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ORIGINAL RESEARCH

# The High Cost of Death After Acute Myocardial Infarctions: Results from a National US Hospital Database

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**Introduction:** This study described the differences in costs and length of stay (LOS) among patients with AMI who died versus survived using a large, nationally representative cohort of AMI patients.

**Methods:** The 2019 HCUP NIS was used to analyze costs, and LOS among all patients with a principal diagnosis of AMI. A propensity-score matched analysis and multivariable regression were used to adjust for patient and hospital characteristics.

**Results:** There were 4559 visits in each of the cohorts (total 9118). The adjusted mean hospital cost was $18,970 (95% CI $16,453 - $21,871) for those that survived and $23,173 (95% CI $20,167 - $26,626; p <0.001) for those that died. The LOS was 3.95 (95% CI 3.41–4.57) in survivors and 4.24 (95% CI 3.67–4.89; p <0.001) in those who died.

**Conclusion:** Survivors of AMI incurred lower costs and length of stay than those who died. Higher costs were attributed to greater LOS and higher-level care. The results suggest that economic evaluations of cardiovascular interventions that do not include the cost of dying may underestimate the benefits of the intervention.

**Keywords:** acute myocardial infarction, healthcare utilization, mortality, cardiovascular

## Introduction

In the United States (US), there are an estimated 605,000 acute myocardial infarctions (AMIs) and 200,000 recurrent AMIs each year.[1] There has been a decline in AMI hospitalizations and mortality rates.[2] These declines are associated with higher levels of therapeutic interventions and advancements in medical technologies.[3] However, there are substantial economic burdens associated with AMI, one of the top five most expensive reasons patients are hospitalized.[4] For AMI, the median hospital charge to the payer was $53,384 (interquartile range [IQR]: $33,282 - $84,551).[5] The TRASLATE-ACS reported the median hospital cost of $15,642 (IQR: $12,390 - $20,222) and length of stay (LOS) of 3 days (IQR: 2–3 days) in 2013.[6] The largest costs for treating AMI were percutaneous coronary intervention and coronary artery bypass graft procedures.[3,6]

Several studies have found healthcare resource utilization and costs substantially increase for those that do not survive the hospitalization.[7,8] However, there is a paucity of data regarding AMI hospitalizations and comparing costs for patients who die to those who survive. The lack of this data complicates the understanding of healthcare resource utilization in AMI hospitalizations and perhaps leads to underestimates of the cost-effectiveness of interventions that reduce mortality. Thus, the objective of the study was to describe the differences in costs and length of stay (LOS) among patients hospitalized with AMI, comparing those who survived versus died.

## Methods

Data were obtained from the 2019 Agency for Healthcare Quality and Research (AHRQ) Healthcare Cost and Utilization Project (HCUP) Nationwide Inpatient Sample (NIS).[9] The HCUP NIS is the most comprehensive source of all-payer hospitalizations from US hospitals (excluding military, Veteran's Affairs, rehabilitation, and long-term acute care hospitals).[9] The NIS contains approximately 20% of all community hospital discharges and can be generalized to represent all hospitalizations in the US.



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All emergent admissions with a principal diagnosis of AMI were included in the analysis. AMI was defined using International Classification of Diseases, 10th Revision (ICD-10) codes found in Appendix A. Patients were stratified based on their discharge status (survived or died). Patient data extracted included: demographics, comorbidities, diagnoses, procedures, insurance, and discharge status. Cardiogenic shock was identified as a measure of severity for the admission. Hospital characteristics extracted included: number of beds, geographic region, teaching status, and location (urban, rural). The primary outcomes of interest were hospitalization cost and LOS. Costs were estimated using the HCUP provided cost-to-charge ratios.[9]

Data were summarized using counts and percentages for categorical data and means and standard deviations (SD) for continuous data. Mann–Whitney *U*-tests were used to assess differences in the unadjusted data for non-normal continuous data. Chi-square tests were used to assess differences in categorical data. Propensity matching without replacement was used, and an exact match for age, sex, race, and cardiogenic shock were used to control for patient differences between the survived and died cohorts. After propensity matching, multivariable generalized linear regression models (GLM) with a gamma distribution and log link were used to estimate the associations between the survived and died cohorts for the primary outcomes. The GLM approach adjusted for the non-normality of the continuous data. Hospital demographics and patient characteristics that remained statistically different after matching were included in the models to further control for observed differences in the populations.

Separate sub-analyses were performed using the aforementioned design for obese and diabetic populations, groups known to have particularly high healthcare costs. Sample weights provided by HCUP were used to calculate the total number of AMIs in the US. A two-sided p value of <0.05 was considered statistically significant and all analyses were performed using SPSS v26. The Xavier University Institutional Review Board exempted this study from review due to the publicly available de-identified nature of data.

