Cardiac Catheterization and Outcomes for Elderly Patients Hospitalized With Heart Failure

Health Services Insights
Volume 17: 1–14

DOI: 10.1177/11786329231224616
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Palak Patel[1], Ivan Richard[1], Giuseppe Filice[1], Ivan Nikiforov[1], Priyaranjan Kata[1], Anish Kumar Kanukuntla[1], Arthur Okere[1], Christopher S Hollenbeak[2] and Pramil Cheriyath[1]

[1]Hackensack Meridian Health Ocean Medical Center, Brick Township, NJ, USA. [2]Department of Health Policy and Administration, College of Health and Human Development, The Pennsylvania State University, University Park, PA, USA.

ABSTRACT

BACKGROUND: Heart failure affects over 6 million people in the United States (US) with limited evidence to support the use of cardiac catheterization. The benefit of its use remains mostly as expert opinion. This study intends to assess the benefits and risks of cardiac catheterization in elderly patients admitted for heart failure.

METHODS: This was a retrospective study using data from the National Inpatient Sample, including admissions 65 years and older hospitalized for heart failure, between 2008 and 2016. The outcomes analyzed were in-hospital mortality, total hospital costs, and length of stay.

RESULTS: After controlling for covariates, cardiac catheterization was found to have a protective association with mortality (OR 0.87, 95% CI 0.833-0.912, $P < .0001$), an increased hospital length of stay by 2.88 days (95% CI: 2.84-2.92 days, $P < .0001$) and approximately $16 255 increase in cost.

CONCLUSIONS: Cardiac catheterization was associated with decreased in-hospital mortality, longer length of stay and higher total costs in admissions with heart failure aged 65 years or older.

KEYWORDS: Heart failure, elderly, cardiac catheterization, mortality, length of stay, retrospective

RECEIVED: September 22, 2022. **ACCEPTED:** November 28, 2023.

TYPE: Original Research

FUNDING: The author(s) received no financial support for the research, authorship, and/or publication of this article.

DECLARATION OF CONFLICTING INTERESTS: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

CORRESPONDING AUTHOR: Pramil Cheriyath, Hackensack Meridian Health Ocean Medical Center, 425 Jack Martin Blvd, Brick Township, NJ 08724, USA. Email: Pramil.cheriyath@hmhn.org

Introduction

Heart failure (HF) is a clinical syndrome that is chronic by nature and results from the inability of the heart to circulate enough blood to meet the demands of the body.[1] In the United States (US), it is estimated that 6.2 million people suffer from HF.[2] The number of HF cases has been increasing over the years, at least in part due to the increased survival of those who are living with HF.[2] Although HF mostly affects people who are 60 years or older, it can affect people as young as 20 years old and about 1.4 million cases are in those younger than 60.[2,3] HF is responsible for about 875 000 hospitalization every year and has a 5-year mortality of over 50%.[3]

It has been estimated that in the US 50% to 70% of HF cases have underlying coronary artery disease, though there is also some evidence that this estimate may be too low.[4] As a result, some research suggests that ischemic heart disease may be instrumental in the progression of HF.[4] Cohort studies have suggested that as many as 95% of people who develop HF have a prior ischemic event.[4] Despite the potential role played by ischemia in HF, there is little evidence to support the use of invasive measure to evaluate HF. Specifically, the American Heart Association (AHA) guidelines recommend coronary arteriography as a level C recommendation when ischemia may be contributing to HF.[1] While there are a number of criteria and guidelines that support the use of cardiac catheterization in heart failure, there are no large-scale studies that explore this issue. In this study, we use a large, national discharge data set to examine the association between cardiac catheterization and outcomes, including in-hospital mortality, length of hospital stay, and total costs, for admissions with a primary diagnosis of HF.

Methods

Data source

Data used in this study were from the National Inpatient Sample (NIS), Healthcare Cost and Utilization Project (HCUP), provided by the Agency for Healthcare Research and Quality (AHRQ). The NIS is the largest all-payer administrative discharge data set in the US and contains information on discharges from community hospitals across the country.[5] NIS data are de-identified and this study was therefore not human subjects research under 45 CFR Part 46 and was exempt from IRB review.

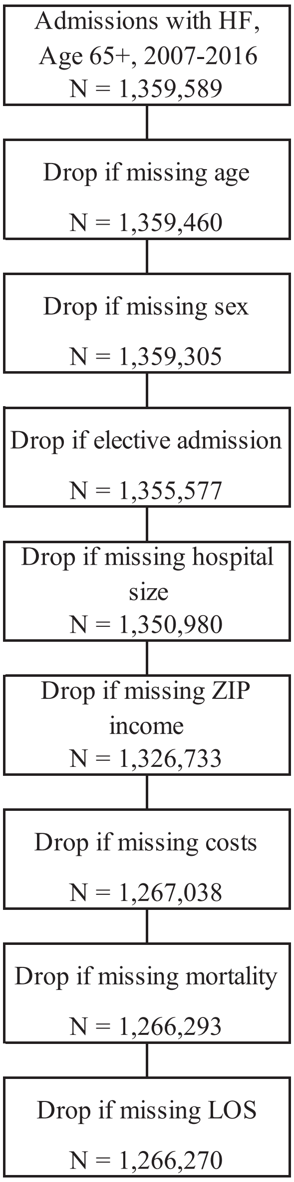

Figure 1. Derivation of the study sample. The study cohort included 1 266 270 admissions of patients with HF between 2007 and 2016 from the NIS.

