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*Research Article*

# Association of Socioeconomic Status with One-Year Readmission and Mortality among Patients with Acute Myocardial Infarction

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Short Title: Association of Socioeconomic Status and Cardiovascular Disease

**(13 June 2021)**

## Abstract

*Background*: Mortality and morbidity are known to be negatively associated with socioeconomic status (SES). This research aims to investigate the magnitude of this association at the individual level: household income (a proxy for the SES) and cardiovascular disease (CVD). CVD accounts for almost one-third of deaths in the world and one-fourth of deaths in the United States. Given the size of CVD incidence and its severity, we examined how it occurs across various levels of SES.

*Methods*: The zip-code based median household income data in the U.S. Census Bureau were matched to CVD patients from the Myocardial Infarction Data Acquisition System (MIDAS), a rich database that comprises cardiovascular admissions to acute care hospitals in New Jersey. Logistic Regression and Cox Proportional Hazards models were applied to study the relationship between income and three cardiovascular clinical outcomes: readmission for acute myocardial infarction (AMI readmission), cardiovascular death (CV death), and all-cause death among patients with a first admission for AMI, while controlling for covariates available in the database, including demographic factors, insurance types, and comorbidities.

*Results*: The main results indicate that patients at the lowest income level had higher risk for AMI readmission and CV death, but not for all-cause death. Ceteris paribus, the chance of one-year AMI readmission increases with lower income levels according to the Logistic Regression outcomes.

*Conclusions*: Our findings may help better allocate limited resources to where they are in greater need, so the costly and deadly incidence of heart disease can be reduced.



***JEL Classification Numbers***: I14; I18

***Keywords***: Socioeconomic Status; Cardiovascular Disease; MIDAS/Census Data; Logistic Regression Model and Cox Proportional Hazards Model

## Introduction

The phenomenon of social gradient in health refers to the worse health outcomes in persons at lower social strata. It was described as "The Status Syndrome" by Marmot who wrote that "Where you stand in the social hierarchy is intimately related to your chance of getting ill, and your length of life" [1]. Previous investigators have described the inverse relationship of income with mortality that persisted after adjustment for demographics and comorbidities and risk factors for ASCVD [2]. Jakobsen et al. [3] reported that even in a tax-financed healthcare system as in Denmark, low-SES patients treated with primary percutaneous coronary intervention had worse prognosis than high-SES patients and the worse outcome was largely explained by differences in baseline patient characteristics. On the other hand, Kee et al. [4] did not find a difference in the use of angiography for ischemic heart disease and zip code (a surrogate for SES), and Britton et al. [5] did not find an association between SES and treatment of coronary heart disease. CVD and acute myocardial infarction (AMI), its common manifestation, are responsible for about one-third of deaths in the US and world [6, 7].

The lack of unanimity on the existence on an inverse SES-health outcomes relationship and the importance of AMI created the need for further research in this issue.
The purpose of this paper is to examine the association of socioeconomic status with mortality and one-year readmission rate among 178,520 patients with acute myocardial infarction who were admitted in NJ hospitals between 2000 and 2015. The data were obtained from the Myocardial Infarction Data Acquisition System (MIDAS), a statewide database of all cardiovascular hospital admissions in New Jersey.

## Material and Methods

The study was approved by the Rutgers New Brunswick/Piscataway Institutional Review Board. Myocardial Infarction Data Acquisition System (MIDAS) was approved by the

Rutgers New Brunswick/Piscataway Institutional Review Board and by the New Jersey Department of Health Institutional Review Board.

*Data Sources and Specifications*

The data for the years 2004 through 2015 were derived from MIDAS, a database of all hospitalizations for cardiovascular diseases in New Jersey. Records with a primary diagnosis (reason for admission) of AMI (International classification of Diseases, Ninth Revision (ICD-9) codes 410.0 to 410.9) were included in the analysis [8].

The zip-code related median household income data was obtained from the U.S. Census and can be downloaded from a commercial website [9]. The median household income reported for all zip codes in New Jersey was collected. The income variable was recoded as a categorical variable with four levels. The lowest to highest income level was based on the three quartiles of income data. Income that fell below the first quartile ($43,000) was the lowest level. The second quartile ($55,000) was used to distinguish the other two income levels. Income that fell above high limit of the third quartile ($68,000) was the highest level. The empirical distribution of household income data is presented in Figure 1.

