Socioeconomic Status and Differences in the Management and Outcomes of 6.6 Million US Patients With Acute Myocardial Infarction

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Little is known about the impact of socioeconomic status (SES) on management strategies and in-hospital clinical outcomes in patients with acute myocardial infarction (AMI) and its subtypes, and whether these trends have changed over time. All AMI hospitalizations from the National Inpatient Sample (2004 to 2014) were analyzed and stratified by zip code-based median household income (MHI) into 4 quartiles (poorest to wealthiest): 0th to 25th, 26th to 50th, 51st to 75th, and 76th to 100th. Logistic regression was performed to examine the association between MHI and AMI management strategy and in-hospital clinical outcomes. A total of 6,603,709 AMI hospitalizations were analyzed. Patients in the lowest MHI group had more co-morbidities, a worse cardiovascular risk factor profile and were more likely to be female. Differences in receipt of invasive management were observed between the lowest and highest MHI quartiles, with the lowest MHI group less likely to undergo coronary angiography (63.4% vs 64.3%, p <0.001) and percutaneous coronary intervention (40.4% vs 44.3%, p <0.001) compared with the highest MHI group, especially in the STEMI subgroup. In multivariable analysis, the highest MHI group experienced better outcomes including lower risk (adjusted odds ratio; 95% confidence intervals) of mortality (0.88; 0.88 to 0.89), MACCE (0.91; 0.91 to 0.92) and acute ischemic stroke (0.90; 0.88 to 0.91), but higher all-cause bleeding (1.08; 1.06 to 1.09) in comparison to the lowest MHI group. In conclusion, the provision of invasive management for AMI in patients with lower SES is less than patients with higher SES and is associated with worse in-hospital clinical outcomes. This work highlights the importance of ensuring equity of access and care across all strata SES. **(Am J Cardiol 2020;129:10−18)**

Lower socioeconomic status (SES) has been previously linked to higher prevalence of traditional cardiovascular risk factors,[1] increased burden of coronary artery disease [2] and higher mortality.[3] Of the individual components of SES, median household income (MHI) has been shown to be a surrogate of SES for the purpose of health research.[4,5] Although previous studies have evaluated the relationship between SES and management strategy or in-hospital outcomes in the context of acute myocardial infarction (AMI), the findings have been subject to limitations such as the inclusion of specific cohorts (e.g., ST-segment elevation myocardial infarction (STEMI) only or elderly patients),[6−8] or were limited to single center analyses.[9] More importantly, there is a lack of temporal data of how disparities in management and outcomes of AMI attributable to SES have changed over time. In this study we sought to evaluate the association of SES, as measured by MHI, on receipt of invasive management and subsequent in-hospital clinical outcomes in a nationwide cohort of AMI hospitalizations in the United States over an 11-year period.

Methods

The National Inpatient Sample (NIS) is the largest publicly available all-payer database of hospitalized patients in the US and is sponsored by the Agency for Healthcare Research and Quality (AHRQ).[10] It includes anonymized data on discharge diagnoses and procedures from >7 million hospitalizations annually. The NIS dataset was designed to approximate a 20% stratified sample of US community hospitals and provides sampling weights to calculate national estimates that represent >95% of the US population.

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All nonelective hospitalizations of adults (≥18 years) discharged between 2004 and 2014 with a principal diagnosis of AMI (STEMI and non-STEMI [NSTEMI]) were extracted from the NIS using the International Classification of Diseases, Ninth revision and Clinical Classification Software codes (Supplementary Table S1). Additional co-morbidities were identified using AHRQ-Elixhauser co-morbidity measures. Charlson Comorbidity Index was extracted using the variables according to the Deyo modification of the score as previously described.[11] Patient characteristics and in-hospital clinical outcomes were stratified according to MHI quartiles in 4 groups: 0th to 25th, 26th to 50th, 51st to 75th, and 76th to 100th, indicating the poorest to the wealthiest groups, respectively (Supplementary Table S2). Missing records for length of stay and total charges were excluded from further analysis (Supplementary Figure S1).