Cohort

Details about the derivation of the study cohort are presented in Figure 1. Inclusion criteria for this study were admissions aged 65 years and older who were hospitalized in the NIS with a principal diagnosis of heart failure between 2008 and 2016. There were no exclusion criteria. Heart failure was identified using a principal International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) code of 428.XX (heart failure) or a principal International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) code of I50.XX (heart failure). This definition of heart failure is broad and includes heart failure with reduced ejection fraction (HFrEF), heart failure with preserved ejection fraction (HFpEF), and congestive heart failure (CHF). Patients receiving procedures, including coronary artery bypass graft (CABG) surgery were included. Admissions with missing values for demographics and outcomes were removed by casewise deletion.

Outcomes

Three outcomes were examined in this study: length of hospital stay, total costs, and in-hospital mortality. Length of hospital stay included all inpatient days from admission until discharge or death. Costs were defined from the hospital perspective and estimated using a ratio of costs-to-charges method. To account for inflation over the time period represented in our sample, costs were adjusted to year 2018 US dollars using the medical care component of the consumer price index.

Covariates

Analyses controlled for important potential confounders, including admission demographics and hospital characteristics. Demographic characteristics included age (65-74, 75-79, 80-84, 85+), sex (male, female), race (white, black, Hispanic, Asian, other), and primary payer (Medicare, Medicaid, commercial, other). We also controlled for the income quartile of the patient's ZIP code as a proxy for socioeconomic status. Comorbidities were controlled using the Charlson et al Comorbidity Index (CCI), weighted index of 17 comorbidities that can be identified using ICD-9-CM and ICD-10-CM diagnosis codes.[6-8] We controlled several hospital characteristics, including the size of the hospital (small, medium, large) the teaching status of the hospital, and the geography of the hospital (rural, urban). We also controlled for clinical characteristics of the admission, including the urgency of admission (elective, nonelective), whether the admission was transferred from another hospital, and whether the admission had either a recent or past acute myocardial infarction (AMI). Recent AMI was identified using a secondary ICD-9-CM code of 410.XX (acute myocardial infarction) or a secondary ICD-10-CM code of I21.XX (acute myocardial infarction) or I22.XX (subsequent ST elevation [STEMI] and non-ST elevation [NSTEMI] myocardial infarction). Past AMI was identified using a secondary ICD-9-CM code of 412.XX (old myocardial infarction) or a secondary ICD-10-CM code of I25.2 (old myocardial infarction). Use of mechanical circulatory support (MCS) was identified defined using ICD-9-CM procedure codes 37.68 (percutaneous) or 37.60 and 37.65 (non-percutaneous); Intra-aortic balloon counterpulsation (IABP) was defined using ICD-9-CM procedure code 37.61, extracorporeal membrane oxygenation (ECMO) using ICD-9-CM procedure code 39.65 (central ECMO), and percutaneous cardiopulmonary support (PCPS; peripheral ECMO) using code 39.66, with corresponding ICD-10-PCS codes. All

ICD-9 and ICD-10 codes used to define study variables are included in Appendix A. There was a small proportion of observations with missing values for covariates; this was handled using casewise deletion.

Statistical analysis

Statistical analyses were designed to determine whether there was a significant association between utilization of cardiac catheterization and outcomes (mortality, length of hospital stay, and total hospitalization costs). Admissions were compared between those with and without cardiac catheterization using t tests for continuous variables and chi-squared tests for binary and categorical variables. Mortality was modeled using logistic regression, controlling for other admission, clinical, and hospital characteristics. Results were presented as odds ratios with 95% confidence intervals and *P*-values for the test of the null hypotheses for all covariates. Linear models were fit to length of stay and total costs using ordinary least squares and controlling for admission, clinical, and hospital characteristics. The primary covariate of interest in all multivariable models was a binary indicator of cardiac catheterization.

To check whether treatment effects in the multivariable models were biased due to potential covariate imbalance, a propensity score analysis was performed. Propensity score analysis was performed using inverse probability weighting.[9] Standardized differences from the propensity score analysis were computed for each covariate in order to determine whether balance was achieved. Results from the propensity score analysis were presented as the average treatment effects (ATE), which is the expected difference in outcome if all patients received (vs not received) cardiac catheterization. Statistical analyses were performed using STATA software (version 15, College Station Texas). Statistical significance was defined as $P < .05$.