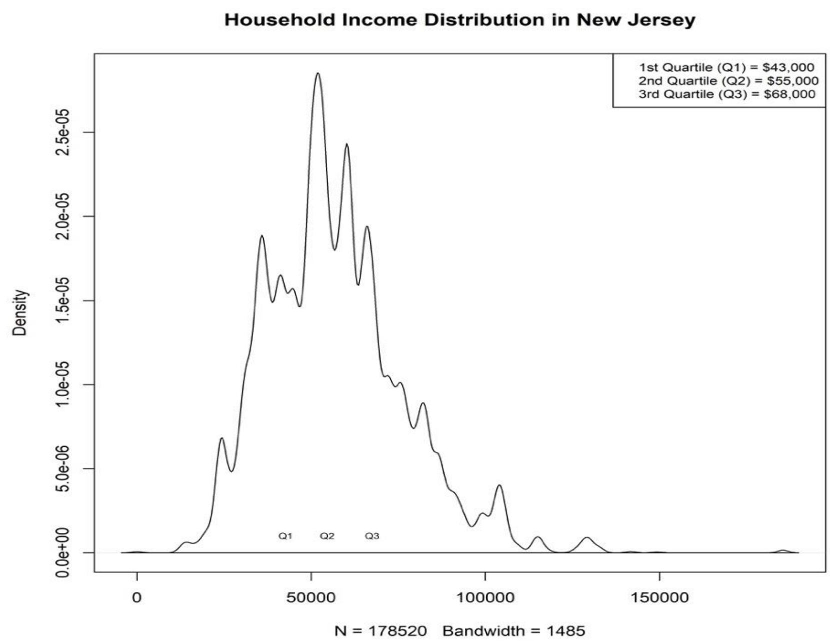


Figure 1: New Jersey household income distribution. The quartiles of income variable are indicated on the horizontal axis ($Q_1$, $Q_2$, and $Q_3$) and are used to convert income to a categorical variable with four levels.

The three main response variables and all covariates used for controlling purposes in our statistical analysis were obtained from the Myocardial Data Acquisition System (MIDAS) database. The MIDAS database records all cardiovascular admissions in New Jersey hospitals dated from March 1985 to December 2015. This database is ample in both its cross-section and time dimension. There are a total of over thirty periods. Researchers with access to the MIDAS database have utilized this rich data set to investigate cardiovascular related diseases and reported several important findings. Kostis et al. [10] found that the mortality rate of patients with AMI was higher for patients who were admitted on weekends than those were admitted on weekdays possibly because they were less likely to undergo invasive cardiac procedures.

We chose a subset of the data based on the following criteria. (1) Patients under age 18 were excluded. (2) AMI was the primary reason for admission according to the main diagnostic code in ICD-9 (International Classification of Disease 9th edition) billing coding system. (3) The AMI admission took place between January 1, 2004 and December 31, 2015, and there was no AMI admission within five years prior to the first AMI. Specifically, patients who were admitted with the AMI codes of transmural AMI (anterior, ICD-9410.0x, 410.1x; inferior, ICD-9 410.2x, 410.4x; lateral, ICD-9 410.3x, 410.5x; posterior, ICD-9 410.6x), subendocardial AMI (ICD-9 410.7x), and other/unspecified AMI (ICD-9 410.8x, 410.9x) were included in the study. The covariates include both patient's demographic characteristics and comorbidities. The demographic attributes contained gender (Female vs. Male), age ($<$ or $\geq 65$), race (White, Black, and Other), and ethnicity (Non-Hispanic,

Hispanic, and Unknown). The patient's insurance type (Medicare, Commercial, and Medicaid/Self-Pay/Other) was also included as part of the demographic inputs. All demographic variables are categorical and their corresponding frequency tables are reported in Figure 2.