We analyzed the database for receipt of in-hospital invasive management (coronary angiography, percutaneous coronary intervention (PCI) and coronary artery bypass grafting [CABG]) for AMI between different incomes groups. Subsequent in-hospital clinical outcomes including major acute cardiovascular and cerebrovascular events (MACCE), mortality, cardiac complications, and acute stroke were assessed for differences among income groups. MACCE was defined as a composite of mortality, acute stroke/transient ischemic attack and cardiac complications. Cardiac complications included hemopericardium, cardiac tamponade, coronary dissection, and any pericardiocentesis procedure.

Statistical Package for the Social Sciences statistical software (IBM Corp, Armonk, New York; version 25) was used for statistical data analysis. We assessed the normality of data distribution graphically and by the Kolmogorov-Smirnov test. Data were expressed as median (interquartile range) for continuous variables and as whole numbers (percentages) for categorical variables. Mann-Whitney *U* test and Kruskal-Wallis test have been used for comparison of quantitative nonparametric variables between the study groups. The Chi-square test was used for the comparison of categorical variables between the different groups according to MHI.

Multivariable logistic regression analysis was used to determine the adjusted odds ratios (aOR [95% confidence interval]) of in-hospital adverse outcomes and the likelihood of an invasive management strategy, according to the different MHI groups in comparison to patients with the MHI in the lowest (0th to 25th) quartile as a reference. Separate models for in-hospital clinical outcomes and invasive management were conducted. Regression models for in-hospital clinical outcomes included PCI as a predictor variable. As well, the following variables were adjusted for in regression analysis: age, sex, weekend admission, dyslipidemia, smoking, previous AMI, previous CABG, history of ischemic heart disease, previous PCI, previous cerebrovascular accident, family history of coronary artery disease, shock during hospitalization, hospital bed size, hospital region, location/teaching status of hospital, year of hospitalization and 27 AHRQ co-morbidities (acquired immune deficiency syndrome, alcohol abuse, deficiency anemias, chronic blood loss anemia, rheumatoid arthritis/collagen vascular diseases, congestive heart failure, chronic pulmonary disease, coagulopathy, diabetes (uncomplicated), diabetes with chronic complications, drug abuse, hypertension, hypothyroidism, liver disease, lymphoma, fluid and electrolyte disorders, metastatic cancer, other neurological disorders, obesity, paralysis, peripheral vascular disorders, pulmonary circulation disorders, renal failure, solid tumor without metastasis, peptic ulcer disease excluding bleeding, valvular heart disease and weight loss). Using a Bonferroni's correction method, threshold of significance for the regression model has been set to $p < 0.001$. A trend analysis with a Mantel-Haenszel test of trend (linear-by-linear association) was conducted in order to establish important changes in in-hospital outcomes and receipt of invasive management over the 11-year time period. Statistical significance was defined at a level of $p < 0.05$.

Results

A total of 6,603,709 hospitalizations for AMI were included in the analysis. The distribution of patients according to MHI quartile was as follows: 0th to 25th: 28.5% (N = 1,884,699), 25th to 50th: 27.4% (N = 1,806,775), 51st to 75th: 23.7% (N = 1,567,720), and 76th to 100th: 20.4% (N = 1,344,515), indicating poorest to wealthiest, respectively (Table 1).

The median age range was similar across MHI groups (67 to 69 years), whereas in the lower MHI subgroups females comprised a higher percentage (42.0% to 37.4%, $p < 0.001$). STEMI prevalence ranged from 34.2% to 35.4% with the highest rates found in the third quartile MHI group (51st to 75th). An inverse relationship between MHI quartile and co-morbidity burden was observed across the groups, as measured by Charlson Comorbidity Index score and overall co-morbidity prevalence ($p < 0.001$). The lowest MHI group was more commonly treated in large hospitals than higher MHI quartiles (67.9% vs 65.7% vs 64.1% vs 62.4%, $p < 0.001$). Furthermore, only 1.1% of high MHI patients were treated in rural hospitals compared with 19.4% of lowest MHI group ($p < 0.001$; Table 1), and had significantly higher total charges of hospitalization (40,939 vs 41,208 vs 44,639 vs 47,676 USD, $p < 0.001$; Table 2).