Results

A total of 1 266 270 admissions for admissions 65 years or older with a primary diagnosis of heart failure were found in the HCUP NIS data between 2007 and 2016. Of these, 72 195 (5.7%) received cardiac catheterization and 1 194 075 (94.3%) did not. Among patients receiving cardiac catheterization, 51.9% received left heart catheterization only, 14.6% received right heart catheterization, and 34.5% received both left and right catheterization. Trends over time in cardiac catheterization rates and outcomes are presented in Figure 2. As seen in Figure 2 (Panel A), overall utilization of cardiac catheterization rose from a low of 5.1% in 2007 to a high of 6.5% in 2016. In addition, the mean total cost of admission remained relatively constant overtime for both admissions with and without cardiac catheterization (Panel B). However, admissions who received cardiac catheterization had consistently higher total costs of approximately $18 000 each year. Part of this cost difference is attributable to a longer length of hospital stay for admissions who received cardiac catheterization. As seen in Panel C, the average length of stay remained relatively constant at 5 days for admissions without cardiac catheterization, length of stay rose slightly over time, from 7.6 days in 2007 to 8.1 days in 2016, for admissions with cardiac catheterization. Finally, trends in mortality, unadjusted for other factors, rose 43.5% from 2.3% in 2007 to 3.3 % in 2016 for admissions with cardiac catheterization (Panel D). Over the same period, mortality fell 15%, from 3.9% into a 2007 to 3.3% in 2016, for admissions without cardiac catheterization.

Characteristics of elderly patients admitted for heart failure, stratified by cardiac catheterization, are presented in Table 1. All characteristics differed significantly between these 2 groups mostly because of the very large sample size. Patients who were admitted and received cardiac catheterization tended to be younger (75.3 years vs 80.1 years, $P < .0001$), more likely to be male (54.2% vs 45.8%, $P < .0001$) and to have had an acute myocardial infarction either recently or in the past (20.8% vs $P < .0001$). They were also more likely to be treated at a large urban teaching hospital, where it is likely that cardiac catheterization was more available.

Results of the multivariable model of mortality are presented in Table 2, which shows that after controlling for admissions and institutional characteristics, admissions who received a cardiac catheterization had 37.1% lower odds of dying relative to admissions who did not receive cardiac catheterization ($P < .0001$). There were several other risk factors for mortality. Increasing age was associated with greater odds of mortality and white race. Each additional one-point increase in the CCI was associated with 4% greater odds of in-hospital mortality. Admissions with a history of acute myocardial infarction had lower odds of dying before discharge ($P < .0001$). Patients receiving MCS had an odds of mortality more than 11 times greater than those that did not (OR = 11.5, $P < .0001$).

As seen in Table 3, after controlling for other factors, admissions who received cardiac catheterization had a hospital stay that was 2.6 days longer ($P < .0001$) than admissions who did not have cardiac catheterization. Several other factors were associated with length of stay, but only receipt of MCS had a larger association with LOS. Admissions receiving MCS were on average 12.2 days longer ($P < .0001$).

Results of the multivariable total hospitalization costs are presented in Table 4, which shows that admissions who received cardiac catheterization cost on average $14 154 more ($P < .0001$) than admissions who did not receive cardiac catheterization. There were several other determinants of costs. Admissions for older patients tended to cost less than those of younger patients, and women incurred lower costs than men. Each additional one-point increase in the CCI was associated $152 in additional costs ($P < .0001$). Patients admitted on an elective basis incurred $4154 more ($P < .0001$) in costs then