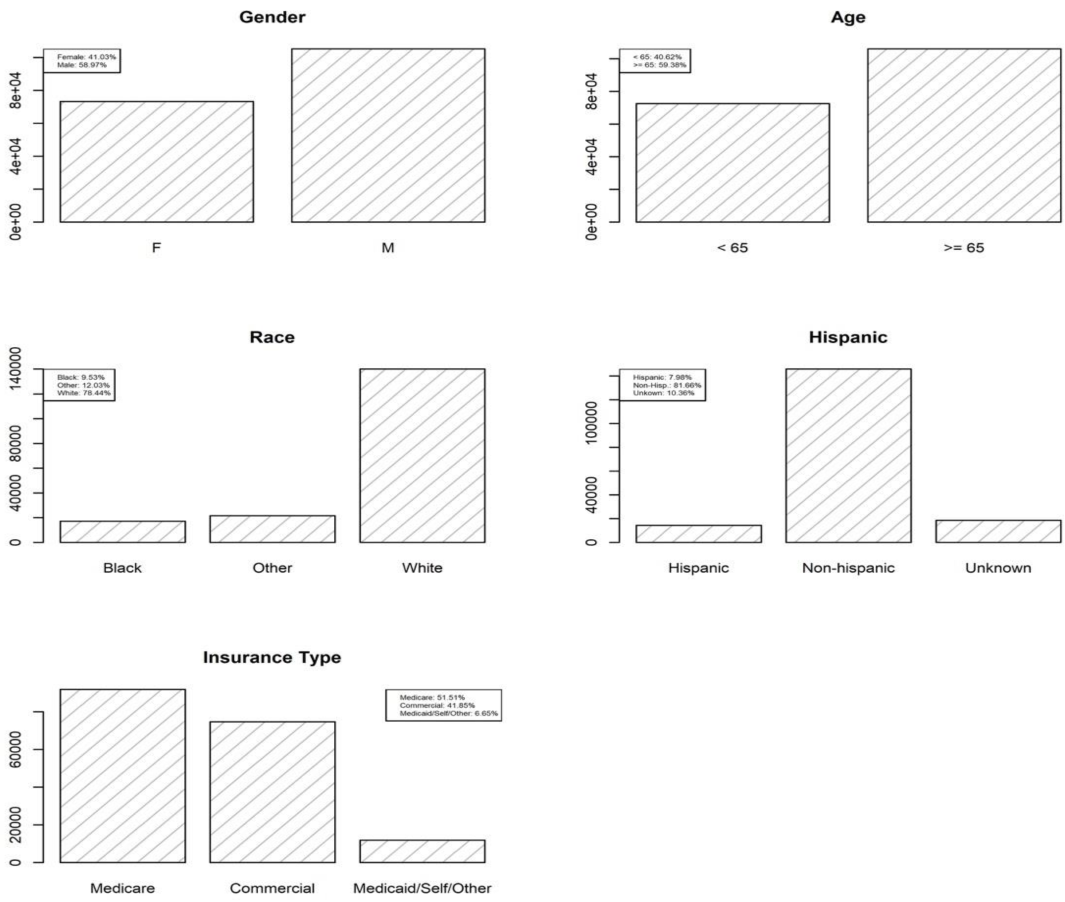



Figure 2: Demographics of Patients. The relative frequency of demographic factors that includes gender, age, race, and ethnicity. The insurance type is also included as part of the demographic factors. The overall sample size is 178,520.

Comorbidities include the history of acute and chronic heart failure (ICD-9 428.xx), hypertension (ICD-9 401.xx to 405.xx), diabetes (ICD-9 250.xx), chronic liver disease (ICD-9 571.xx), chronic kidney disease (ICD-9 585.xx), chronic obstructive pulmonary disease

(COPD, ICD-9 490.xx to 496.xx), and dyslipidemia (272.x). The inclusion of the aforementioned comorbidities was based on the data availability and their important associations with the clinical responses used in this study. The same set of the comorbidities was also used in AMI studies by Kostis et al. [11] and Wellings et al. [12] as part of the control covariate group. All comorbidity variables are binary.

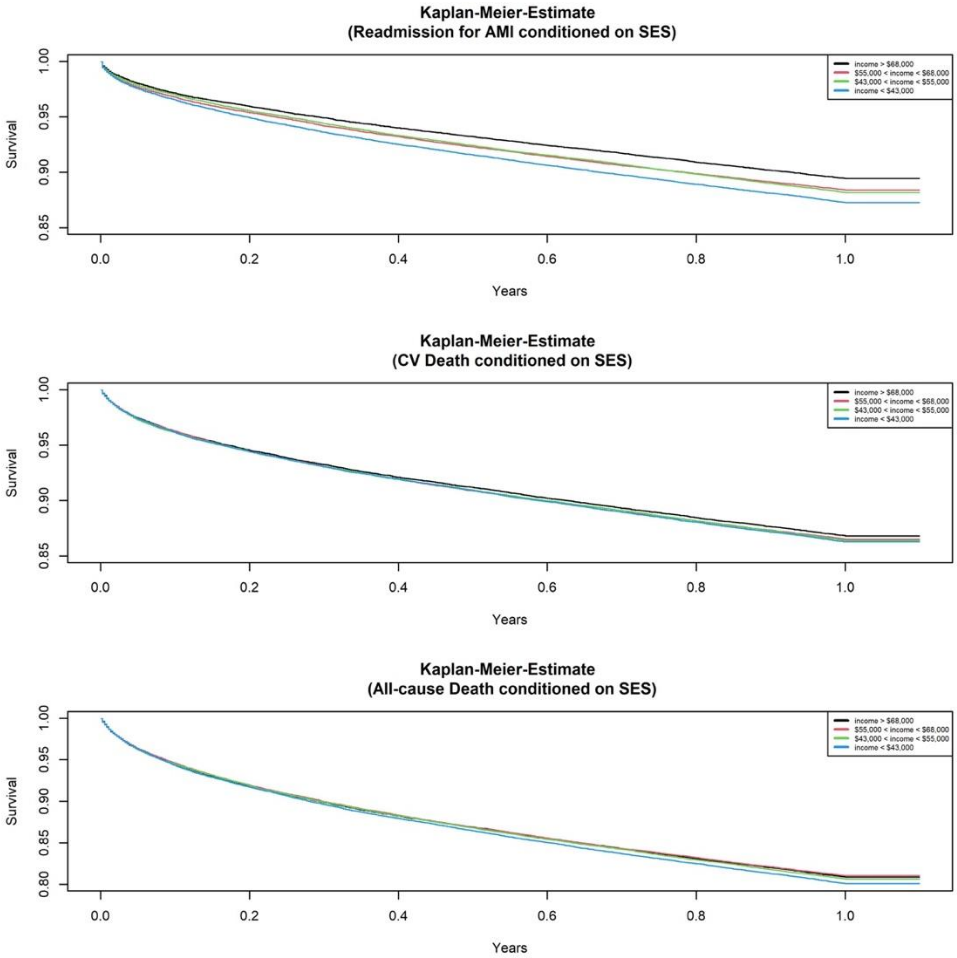
Three well-defined clinical outcomes were used in this study: AMI readmission, cardiovascular death (CV death), and all-cause death. Patients who suffered from either one of the aforementioned clinical outcomes within one-year time after their first AMI discharge were our target cases. Table I reports the relationships between income and three main clinical outcomes and paves the way for more sophisticated data analysis.