## Results

Prior to matching, 112,772 total emergent hospital visits with a principal diagnosis of AMI were identified. Of these, 4775 (4.23%) died. The weighted population was 563,860 total hospitalizations of which 23,870 resulted in death. The average ages were 66.7 and 73.7 (p <0.001) for those that survived versus died, and females comprised 36.95% and 41.01% of the survived versus died cohorts (p <0.001). Survivors prior to matching had fewer comorbid conditions: hypertension (HTN; complicated or uncomplicated), diabetes (DM; complicated or uncomplicated), chronic obstructive pulmonary disease (COPD), peripheral artery disease (PAD), and obesity (p <0.001), and those who died had nearly a 2-fold greater risk for cardiogenic shock (7.6% vs 3.8%; p <0.001).

The propensity matched cohorts consisted of 4559 pairs of patient visits who survived or died (total 9118). In the propensity matched cohort, survivors were less likely to have HTN, DM, and PAD (p <0.001). Those that died had a higher overall cost ($37,634; SD $49,909; p <0.001) and LOS (5.26 days; SD 7.81; p <0.001) compared to those that survived (Table 1).

Multivariable GLM regression analyses controlled for hospital characteristics and remaining statistically significant patient visit characteristics after propensity matching. The mean hospitalization cost was $18,970 (95% CI $16,453 - $21,871) and $23,173 (95% CI $20,167 - $26,626; p <0.001) for those that survived versus died. The mean LOS was 3.95 days (95% CI 3.41 - 4.57) and 4.24 (95% CI 3.67 - 4.89; p <0.001) for those that survived versus died (Table 2). Those patients who died in the hospital had an average increased cost and LOS of $4203 and 0.29 days compared to patients that survived. The national estimated excess hospital cost and LOS associated with AMIs resulting in the death were $100,325,610 and 6922 days.

The multivariable GLM regression analyses of the propensity matched obese (690 matched pairs) and diabetic (1973 matched pairs) sub-populations are shown in Table 3. Appendices B and C provide the propensity matched population patient characteristics for the obese and diabetic populations. After multivariable regression of the propensity matched cohort, the obese population who died cost $11823 (p <0.001) more than those who survived and had a longer LOS of 0.64 days (p =0.032). The diabetic population who died cost $4057 (p <0.001) more than those who survived and had a nonsignificant lower LOS of 0.22 days (p =0.266) after multivariable GLM regression analysis of the propensity matched cohort.