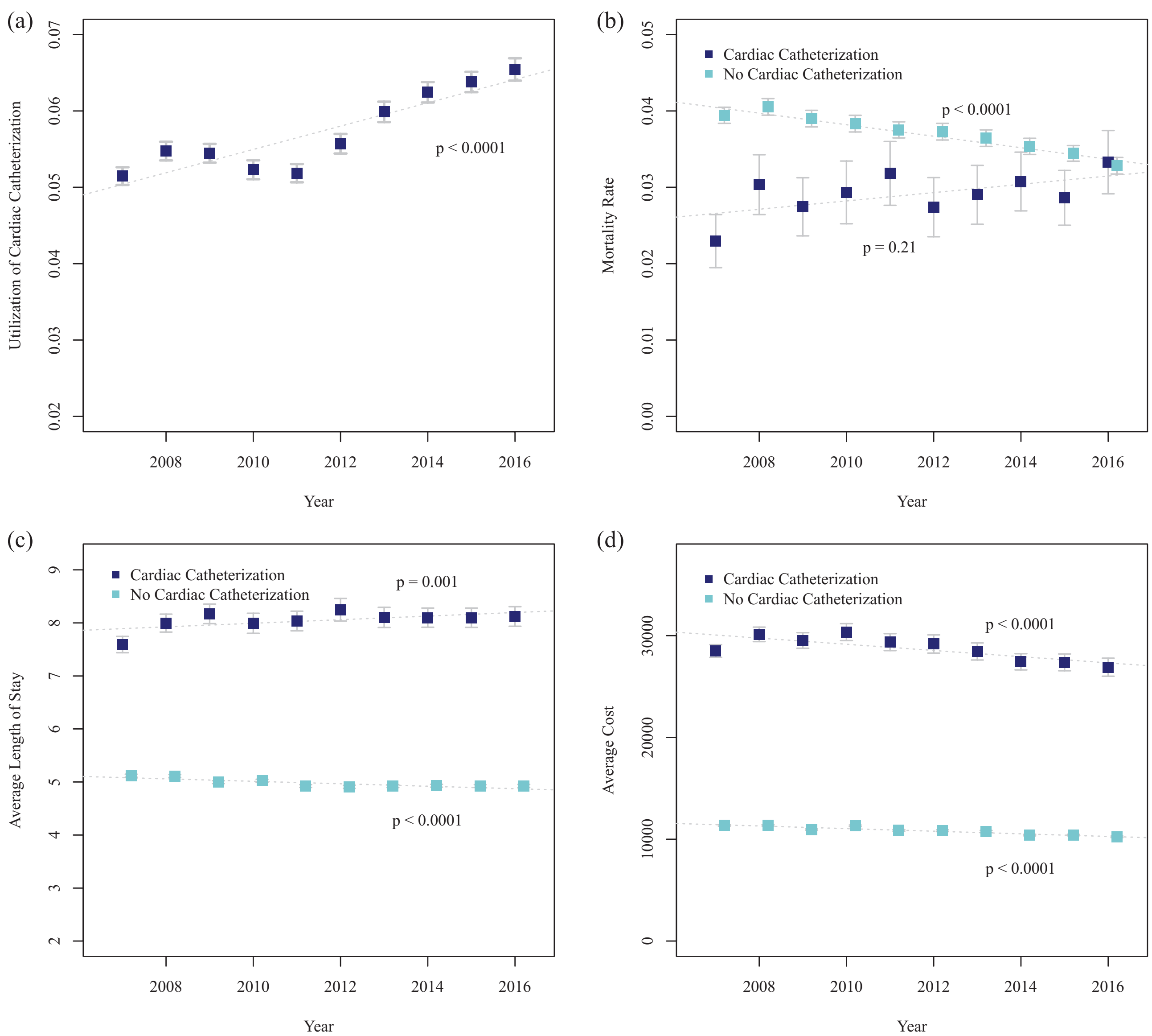

Figure 2. Trends in utilization of cardiac catheterization (A), mortality (B), length of hospital stay (C), and total costs (D) for admissions admitted for heart failure.

patients admitted on an urgent/emergent basis. Patients who were transferred from another institution incurred \$2154 more ($P < .0001$) in costs then patients admitted directly. Notably, patients with a history of acute myocardial infarction incurred costs that were not substantially different from patients without such a history. Admissions requiring MCS cost on average \$82 967 more than those that did not require MCS ($P < .0001$).

Results of the multivariable models were largely confirmed by the propensity score analysis. Standardized differences suggested good balance in the propensity score analysis, with all but 3 covariates within the 0.25 limit (Appendix B). The average treatment effect for mortality implied an odds ratio for cardiac catheterization of 78.6% (95% CI: 73.1-84.0). This was a slightly larger effect than was observed in the multivariable model. For LOS the average treatment effect implied that if all patients had received cardiac catheterization the expected mean LOS would have been 2.67 days longer (95% CI: 2.62-2.74). And expected costs would have been \$15 067.11 more on average (95% CI: \$14 845.05-\$15 289.17) had all patients received cardiac catheterization.

Discussion

This study found that there were several factors that impacted the mortality of HF admissions. By itself, cardiac catheterization greatly reduced the odds of mortality, as well as, younger age, female gender, type of insurance, elective versus emergent procedures, hospital size and location, and transfer from another hospital. We also observed that many patients admitted for left heart catheterization also received right heart catheterization. Racial disparities were also present with whites having higher mortality than all other races, though not all the results were statistically significant. Receiving cardiac

Table 1. Characteristics of admissions admitted for HF, stratified by receipt of cardiac catheterization.

VARIABLE	CARDIAC CATHETERIZATION	NO CARDIAC CATHETERIZATION	*P*-VALUE
	N = 72 195	N = 1 194 075	
Age	75.30	80.107	<.0001
65-74	48.5%	27.7%	
75-79	22.5%	17.4%	
80-84	18.2%	20.3%	
85+	10.8%	34.5%	
Sex			<.0001
Male	54.2%	45.8%	
Female	45.8%	54.2%	
Race			<.0001
White	65.7%	68.2%	
Black	12.3%	10.9%	
Hispanic	6.7%	5.9%	
Asian	1.8%	1.6%	
Other	3.1%	2.4%	
Missing	10.5%	11.1%	
Payer			<.0001
Medicare	87.8%	90.6%	
Medicaid	1.8%	1.4%	
Commercial	8.5%	6.3%	
Other	1.7%	1.6%	
Missing	0.1%	0.1%	
Charlson Comorbidity Index	3.02	3.18	<.0001
Acute myocardial infarction			<.0001
Recent	10.1%	3.3%	
Past	11.6%	11.5%	
Any	20.8%	14.5%	
None	79.2%	85.5%	
Mechanical circulatory support			<.0001
Yes	0.1%	2.7%	
No	99.9%	97.3%	
Urgency of admission			<.0001
Elective	11.8%	7.7%	
Urgent/Emergent	88.2%	92.3%	
Hospital bed size			<.0001
Small	9.8%	18.2%	