| | Readmission for AMI | | Cardiovascular Death | | All-cause Death | |
|---|---|---|---|---|---|---|
| Income | Yes | No | Yes | No | Yes | No |
| >$68,000 | 4654 (10.56%) | 39420 (89.44%) | 5814 (13.19%) | 38260 (86.81%) | 8430 (19.13%) | 35644 (80.87%) |
| $55,000-68,000 | 5077 (11.60%) | 38695 (88.40%) | 5901 (13.48%) | 37871 (81.52%) | 8303 (18.97%) | 35469 (81.03%) |
| $43,000-55,000 | 5391 (11.82%) | 40201 (88.18%) | 6196 (13.59%) | 39396 (86.41%) | 8825 (19.36%) | 36767 (80.64%) |
| <$43,000 | 5739 (12.73%) | 39343 (87.27%) | 6185 (13.72%) | 38897 (86.28%) | 8972 (19.90%) | 36110 (80.10%) |

Abbreviation: AMI: acute myocardial infarction

Table I: The relationship between clinical response rates and the levels of household income; both of them are categorical variables.

It reveals that the proportion of patients readmitted for AMI increases as the income level decreases. However, this pattern is not apparent in the other two clinical outcomes; the proportions of CV death or all-cause death are approximately the same in all four income levels. Figure 3 presents the income adjusted survival curves using the Kaplan-Meier method for all three post-AMI outcomes.




Abbreviation: AMI: acute myocardial infarction, SES: socioeconomic status; CV: cardiovascular.

Figure 3: Income-Adjusted Survival Curves for AMI Readmissions, Cardiovascular Death, and All-Cause Death. Kaplan-Meier diagrams for three responses are used to visualize how their survival rates vary over time within one-year period. Various colors are used to indicate the respective income level. The survival curves for AMI readmission are visually separate, while the adjusted survival curves are quite close to each other for both CV and all-cause death.

Two statistical models, Logistic Regression and Cox Proportional Hazards model, were used in this study. The Logistic model is a valid statistical method, but it does not consider the time dimension (time to event) of the data. Therefore, the Cox model [13] was also utilized to reflect the instantaneous risk through hazard ratios. We briefly address both modeling methods in the appendix.

**Results**

For both Logistic Regression and Cox Proportional Hazards models, we examined the three clinical outcomes: readmission for AMI, CV death and all-cause death at one year after discharge.

a. *Logistic Regression Model*

The results from the Logistic Regression Models are shown in Table II. The left panel in Table II (response of readmission for AMI) shows that, compared to the highest income level (reference, income > $68,000), patients who were at the lower income levels (< $43,000; $43,000-55,000; $55,000-68,000) had higher adjusted risk of AMI readmission. In addition, the relative odds ratios increased (1.1388 > 1.0971 > 1.0888) as the income level decreased. This suggests that the relative risk of being readmitted became larger when patient's income level decreased from the highest to the lowest level.

The middle panel in Table II (response of CV death) indicates that patients who were from the lowest income level had higher risk of CV death (1.0497 times larger or 4.79%, $p=0.0254$) in comparison with the highest income group. However, the associations between SES and CV death were not statistically significant for the other two income groups at the $p<0.05$ level. The adjusted estimated associations between income and all-cause death were not statistically significant as shown in the right panel of the same table.