**Table 1** Patient Characteristics and Outcomes

| | Unmatched Population | | | | | Propensity Matched Population | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Survived | | Died | | P value | Survived | | Died | | P value |
| **Population** | 107,997 | 100.00% | 4775 | 100.00% | | 4559 | 100% | 4559 | 100% | |
| **Age** | 66.67 | 13.26 | 73.54 | 12.06 | <0.001 | 73.70 | 12.00 | 73.70 | 12.00 | 1.000 |
| **Female** | 39,900 | 36.95% | 1958 | 41.01% | <0.001 | 1879 | 41.22% | 1879 | 41.22% | 1.000 |
| **Race / Ethnicity*** | | | | | | | | | | |
| White | 77,105 | 71.40% | 3376 | 70.70% | | 3375 | 74.03% | 3375 | 74.03% | |
| Black | 12,115 | 11.22% | 437 | 9.15% | | 434 | 9.52% | 434 | 9.52% | |
| Hispanic | 9195 | 8.51% | 398 | 8.34% | | 396 | 8.69% | 396 | 8.69% | |
| Asian or Pacific Islander | 3029 | 2.80% | 176 | 3.69% | | 175 | 3.84% | 175 | 3.84% | |
| Native American | 645 | 0.60% | 30 | 0.63% | | 30 | 0.66% | 30 | 0.66% | |
| Other | 3075 | 2.85% | 153 | 3.20% | <0.001 | 149 | 3.27% | 149 | 3.27% | 1.000 |
| **Payer*** | | | | | | | | | | |
| Medicare | 60,836 | 56.33% | 3493 | 73.15% | | 3259 | 71.48% | 3357 | 73.63% | |
| Medicaid | 10,157 | 9.40% | 290 | 6.07% | | 289 | 6.34% | 272 | 5.97% | |
| Private | 28,086 | 26.01% | 687 | 14.39% | | 751 | 16.47% | 646 | 14.17% | |
| Self-Pay | 5142 | 4.76% | 183 | 3.83% | | 98 | 2.15% | 168 | 3.69% | |
| No Charge | 47 | 0.04% | 11 | 0.23% | | 1 | 0.02% | 11 | 0.24% | |
| Other | 3153 | 2.92% | 106 | 2.22% | <0.001 | 124 | 2.72% | 114 | 2.50% | <0.001 |
| **Cardiogenic Shock** | 4104 | 3.80% | 362 | 7.58% | <0.001 | 334 | 7.33% | 334 | 7.33% | 1.000 |
| **Comorbid Conditions** | | | | | | | | | | |
| Acquired Immune Deficiency Syndrome | 477 | 0.44% | 18 | 0.38% | 0.291 | 16 | 0.35% | 18 | 0.39% | 0.864 |
| Alcohol Abuse | 3549 | 3.29% | 153 | 3.20% | 0.394 | 125 | 2.74% | 142 | 3.11% | 0.320 |
| COPD | 23,077 | 21.37% | 1146 | 24.00% | <0.001 | 1026 | 23.50% | 1106 | 24.26% | 0.051 |
| Diabetes w/ Complications | 29,309 | 27.14% | 1583 | 33.15% | <0.001 | 1179 | 25.86% | 1509 | 33.10% | <0.001 |
| Diabetes w/ No Complications | 15,723 | 14.56% | 496 | 10.39% | <0.001 | 683 | 14.98% | 472 | 10.35% | <0.001 |
| Dementia | 5325 | 4.93% | 518 | 10.85% | <0.001 | 343 | 7.52% | 499 | 10.95% | <0.001 |
| Depression | 10,182 | 9.43% | 371 | 7.77% | <0.001 | 479 | 10.51% | 354 | 7.76% | 0.020 |
| Drug Abuse | 3171 | 2.94% | 87 | 1.82% | <0.001 | 74 | 1.62% | 83 | 1.82% | 0.520 |
| Hypertension, Complicated | 47,300 | 43.80% | 2866 | 60.02% | <0.001 | 2210 | 48.48% | 2741 | 60.12% | <0.001 |
| Hypertension, Uncomplicated | 42,893 | 39.72% | 895 | 18.74% | <0.001 | 1617 | 35.47% | 868 | 19.04% | <0.001 |
| Hypothyroidism | 13,653 | 12.64% | 603 | 12.63% | 0.453 | 640 | 14.04% | 579 | 12.70% | 0.061 |
| Obesity | 23,323 | 21.60% | 722 | 15.12% | <0.001 | 757 | 16.60% | 696 | 15.27% | 0.081 |
| Other Thyroid Disorders | 1089 | 1.01% | 34 | 0.71% | 0.024 | 60 | 1.32% | 33 | 0.72% | 0.006 |
| Peripheral Artery Disease | 11,351 | 10.51% | 777 | 16.27% | <0.001 | 547 | 12.00% | 739 | 16.21% | <0.001 |

(*Continued*)


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**Table 1** (Continued).

| | Unmatched Population | | | | | Propensity Matched Population | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Survived | | Died | | P value | Survived | | Died | | P value |
| **Outcomes** | | | | | | | | | | |
| Total Cost of Visit | $23,162 | $24,863 | $38,467 | $50,876 | <0.001 | $25,266 | $27,973 | $37,634 | $49,909 | <0.001 |
| Length of Stay, days | 4.33 | 5.12 | 5.27 | 7.79 | <0.001 | 4.92 | 6.15 | 5.26 | 7.81 | <0.001 |

**Note**: *Unmatched Population does not add to 100% due to missing data.

**Table 2** Propensity Matched Population Multivariable Regression Results

| **Cost** | **Mean** | **Std. Error** | **95% Confidence Interval** | | **P value** |
|---|---|---|---|---|---|
| Survived | $18,970 | $1377 | $16,453 | $21,871 | |
| Died | $23,173 | $1643 | $20,167 | $26,626 | |
| Difference | $4203 | | | | <0.001 |
| **Length of Stay** | **Mean** | **Std. Error** | **95% Confidence Interval** | | **P value** |
| Survived | 3.95 | 0.29 | 3.41 | 4.57 | |
| Died | 4.24 | 0.31 | 3.67 | 4.89 | |
| Difference | 0.29 | | | | 0.019 |

**Note**: GLM model adjusted for hospital characteristics and patient characteristics variables that were statistically different after propensity match and adjusted for non-normality of the data (see Table 1).