(Continued)

Table 1. (Continued)

VARIABLE	CARDIAC CATHETERIZATION N = 72 195	NO CARDIAC CATHETERIZATION N = 1 194 075	*P*-VALUE
Medium	23.1%	26.8%	
Large	67.1%	55.1%	
Geography			<.0001
Rural	6.0%	16.8%	
Urban	94.0%	83.2%	
Teaching			<.0001
No	41.1%	57.9%	
Yes	58.9%	42.1%	
Transfer			<.0001
No	78.6%	82.5%	
Yes	11.2%	6.1%	
Missing	10.3%	11.4%	
Income quartile			<.0001
1	28.7%	30.1%	
2	26.2%	26.9%	
3	24.3%	23.4%	
4	20.9%	19.6%	

catheterization was associated with longer length of stay and higher costs.

HF continues to be one of the largest health concerns in developed and less-developed nations in the world. In the US, The Framingham Heart Study looked at the diagnosis of HF and outcomes and estimated a 30-day mortality of 10%, a 1-year mortality of 30%, and a 5-year mortality of 60%.[10] A more recent study found a 1-year mortality of 35.6% to 37.5% in HF admissions.[10] HF is a growing concern in the US as the incidence increased from 550 000 in 2005 to 915 000 in 2016.[10,11] The cost of HF in the US is estimated to be around $30.7 billion dollars annually.[12] It significantly contributes to the hospital utilization with readmission rates varying between 24.3% and 30.9% depending on the severity of HF.[11] Despite advances in treatment, HF mortality remains high. The current The American College of Cardiology Foundation and AHA guidelines recommend cardiac catheterization as part of the work up to evaluate for ischemia.

This study of elderly patients admitted for heart failure in the US suggests that cardiac catheterization is increasingly utilized in this population. Results suggested that admissions who received cardiac catheterization had significantly lower odds of dying before discharge compared to HF admissions who did not receive cardiac catheterization. This effect was observed after controlling for important admission and hospital characteristics. This highlights the significant impact cardiac catheterization can play in admissions with HF. It has been established for decades that ischemia is not only the leading cause of HF but also significantly increases morbidity and mortality of HF in the US.[13] MI is the other factor that significantly increases morbidity and mortality in HF.[13] These 2 factors are interconnected as ischemia is caused by the build-up of plaque in the coronary arteries, while MI is caused by rupture or erosion of the plaque leading to occlusions of the coronary vessels.[4] The presence of ischemia causes necrosis therefore leading to fibrosis and hypertrophy.[4] As these events continue, there is a remodeling of the heart that leads to the development of HF. These events may not have any accompanying clinical symptoms, which may delay the diagnosis until overt symptoms of HF are present. MI results in a more drastic loss of myocardial tissue and is associated with a 4-fold risk in mortality.[14]

The other factor that impacted mortality was age. As the study population got older, the chances of mortality increased significantly. In this study, the reference age group was 65 to 74 years, and for every decade beyond that the mortality rose.

Table 2. Results of multivariable model of mortality.

VARIABLE	ODDS RATIO	95% CONFIDENCE		*P*-VALUE
		LOWER	UPPER	
Cardiac catheterization	0.629	0.599	0.661	<.0001
Age				
65-74	REFERENCE			
75-79	1.318	1.276	1.361	<.0001
80-84	1.657	1.608	1.707	<.0001
85+	2.194	2.137	2.253	<.0001
Sex				
Male	REFERENCE			
Female	0.881	0.864	0.898	<.0001
Race				
White	REFERENCE			
Black	0.712	0.687	0.739	<.0001
Hispanic	0.824	0.788	0.861	<.0001
Asian	0.924	0.856	0.997	.043
Other	0.959	0.902	1.020	.184
Missing	0.882	0.855	0.910	<.0001
Payer				
Medicare	REFERENCE			
Medicaid	0.952	0.867	1.046	.306
Commercial	1.697	1.641	1.754	<.0001
Other	2.918	2.773	3.070	<.0001
Missing	2.324	1.920	2.813	<.0001
Charlson Comorbidity Index	1.041	1.035	1.047	<.0001
Acute myocardial infarction				
Yes	REFERENCE			
No	2.886	2.789	2.986	<.0001
Mechanical circulatory support				
No	REFERENCE			
Yes	11.506	10.462	12.654	<.0001
Urgency of admission				
Elective	1.363	1.321	1.406	<.0001
Urgent/Emergent	REFERENCE			
Hospital bed size				
Small	0.957	0.932	0.982	.001

(Continued)

Table 2. (Continued)