| Response | Readmission for AMI | | Cardiovascular Death | | All-cause Death | |
|---|---|---|---|---|---|---|
| | Adjusted Estimate | p value | Adjusted Estimate | p value | Adjusted Estimate | p value |
| (Intercept) | 0.0754 (0.0688, 0.0825) | 0 | 0.0537 (0.049, 0.0589) | 0 | 0.0692 (0.0638, 0.075) | 0 |
| **Income** | | | | | | |
| $55,000-68,000 | 1.0888 (1.0435, 1.1361) | 1.00E-04 | 1.0345 (0.9941, 1.0764) | 0.0952 | 0.9934 (0.959, 1.0291) | 0.714 |
| $43,000-55,000 | 1.0971 (1.0519, 1.1441) | 0 | 1.031(0.9912, 1.0724) | 0.1285 | 0.9968 (0.9627, 1.0322) | 0.8589 |
| <$43,000 | 1.1388 (1.0905, 1.1893) | 0 | 1.0479 (1.0058, 1.0917) | 0.0254 | 1.0233 (0.987, 1.0611) | 0.2114 |
| **Male** | 1.0216 (0.9908, 1.0533) | 0.1708 | 0.9466 (0.9198, 0.9742) | 2.00E-04 | 0.93 (0.9068, 0.9539) | 0 |
| **Age** (>65) | 1.1249 (1.0781, 1.1739) | 0 | 1.8331 (1.7561, 1.9135) | 0 | 2.1816 (2.0999, 2.2664) | 0 |
| **Insurance Type** | | | | | | |
| Medicaid/Self/Other | 1.1828 (1.1124, 1.2578) | 0 | 1.1576 (1.0815, 1.2391) | 0 | 1.1396 (1.0708, 1.2127) | 0 |
| Medicare | 1.0813 (1.0373, 1.1271) | 2.00E-04 | 1.2353 (1.1874, 1.2852) | 0 | 1.3509 (1.3047, 1.3988) | 0 |
| **Race/Ethnicity** | | | | | | |
| Race (Other) | 1.0137 (0.9518, 1.0796) | 0.6726 | 1.0898 (1.0215, 1.1626) | 0.0092 | 0.9881 (0.933, 1.0464) | 0.682 |
| Race (White) | 0.9414 (0.8954, 0.9898) | 0.0183 | 1.147 (1.0903, 1.2066) | 0 | 1.1078 (1.0597, 1.158) | 0 |
| **Hispanic** Non-Hispanic | 0.9842 (0.9315, 1.0398) | 0.5694 | 1.2156 (1.1475, 1.2877) | 0 | 1.2633 (1.2001, 1.3298) | 0 |
| Unknown Ethnicity | 0.9138 (0.8518, 0.9804) | 0.012 | 1.1166 (1.0397, 1.1991) | 0.0024 | 1.1653 (1.0939, 1.2414) | 0 |
| **Comorbidity** | | | | | | |
| Acute Heart Failure | 1.0118 (0.9692, 1.0564) | 0.5922 | 1.6203 (1.5611, 1.6816) | 0 | 1.8399 (1.7807, 1.901) | 0 |
| Chronic Heart Failure | 1.9238 (1.7699, 2.091) | 0 | 1.9031 (1.7617, 2.0558) | 0 | 1.7553 (1.6296, 1.8907) | 0 |
| Hypertension | 1.225 (1.1783, 1.2735) | 0 | 1.1732 (1.1303, 1.2177) | 0 | 1.1631 (1.1255, 1.2019) | 0 |
| Diabetes | 1.2503 (1.2119, 1.29) | 0 | 0.9915 (0.9619, 1.022) | 0.5814 | 1.0815 (1.053, 1.1107) | 0 |
| Chronic Liver Disease | 1.2013 (1.07, 1.3488) | 0.0019 | 1.1831 (1.0567, 1.3246) | 0.0035 | 1.51 (1.3699, 1.6645) | 0 |
| Chronic Kidney Disease | 1.4906 (1.4255, 1.5586) | 0 | 1.6145 (1.5495, 1.6822) | 0 | 1.8529 (1.7861, 1.9222) | 0 |
| COPD | 1.0545 (1.0186, 1.0918) | 0.0027 | 1.0753 (1.0413, 1.1104) | 0 | 1.2918 (1.2562, 1.3283) | 0.0034 |
| Dyslipidemia | 1.1789(1.1435, 1.2154) | 0 | 0.8702 (0.8455, 0.8956) | 0 | 0.7418 (0.7231, 0.761) | 0 |

Abbreviations: AMI: acute myocardial infarction; COPD: chronic obstructive pulmonary disease

All of the independent variables (listed in the first column) are categorical. While Income (reference group: > $68,000), Insurance Type (reference group: commercial), Race/Ethnicity (reference group: Black) and Hispanic (reference group: Hispanic) have multiple levels, the rest of the variables are binary.

Table II.: Results of the Logistic model with responses of Readmission for AMI, Cardiovascular Death, and All-Cause Death

### *b. Cox Proportional Hazards Model*

The results in the Cox model, shown in Table III, were similar to the Logistic model. The adjusted hazard ratios for AMI readmission were significant for all income levels (shown in the left panel of Table III). The only statistically significant hazard ratio was for the lowest income patient group when the response was CV death (shown in the middle panel of Table III). None of the hazard ratios was statistically significant for all-cause death (shown in the right panel of Table III).