**Table 3** Obese and Diabetic Results

| **Propensity Matched Obesity Population (n=1380) Regression Results** | | | | | |
|---|---|---|---|---|---|
| **COST** | **Mean** | **Std. Error** | **95% Confidence Interval** | | **P value** |
| Survived | $20,816 | $1,25 | $18,032 | $24,031 | |
| Died | $32,639 | $2047 | $28,864 | $36,907 | |
| Difference | $11,823 | | | | <0.001 |
| **Length of Stay** | **Mean** | **Std. Error** | **95% Confidence Interval** | | **P value** |
| Survived | 4.09 | 0.31 | 3.52 | 4.75 | |
| Died | 4.73 | 0.31 | 4.15 | 5.38 | |
| Difference | 0.64 | | | | 0.032 |
| **Propensity Matched Diabetes Population (n=3946) Regression Results** | | | | | |
| **COST** | **Mean** | **Std. Error** | **95% Confidence Interval** | | **P value** |
| Survived | $21,931 | $1215 | $19,674 | $24,446 | |
| Died | $25,988 | $1260 | $23,632 | $28,580 | |
| Difference | $4057 | | | | <0.001 |
| **Length of Stay** | **Mean** | **Std. Error** | **95% Confidence Interval** | | **P value** |
| Survived | 4.68 | 0.26 | 4.19 | 5.21 | |
| Died | 4.46 | 0.22 | 4.06 | 4.91 | |
| Difference | −0.22 | | | | 0.266 |

**Note**: GLM model adjusted for hospital characteristics and patient characteristics variables that were statistically different after propensity match and adjusted for non-normality of the data (See Appendices B and C).

## Discussion

Our study found that AMI hospitalizations impose a considerable cost on hospitals, especially for patients that died. In this nationally representative analysis of AMI hospitalizations, we estimated that the aggregate cost of dying in the hospital is $100 million more than surviving, and those who died incurred more than 6900 additional days in the hospital. This finding suggests higher resource utilization and more intensive procedures were performed in attempt to prevent death.

Among patients who died, the costs of AMI were also high in both the obese sub-analysis and the diabetic sub-analysis compared to the overall population who died. Obese and diabetic patients carry a greater number of comorbidities that raise the risk for in-hospital mortality and require greater healthcare utilization to manage respiratory and circulatory disease.

As expected, the costs of AMI were higher for obese and diabetic survivor populations compared to the overall population. The LOS was lower for the obese and higher in diabetic populations. The longer LOS in the diabetic survivors is attributed to the need for cardiothoracic surgery and other cardiovascular procedures. Higher resource utilization in this group is consistent with prior studies indicating the cost of managing diabetes is much higher overall.[10]

AMI patients who died were much more likely to present in cardiogenic shock and thus had a higher likelihood of mortality prior to propensity matching and analyses. After matching and analyses we still found a substantial increase in costs among those who died. Cardiovascular interventions in AMI patients presenting in shock are known to incur substantial costs and require higher technology utilization.[11] Both health economic and outcomes research studies that stratify patients by their baseline clinical risk, including presentation with cardiogenic shock or using tools such as the All Patient Refined-Diagnosis Related Group (APR-DRG), will further help estimate AMI cost and utilization in high-risk populations. Despite new technologies often raising procedure costs, we found these steps will likely lead to better estimates of the overall cost of interventions. Expanding our understanding of the AMI resource burden will further allow hospitals to better estimate the cost of innovative treatments for AMI that aim to improve outcomes and allocation of resources.

There are several limitations common to observational research with retrospective data. First, the HCUP NIS is an administrative claims database subject to the accuracy of the coding. Second, only observed differences were accounted for in the analyses. It was possible for unobserved patient characteristics, in particular clinical lab values, to influence the primary outcomes. Finally, our study can only quantify the differences between the cohorts. The data were not sufficient to understand why these differences exist. Additional research investigating the effect of unobserved characteristics is necessary to further understand resource utilization and impact on clinical outcomes. Despite these limitations, claims data remain an important source when examining healthcare utilization and costs.[12]

## Conclusion

Using a large nationally representative cohort of emergent AMI patient visits, those that died incurred substantially more costs and LOS compared to those who survived. Our results quantified the increase in resource utilization in emergent AMI patients who died. The results suggest that economic evaluations of cardiovascular interventions that do not include the cost of dying may under estimate the benefits of the intervention.

## Institutional Review Board Approval

The Xavier University IRB determined that this study does not involve human subjects research and does not require IRB review.

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## Disclosure

Dr Peter J Mallow reports personal fees from Abiomed, Inc., Endologix, Cardinal Health, Medtronic, and CTI Clinical Trial and Consulting, outside the submitted work. Dr Kamal Shemisa reports personal fees from Boehringer Ingelheim, Pfizer, AstraZeneca, Merck, Amarin, Janssen, and Bayer, during the conduct of the study. The authors report no other conflicts of interest in this work.

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