VARIABLE	ODDS RATIO	95% CONFIDENCE		*P*-VALUE
		LOWER	UPPER	
Medium	0.969	0.947	0.991	.005
Large	REFERENCE			
Geography				
Rural	1.101	1.070	1.133	<.0001
Urban	REFERENCE			
Teaching				
No	REFERENCE			
Yes	1.014	0.993	1.035	.194
Transfer				
No	REFERENCE			
Yes	1.974	1.916	2.033	<.0001
Missing	1.170	1.136	1.205	<.0001
Income quartile				
1	0.969	0.942	0.997	.031
2	0.938	0.912	0.964	<.0001
3	0.945	0.919	0.972	<.0001
4	REFERENCE			

One of the reasons cited for this by experts is the increase in frailty levels as people get older.[15] Although there is no gold standard or consensus for a clinical definition of frailty, there are certain criteria to evaluate it.[16,17] One strong reason to consider that frailty may be more important than age is highlighted in a single center study that looked at cardiac catheterization and percutaneous coronary intervention (PCI) in nonagenarians.[18] In a study by LeBude et al, of 53 patients who received PCI, there was a 0% mortality rate during the inpatient stay and for the following month. The 1-year mortality was only 13%, which is much lower than the 30% to 37.5% in previously mentioned studies.[10,18] This highlights that there may be benefit to cardiac catheterization even in nonagenarians as long as other factors are considered. Finally, admissions that required hospital transfer had roughly double the odds of mortality. There does not seem to be any research to explain this, which makes this an issue appropriate for future research.

Another factor that is often cited for consideration is comorbidities. In this study, for every additional increase in the CCI, the odds of mortality increased by about 3%. Despite this, the difference in the absolute number of comorbidities between the 2 groups was quite small—only 0.06 comorbidities. The difference in the CCI was also not very large—0.16 points. Although both of these effects were statistically significant, they do not seem to be clinically significant. Despite this, not all comorbidities were considered equally to determine the appropriateness of cardiac catheterization. The comorbidities that seemed to be the most different in the 2 groups were dementia, chronic obstructive pulmonary disease (COPD), renal disease, and cancer. Those 4 conditions seemed to deter the use of cardiac catheterization. Renal failure and COPD were strong predictors of mortality in coronary artery disease and HF in other studies, therefore this difference is somewhat expected.[19,20]

Unsurprisingly, those that received cardiac catheterization had longer hospital stays than those who did not by about 3 days. The increase in the length of stay that was attributed to cardiac catheterization after adjusting for other factors was about one and a half days. Most other factors only added about 2 to 8 hours to the length of the hospital stay, except transfer, which added about 30 additional hours of hospital stay.

This study has limitations, most of which are common to observational studies using large administrative data sets. While the overall population reflects utilization and outcomes across the US, there are still concerns about the ability

Table 3. Multivariable model of length of hospital stay.

VARIABLE	COEFFICIENT	95% CONFIDENCE		*P*-VALUE
		LOWER	UPPER	
Cardiac catheterization	2.572	2.533	2.610	<.0001
Age				
65-74	REFERENCE			
75-79	0.077	0.050	0.103	<.0001
80-84	0.088	0.063	0.113	<.0001
85+	0.033	0.010	0.056	.005
Sex				
Male	REFERENCE			
Female	0.178	0.160	0.195	<.0001
Race				
White	REFERENCE			
Black	0.138	0.108	0.167	<.0001
Hispanic	0.060	0.023	0.098	.002
Asian	−0.040	−0.109	0.030	.264
Other	0.191	0.134	0.248	<.0001
Missing	−0.221	−0.250	−0.193	<.0001
Payer				
Medicare	REFERENCE			
Medicaid	0.604	0.531	0.677	<.0001
Commercial	−0.188	−0.223	−0.152	<.0001
Other	−0.242	−0.312	−0.173	<.0001
Missing	−0.234	−0.484	0.015	.065
Charlson Comorbidity Index	0.205	0.199	0.210	<.0001
Urgency of admission				
Elective	0.264	0.232	0.296	<.0001
Urgent/Emergent	REFERENCE			
Hospital bed size				
Small	−0.577	−0.601	−0.553	<.0001
Medium	−0.390	−0.411	−0.370	<.0001
Large	REFERENCE			
Geography				
Rural	−0.519	−0.546	−0.492	<.0001
Urban	REFERENCE			
Teaching				

(Continued)

Table 3. (Continued)

VARIABLE	COEFFICIENT	95% CONFIDENCE		*P*-VALUE
		LOWER	UPPER	
No	REFERENCE			
Yes	0.420	0.401	0.439	<.0001
Transfer				
No	REFERENCE			
Yes	1.223	1.187	1.259	<.0001
Missing	0.326	0.298	0.353	<.0001
Income quartile				
1	−0.091	−0.118	−0.064	<.0001
2	−0.201	−0.227	−0.175	<.0001
3	−0.209	−0.236	−0.183	<.0001
4	REFERENCE			
Acute myocardial infarction				
No	REFERENCE			
Yes	−0.628	−0.653	−0.603	<.0001
Mechanical circulatory support				
No	REFERENCE			
Yes	12.175	11.989	12.361	<.0001
Intercept	4.402	4.366	4.437	<.0001