| Response | Readmission for AMI | | Cardiovascular Death | | All-cause Death | |
|---|---|---|---|---|---|---|
| | Adjusted Estimate | p value | Adjusted Estimate | p value | Adjusted Estimate | p value |
| **Income** | | | | | | |
| $55,000-68,000 | 1.0855 (1.0431, 1.1297) | 1.00E-04 | 1.0302 (0.9934, 1.0683) | 0.1086 | 0.9927 (0.963, 1.0233) | 0.6355 |
| $43,000-55,000 | 1.0901 (1.048, 1.1339) | 0 | 1.0273 (0.9911, 1.0649) | 0.1417 | 0.9958 (0.9664, 1.0261) | 0.7839 |
| <$43,000 | 1.1314 (1.0865, 1.1783) | 0 | 1.0439 (1.0057, 1.0837) | 0.024 | 1.0182 (0.9871, 1.0503) | 0.2554 |
| **Male** | 1.0209 (0.9922, 1.0504) | 0.1549 | 0.949 (0.9245, 0.9741) | 1.00E-04 | 0.9394 (0.9192, 0.96) | 0 |
| **Age** (>65) | 1.1175 (1.0738, 1.1629) | 0 | 1.7801 (1.7101, 1.853) | 0 | 2.0618 (1.9916, 2.1344) | 0 |
| **Insurance Type** | | | | | | |
| Medicaid/Self/Other | 1.167 (1.1019, 1.236) | 0 | 1.1425 (1.0715, 1.2181) | 0 | 1.1211 (1.0588, 1.1872) | 1.00E-04 |
| Medicare | 1.0789 (1.0378, 1.1216) | 1.00E-04 | 1.2206 (1.1769, 1.2659) | 0 | 1.3085 (1.2689, 1.3494) | 0 |
| **Race/Ethnicity** | | | | | | |
| Race (Other) | 1.0137 (0.9562, 1.0748) | 0.6473 | 1.0832 (1.0209, 1.1493) | 0.0082 | 0.9895 (0.9414, 1.0399) | 0.6765 |
| Race (White) | 0.9462 (0.9033, 0.9911) | 0.0195 | 1.1448 (1.0931, 1.1989) | 0 | 1.1039 (1.0629, 1.1464) | 0 |
| **Hispanic** | | | | | | |
| Non-Hispanic | 0.9841 (0.935, 1.0357) | 0.5384 | 1.2004 (1.1381, 1.2661) | 0 | 1.2302 (1.1759, 1.2871) | 0 |
| Unknown Ethnicity | 0.921 (0.8624, 0.9836) | 0.0141 | 1.117 (1.0458, 1.1932) | 0.001 | 1.1541 (1.0917, 1.2202) | 0 |
| **Comorbidity** | | | | | | |
| Acute Heart Failure | 1.0109 (0.9714, 1.0521) | 0.5936 | 1.5515 (1.5009, 1.6038) | 0 | 1.6629 (1.6187, 1.7083) | 0 |
| Chronic Heart Failure | 1.7571 (1.6344, 1.8891) | 0 | 1.6729 (1.5715, 1.7809) | 0 | 1.4708 (1.3943, 1.5515) | 0 |
| Hypertension | 1.2149 (1.1709, 1.2605) | 0 | 1.1601 (1.1204, 1.2011) | 0 | 1.1439 (1.1108, 1.178) | 0 |
| Diabetes | 1.2318 (1.1964, 1.2682) | 0 | 0.9864 (0.9596, 1.014) | 0.3303 | 1.0578 (1.0339, 1.0822) | 0 |
| Chronic Liver Disease | 1.1753 (1.0577, 1.306) | 0.0027 | 1.1481 (1.0391, 1.2686) | 0.0067 | 1.369 (1.2675, 1.4786) | 0 |
| Chronic Kidney Disease | 1.4296 (1.3726, 1.489) | 0 | 1.5149 (1.4613, 1.5705) | 0 | 1.6299 (1.5828, 1.6785) | 0 |
| COPD | 1.0494 (1.016, 1.0838) | 0.0034 | 1.0644 (1.0339, 1.0957) | 0 | 1.2337 (1.2049, 1.2631) | 0 |
| Dyslipidemia | 1.1623 (1.1296, 1.196) | 0 | 0.8719 (0.8493, 0.895) | 0 | 0.763 (0.7465, 0.7799) | 0 |

Abbreviations: AMI: acute myocardial infarction; COPD: chronic obstructive pulmonary disease

All of the independent variables (listed in the first column) are categorical. While Income (reference group: > $68,000), Insurance Type (reference group: commercial), Race/Ethnicity (reference group: Black) and Hispanic (reference group: Hispanic) have multiple levels, the rest of the variables are binary.

Table III: Results of the Cox Proportional Hazards Model with responses of Readmission for AMI, Cardiovascular Death, and All-cause Death

The similarity of the results between the Logistic regression and the Cox models highlight the robustness of findings in both static and dynamic model settings though the interpretation of the response variables are different (i.e., odds ratios vs. hazard ratios).

## Discussion

In this study, we aimed to find the association between income and three well-defined cardiovascular related clinical outcomes of readmission due to AMI, cardiovascular death, and all-cause death among patients with a first admission for AMI in the MIDAS database. Our main findings suggest that patients with low income tend to have higher risks for readmission for AMI and death to AMI.

Many empirical studies have focused on the association between income and specific clinical cardiovascular outcomes. However, the results are mixed with studies showing both positive and negative associations between SES and CVD. Using the FINMONICA Myocardial Infarction Register data, Salomaa et al. [14] found low SES was associated with increased coronary heart disease (CHD) mortality rate in Finland. They indicated that while the CHD declined by 60% due to improved treatment and prevention, the socioeconomic differentials in CHD mortality rates were not narrowed [15]. Jakobsen et al. [3] studied the impact of SES (using income, education, and employment status) with high and low level on CV related diseases such as cardiac death, recurrent myocardial infarction, and target vessel revascularization for a group of 7,385 patients after receiving primary percutaneous coronary intervention (PCI) in Denmark. They found that the low-SES patients had higher risk comparing to the high-SES patients [3]. Using telephone survey data, Lemstra et al. [15] found that household income was not only strongly and independently associated with heart disease, it was also associated with its main disease intermediary, high blood pressure, and its main behavioral risk factors, smoking and physical inactivity.

