among predictors for worse 30-day survival [27]. The CardioShock study analyzed AMI and non AMI CS, to find that older age, previous MI, lower ejection fraction, low glomerular filtration rate were independently associated with increased in-hospital mortality [28]. We found that patients in older age groups (≥50 years), underlying acute or chronic kidney injury, sepsis, ventilator use, metastatic cancer, and acute ischemic stroke among others were independently associated with higher mortality. Older age remains a prominent risk factor for worsened mortality among patients with AMI and non AMI associated CS [26]. Non-ischemic cardiomyopathy is typically associated with better intermediate to short terms outcomes compared with ischemic etiology, however our study revealed a previously unrealized short term survival advantage with CS within this subgroup.

The rate of use of short term MCS (either IABP, Impella/TandemHeart or ECMO) in the entire study population was 11.2%, much lower than has been reported with CS complicating STEMI (>50%) [26, 29]. We found no difference between the calendar years on use of revascularization or total short term MCS use ($p > 0.05$). There was a slight increase in the subset of patients receiving ECMO in 2014 from 2013 (2.1% vs. 1.7%, $p < 0.05$). While the use of short term MCS devices has failed to show definitive mortality benefit in patients with CS complicating AMI, use of short term MCS devices with non-AMI CS predicted higher in-hospital mortality according to our results [30, 31]. Caution must be advised before more widespread implementation of MCS in such a population.

Medicare payments for unplanned rehospitalizations in year 2004 accounted for about $17.4 billion of the $102.6 billion in hospital payments from Medicare. The data on all-cause readmissions from 2009 to 2013 showed that the average cost of a readmission was higher than the average cost of an index admission [32]. Our economic analysis revealed that the average cost of 30-day readmissions was 6.5% of the total costs involved for readmitted patients. Data on predictors of readmission following hospital discharge for CS is lacking. A recent post discharge analysis of patients treated for CS with either Impella or ECMO found a lower rate of readmission with Impella at 30-days (25.9% vs. 34.1% respectively). The authors concluded that Impella use reduced risk of hospitalization, shortened length of hospital stay and eventually lower expenditures [33]. These findings were also seen in study of 1188 patients receiving either Impella or ECMO for CS complicating AMI, where Impella use resulted in better survival, shorter length of stay, and lower costs compared to ECMO [34]. Our findings were consistent in that Impella/TandemHeart use predicted lower 30-day readmission even in the case of non AMI CS. Discharge to a SNF or home with home health care was seen to predict lower readmission, which emphasizes the role of transition of care and appropriate allocation of resources to improve patient outcomes as noted in previous studies [35, 36]. We suspect that several risk factors such as acute or chronic renal disease, and sepsis were factors that counterintuitively predicted lower readmission rates possibly from either a bias towards survival among less sick patients within that category or from an inability of the database to track outcomes outside of an inpatient setting. It is possible that such patients had a more closely monitored post-discharge course, earlier outpatient visits with a more focused approach on prevention of readmission within this population, since they are expected to be at higher risk for worse outcomes. Our findings will certainly need validation in future prospective and retrospective cohort studies.

Our study has several limitations, some of which are inherent to the administrative nature of database and reliance on ICD-9CM codes. Non-AMI CS is a relatively heterogeneous disease, especially when compared

to AMI-related CS further limiting generalizability of these findings. The national readmission and inpatient databases maybe especially poor at identifying certain treatment approaches such as inotrope/vasopressor use (measured at only 10.9% within our study) which would be expected to be a common initial strategy in cardiogenic shock. Several of the included variables including mechanical support devices formed a relatively minor subset (between 1 and 10%) of study population, limiting their ability in predicting outcomes across all non-AMI CS admissions. Causes of readmission were identified using the primary discharge diagnosis codes. However, such a methodology has been used in previously published studies [37–39]. Inclusion of several variables within the multivariate model raises potential for correlations affecting the analysis, however we did not find evidence of multicollinearity among the variables within the model. Patients who are readmitted to a hospital in a different state are not tracked in the NRD. Inability to track mortality data on patients who died outside the hospital may have led to underestimation, but we found that 10.5% of the readmitted patients died during rehospitalization within 30-days reaffirming that these patients continue to be at risk for higher mortality in the short term. We were unable to determine at exact etiology for non AMI CS, and considering the heterogeneity of non AMI CS seen in clinical practice including the phenomenon of acute worsening of a chronic low-flow state, further research may be needed to differentiate outcomes depending on responsible etiology. We mitigated several of these limitations by studying a large group of non AMI CS admissions that are representative of real world practice.

Patients with non AMI CS are subject to high in-hospital mortality while survivors remains at risk for elevated short term mortality and early readmission. A majority of the readmissions occurred for non-cardiovascular etiologies which has potential to impact future strategies. As both outpatient and inpatient care of cardiovascular disease patients improves, we expect to see more patients surviving with more advanced cardiac disease, possibly leading to the higher rates of non AMI associated CS over time in clinical practice. Information on the etiologies and predictors for readmission and mortality will help clinicians and hospitals devise strategies to tackle these issues and enhance outcomes, cost-effectiveness of care and quality of patient care.

Disclosures

None of the authors has any disclosures relevant to the content of the manuscript.

Funding sources

No study specific funding was used to support this work. The authors are solely responsible for the study design, conduct and analyses, drafting and editing of the manuscript and its final contents. All authors had access to the data and a role in writing the manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijcard.2018.06.036.

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