to generalize to specific populations. While we were able to control for a robust set of demographic characteristics and hospital characteristics, there are other clinical variables that we could not control for and which may impact outcomes. Specifically, we did not know the severity of comorbidities such as COPD and renal failure. We also observed that admissions who received cardiac catheterization differed somewhat from admissions who did not. For example, admissions receiving cardiac catheterization tended to be younger and more likely to be male. Thus, there is concern that there may be selection bias in our results. As a robustness check, we performed a propensity score analysis. The results of this sensitivity analysis were very similar to those of our multivariable modeling, which allays concerns about selection bias to some degree. However, even this robustness check cannot control for selection bias from variables not available in the data set, and selection bias remain a potential limitation and association does not imply causation. Finally, it is possible that patients who received cardiac catheterization were more closely monitored than those that did not receive cardiac catheterization.

Conclusions

Ischemia is the number one cause of HF in the US. Currently cardiac catheterization is utilized in only a relatively small percentage of hospitalized HF admissions despite being considered beneficial according to AHA guidelines. This study provides evidence to support these recommendations by showing that admissions who received cardiac catheterization were substantially less likely to expire during their hospital stay. The overall effect was large, even after controlling for a number of confounders. While it may be difficult to generate evidence of this relationship in prospective trials, other retrospective studies may provide additional evidence to this observation.

Abbreviations

AHA: American Heart Association
AHRQ: Agency for Healthcare Research and Quality
AMI: Acute myocardial infarction
CCI: Charlson Comorbidity Index
COPD: Chronic obstructive pulmonary disease
HCUP: Healthcare Cost and Utilization Project
HF: Heart Failure

Table 4. Multivariable model of total hospital costs.

VARIABLE	COEFFICIENT	95% CONFIDENCE		*P*-VALUE
		LOWER	UPPER	
Cardiac catheterization	$14 154	$14 036	$14 272	<.0001
Age				
65-74	REFERENCE			
75-79	−$689	−$769	−$608	<.0001
80-84	−$1304	−$1382	−$1226	<.0001
85+	−$2340	−$2411	−$2269	<.0001
Sex				
Male	REFERENCE			
Female	−$554	−$609	−$500	<.0001
Race				
White	REFERENCE			
Black	$84	−$6	$174	.068
Hispanic	$1874	$1758	$1990	<.0001
Asian	$2830	$2615	$3044	<.0001
Other	$1654	$1480	$1829	<.0001
Missing	−$50	−$138	$38	.264
Payer				
Medicare	REFERENCE			
Medicaid	$791	$565	$1016	<.0001
Commercial	−$288	−$397	−$179	<.0001
Other	−$1708	−$1923	−$1493	<.0001
Missing	−$1148	−$1916	−$380	.003
Charlson Comorbidity Index	$152	$136	$169	<.0001
Urgency of admission				
Elective	$4154	$4055	$4254	<.0001
Urgent/Emergent	REFERENCE			
Hospital bed size				
Small	−$1325	−$1398	−$1252	<.0001
Medium	−$1123	−$1186	−$1060	<.0001
Large	REFERENCE			
Geography				
Rural	−$1083	−$1166	−$1000	<.0001
Urban	REFERENCE			
Teaching				

(Continued)

Table 4. (Continued)

VARIABLE	COEFFICIENT	95% CONFIDENCE		*P*-VALUE
		LOWER	UPPER	
No	REFERENCE			
Yes	$1518	$1459	$1577	<.0001
Transfer				
No	REFERENCE			
Yes	$2154	$2044	$2264	<.0001
Missing	$773	$687	$858	<.0001
Income quartile				
1	−$2758	−$2840	−$2675	<.0001
2	−$2220	−$2301	−$2139	<.0001
3	−$1607	−$1688	−$1525	<.0001
4	REFERENCE			
Acute myocardial infarction				
No	REFERENCE			
Yes	−$217	−$293	−$140	<.0001
Mechanical circulatory support				
No	REFERENCE			
Yes	$82967	$82394	$83541	<.0001
Intercept	$13042	$12933	$13151	<.0001

ICD-CM: International Classification of Diseases Clinical Modification
NIS: National Inpatient Sample
NSTEMI; Non-ST elevation myocardial infarction
PCI: Percutaneous coronary intervention
STEMI: ST elevation myocardial infarction
US: The United States of America

Acknowledgements

We want to thank the research teams and supporting members at Hackensack Meridian Health Ocean Medical Center and the Pennsylvania State University.

Author Contributions

Palak Patel – Conceptualization, Writing – Review & Editing.
Ivan Richard - Conceptualization, Writing – Review & Editing.
Giuseppe Filice - Conceptualization, Writing – Review & Editing.
Ivan Nikiforov - Conceptualization, Methodology, Writing – Original Draft, Drafting – Review & Editing.
Priyaranjan Kata - Conceptualization, Writing – Review & Editing.
Anish Kumar Kanukuntla - Conceptualization, Writing – Review & Editing.
Arthur Okere - Conceptualization, Writing – Review & Editing.
Christopher S Hollenbeak - Conceptualization, Data Curation, Formal Analysis, Methodology, Software, Visualization, Writing – Original Draft.
Pramil Cheriyath – Conceptualization, Methodology, Supervision, Writing – Original Draft.