While most of the recent studies revealed a strong negative association between SES and CVD, there were also studies indicating that the strength of these negative associations was either overstated or did not exist based on empirical analysis. For example, Alter et al. [2] found that income was strongly and inversely correlated with two-year mortality rate using hazard ratio statistics. However, the strength of this negative association was reduced after adjusting for other factors such as age, preexisting cardiovascular events and current vascular risk factors. Denvir et al. [16] conducted a similar PCI study as the study done by Jakobsen et al. [3] and found that SES, measured using the Carstair's Deprivation Score, did not have an impact on the health outcome using a self-reported and health-related quality of life. Similarly, Britton et al. [5] found no association between SES, as measured by social/ethnic differences using a civil service employment grade, and treatment of coronary heart disease through drugs or procedures in a South Asian civil servant population (aged 35-55 years old). Moreover, Kee et al. [4] did not find a difference in the age-standardized catherization-angiography utilizations rates for ischemic heart disease and patient's zip code after controlling for clinical cofounders.

Using the Minnesota Survey data over two three-year periods (1980-1982, 1985-1987) for a total of 7,781 patients, Luepker et al. [17] found that SES (using education, income, and occupations) were associated with coronary disease risk factors, morbidity, and mortality. Strauss et al. [18] conducted a study to determine the association between multiple measures of SES and health outcomes in two Chinese provinces, Gansu and Zhejiang. Results showed that SES using education tended to be positively correlated with health outcomes [18]. Similarly, a U.S. study by Winkleby et al. [19] found that among three commonly used SES measurements (income, education, and occupation), only education showed a strong positive association with CV disease risk factors including cigarette smoking, blood pressure, total lipoprotein and high-density lipoprotein cholesterol using the Stanford Five-City Project data that involved 2,380 participants. Nevertheless, the other two dimensions of SES seemed to play an insignificant role in determining health outcomes [19].

Besides the mixed outcomes from some studies, another challenge faced by researchers is the conceptualization and measurement of SES. Kaplan and Keil [20] provided a detailed literature review by summarizing the effects of SES on cardiovascular disease. They also emphasized that the measurement of SES should be multidimensional, encompassing education, income, occupation, employment status, indexes of social class, etc. [20]. Most of those measurements were difficult to obtain in observational data, so the empirical outcomes were influenced by the availability of the SES. This may explain the mixed outcomes in various studies. Winkleby et al. [19] were able to obtain the SES measurement using education, income, and occupation data from the Stanford Five-City Project. However, they did not investigate the association between SES and cardiovascular disease but their potential contributing risk factors [19]. Moreover, their sample size was small and not racially representative [19].

The aforementioned relevant research indicates several common challenges in these types of studies: (1) SES measurements are often multidimensional and their association with health outcomes such as CV related disease can be mixed, (2) small sample sizes (usually in the thousands) may result in risks of errors or a potential sampling bias issue, and (3) most of the studies have a relatively smaller time dimension. In our paper, we overcame the last two of these challenges by using the data retrieved from the Myocardial Infarction Data Acquisition System (MIDAS) database. Our filtered data includes a total of 178,520 patients over a twelve-year period (from 2004 to 2015). Although it is state-level data, our findings could be generalizable to other geographic areas in the United States. New Jersey has a large, diverse population with proportions of whites, Hispanics, and African Americans as well as young and old males and females similar (within 10%) to the United States overall [21, 8]. Moreover, the rate of uninsured residents in New Jersey is comparable to that in the overall United States (7.9% versus 8%) [22, 8]. Meanwhile, the adoption of the Cox Proportional Hazards model can be used to examine whether the outcomes obtained from the Logistic Regression model are robust if both the time dimension of the data (duration or time-to-event) and the data censoring problem are taken into consideration.

**Application: Predictive Modeling using the Logistic Regression Outcomes**

The empirical findings based on the Logistic Regression Model reveals that AMI readmission is significantly associated with all income levels (Table II). We take one step further to build a predictive model for the one-year AMI readmission cases. Plugging the linear predictor "X*β" into equation (2) (shown in the Appendix) can predict the probability of one-year AMI readmission as shown in Table IV. We only illustrate some scenarios based on the category of each independent variable. For example, the bottom cell in column four in the table indicates that the probability to have one-year AMI readmission for a high-income (> $68K), White, senior (age > 65), non-Hispanic, individual with history of two comorbidities (hypertension and disorder of lipid metabolism) is 11.14%. Other things being held the same, this probability increases to 12.01%, 12.09% and 12.49% (the bottom row of column five, six and seven) respectively when the corresponding income level drops to the lower levels ($55K~68K, 43K~55K and < 43K). This increasing probability phenomenon happens to females with the same demographics and comorbidities (bottom cell from 8th to 11th column). In general, the chance of AMI readmission increases with decreasing income when other covariates are being held the same.

| Variables | Category | Estimates | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Intercept | | -2.5854 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **SES** | $55K ~ 68K | 0.0851 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| | 43K ~ 55K | 0.0926 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| | < 43K | 0.13 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| **Sex** | Male | 0.0214 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| **Age** | > 65 | 0.1177 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Insurance** | Medicaid/Self/Other | 0.1679 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Medicare | 0.0782 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Race/Ethnicity** | Other | 0.0136 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | White | -0.0604 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Hispanic** | None | -0.016 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Unknown | -0.0901 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Acute Heart Failure** | Yes | 0.0118 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Chronic Heart Failure** | Yes | 0.6543 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Hypertension** | Yes | 0.2029 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Diabetes** | Yes | 0.2234 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Chronic Liver Disease** | Yes | 0.1834 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Chronic Kidney Disease** | Yes | 0.3992 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **COPD** | Yes | 0.0531 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Dyslipidemia** | Yes | 0.1646 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Probability** | Predicted value | | 0.1114 | 0.1201 | 0.1209 | 0.1249 | 0.1093 | 0.1178 | 0.1186 | 0.1226 |