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Appendix A: ICD9 and ICD10 codes used in the analysis

Heart failure

ICD-9: 428.XX
ICD-10: I50.XXX

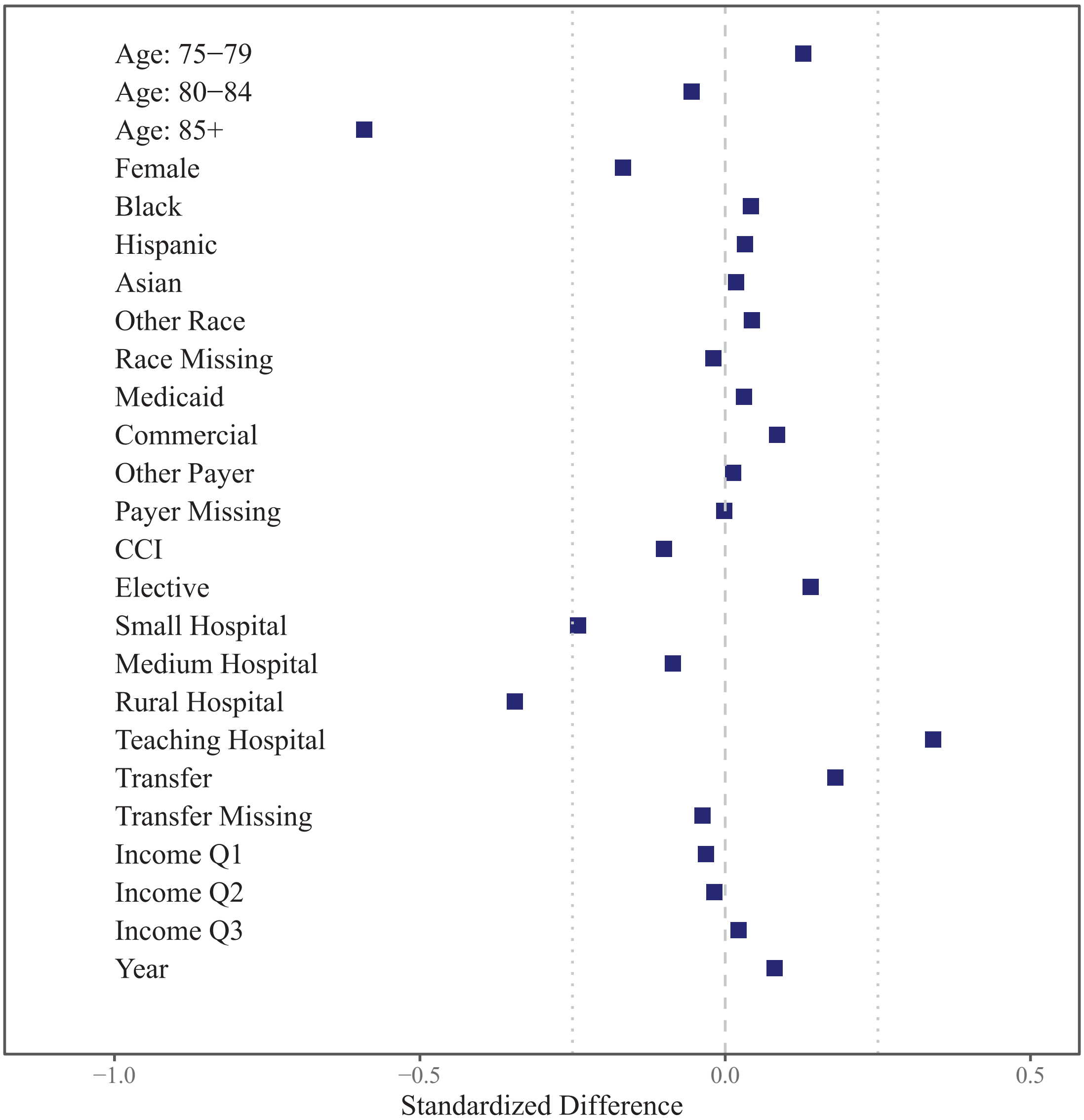
Cardiac catheterization

ICD-9: 37.21, 37.22, 37.23
ICD-10-PCS: 4A020N6, 4A023N6, 4A020N7, 4A023N7, 4A020N8, 4A023N8

Mechanical Circulatory Support

ICD-9: 37.60, 37.65, 37.68, 37.61, 39.65, 39.66
ICD-10-PCS: 02HA0RS, 02HA3RS, 02HA4RS, 5A02116, 5A02216, 5A02110, 5A02210, 02HA0RZ, 02HA4RZ, 5A02116, 5A02216, 02HA3RZ, 5A02116, 5A0211D, 5A02216, 5A02216, 5A0221D, 5A15223, 5A1221Z

Appendix B



Standardized differences following inverse probability weighted propensity score analysis.