Abbreviation: COPD: chronic obstructive pulmonary disease

The independent variables used in the Logistic Regression Model is denoted as a row vector “X” and can be found in the 1$^{st}$ column in the above table. The estimated coefficient vector “$\hat{\beta}$” is presented in the 4$^{th}$ column. The predicted probability at the bottom row is computed using the logistic function $\frac{\mathrm{EXP}(X*\hat{\beta})}{1+\mathrm{EXP}(X*\hat{\beta})}$. Take the exponentiation of the “$\hat{\beta}$” vector will result in the adjusted estimates for the Readmission for AMI response variable (2$^{nd}$ column) in Table II.

Table IV: Prediction of one-year AMI Readmission using the Logistic Regression Model

## Conclusion

It is important to understand how socioeconomic standings and social determinants are associated with such wide-spread health effects and outcomes of cardiovascular disease. While the mechanism of this association has not been clearly established, our findings reveal that socioeconomic status has a strong negative association with AMI readmission. The possible explanations for this negative association may include disparities in low-income patients access to healthcare, health insurance, diagnostic and interventional procedures, and adherence to medications, among others [23-25]. For instance, lower-income patients post-AMI are less likely to undergo or receive interventions, such as percutaneous coronary intervention, or receive or comply with medications, including statins, beta-blockers, and angiotensin-converting enzyme inhibitors [23, 26-30]. Moreover, patients with financial barriers in accessing care face reduced annual checkups, limited health literacy, less compliance to medications, and greater vascular morbidity [23, 25].

Once this disadvantaged group of low SES is identified, intervention strategies can be designed and implemented to help reduce the chance of such incidence. Healthcare workers should pay closer attention to these disadvantaged group of patients once they are discharged from the hospital after their first AMI admission. The National Academy of Medicine has recommended incorporating social and behavioral determinants of health in patient's electronic medical records to help healthcare workers identify at-risk patients and improve outcomes [31]. Moreover, there are several evidence-based heart disease prevention programs, such as Million Hearts 2022, launched by the Center for Disease Control and Prevention [32] in 2013; however, it is not fully implemented yet due to limited congressional resources. Furthermore, the Walk Your Heart to Health program has proven effective in increasing physical activity and improving cardiovascular health in low-income patients [23,33]. The US Preventative Services Task Force recommends behavioral and heart counseling to promote dietary changes and increase physical activity in AMI patients [23, 34-35]. We should encourage policy makers to help allocate resources to those who are in greater need, so the costly and deadly incidence of heart disease can be reduced.

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**Data Sharing Statement**

Our data is unavailable to access because this research data is confidential.

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**Appendix**

Statistical Methods

*a. Logistic Regression Model*

Y is a binary variable with two possible outcomes 1 and 0, and the corresponding probabilities are P and 1 - P, respectively.

$$Y = \begin{cases} 1 \text{ with probability } P \\ 0 \text{ with probability } 1 - P \end{cases}$$

$$E(Y) = 1*P + 0*(1 - P) = P \quad (1)$$

The conditional mean function of Y can be written as follows:

$$E(Y|X) = P(Y = 1|X) = \frac{\exp(X*\beta)}{1+\exp(X*\beta)} \quad (2)$$

Where X is a row vector that includes a constant and a group of independent variables that may contribute to the variation of Y. The associated β is a column of coefficient vector. The main reason for selecting the logit function on the right of equation (2) was to ensure that the mapped value was always between zero and one. The second reason for adopting the logit function was that it can be rearranged as the following odds function:

$$\frac{P}{1-P} = \exp(X*\beta) \quad (3)$$

The left term in equation (3) is interpreted as the odds, and the log odds ratio can be shown as a linear function of the X:

$$\log\left(\frac{P}{1-P}\right) = X*\beta \quad (4)$$

Equation (4) indicates that one-unit change in $X_j$ would result in an increase in the odds ratio by exp ($\beta_j$). We used the estimated betas to uncover how the change in each covariate affects the odds ratio of either AMI readmission, CV death, or all-cause death.

*b. Cox Proportional Hazards Model*

The Cox Proportional Hazards model was similar to the Logistic Regression model, yet it also takes the "time to event" and problem of censored data into consideration. The model can be specified as follows:

$$H(t) = H_0(t)*\exp(X*\beta) \quad (5)$$

In equation (5), H(t) is defined as the hazard ratio; it is a function of the product of an unspecified baseline function $H_0(t)$ and the exponential function of the linear covariate vector

$X^*\beta$. Although the term $H_0(t)$ is unspecified, it can still be estimated using the method of partial likelihood function developed by David Cox. According to equation (5), the hazard ratio equals to $\beta_j$ if there is an increase of $X_j$ by one unit. A positive (negative) estimated beta indicates that an increase of one-unit change in X results in a higher (lower) hazard ratio.