The lowest MHI group was less likely to undergo coronary angiography (63.4% vs 64.3% to 65.7%, $p < 0.001$) and PCI (40.4% vs 42.7% to 44.8%, $p < 0.001$; Table 2, Figure 1). In contrast, the wealthiest group was less likely to undergo CABG (8.5% vs 8.9% to 9.1%, $p < 0.001$; Table 2). These differences persisted irrespective of the AMI subtype, except for the coronary angiography which was the least utilized in NSTEMI patients from the highest MHI group (57.8% vs 59.7% to 60.1%, $p < 0.001$).

After adjustment for baseline differences, the highest MHI group had greater odds of receipt of PCI (aOR 1.10 [1.10, 1.11]) in comparison to the lowest income group (Table 3), irrespective of the AMI subtype ($p < 0.001$; Table 4). On the other hand, odds of receipt of coronary angiography have been dependent on AMI subtype, showing lower odds in NSTEMI and higher odds in STEMI patients from the highest MHI group (Table 4).

The highest MHI subgroup experienced the lowest MACCE, mortality and acute stroke rates ($p < 0.001$). In contrast, all-cause bleeding and receipt of circulatory support (left-ventricle assist device and intra-aortic balloon pump) were more commonly observed in the highest MHI group. In sensitivity analysis, these differences decreased in

Table 1
Patient characteristics according to median household income (percentile)

Variables	0th-25th (n = 1884699)	26th-50th (n = 1806775)	51st-75th (n = 1567720)	76th-100th (n = 1344515)	p value
Age at admission (years), median (IQR)	67 (56, 78)	68 (57, 79)	68 (57, 79)	69 (57, 80)	<0.001
Women	42.0%	40.1%	38.8%	37.4%	<0.001
STEMI	34.2%	35.4%	35.5%	35.4%	<0.001
Charlson comorbidity index (CCI) score					<0.001
0	37.8%	40.5%	42.4%	45.9%	
1	38.4%	37.3%	36.3%	34.9%	
2	16.8%	15.7%	15.0%	13.5%	
≥3	7.0%	6.5%	6.3%	5.7%	
Dyslipidaemia	51.5%	54.1%	55.8%	56.3%	<0.001
Smoker	35.5%	35.2%	33.9%	30.4%	<0.001
Previous AMI	10.1%	10.1%	10.3%	10.3%	<0.001
Previous PCI	11.3%	11.4%	11.4%	11.5%	0.001
Previous CABG	7.6%	7.6%	7.4%	7.4%	<0.001
Previous CVA	4.0%	3.7%	3.7%	3.5%	<0.001
Atrial fibrillation	15.3%	16.4%	17.0%	17.9%	<0.001
History of IHD	75.5%	76.9%	77.7%	77.0%	<0.001
Family history of CAD	7.2%	7.6%	8.1%	8.5%	<0.001
Deficiency anemias	15.2%	14.1%	14.5%	14.4%	<0.001
Chronic blood loss anemia	1.1%	1.1%	1.1%	1.1%	0.018
Congestive heart failure	1.0%	0.9%	0.8%	0.8%	<0.001
Valvular disease	0.2%	0.3%	0.2%	0.3%	<0.001
Hypertension	67.7%	66.0%	65.9%	65.2%	<0.001
Cardiogenic shock	4.7%	4.8%	5.0%	5.1%	<0.001
Peripheral vascular disorders	11.0%	11.1%	10.8%	10.1%	<0.001
Pulmonary circulation disorders	0.1%	0.1%	0.1%	0.1%	0.001
Chronic pulmonary disease	23.2%	21.6%	19.6%	17.0%	<0.001
Coagulopathy	4.1%	4.1%	4.4%	4.6%	<0.001
Obesity	12.0%	11.9%	11.8%	10.3%	<0.001
Weight loss	2.4%	2.1%	2.1%	1.8%	<0.001
Diabetes, uncomplicated	30.8%	28.3%	27.1%	24.6%	<0.001
Diabetes with chronic complications	6.2%	5.9%	6.1%	5.7%	<0.001
Hypothyroidism	8.8%	9.7%	10.0%	10.1%	<0.001
Drug abuse	2.9%	1.8%	1.6%	1.2%	<0.001
Alcohol abuse	3.2%	2.8%	2.6%	2.3%	<0.001
AIDS	0.2%	0.1%	0.1%	0.1%	<0.001
Depression	6.3%	6.5%	6.3%	6.1%	<0.001
Peptic ulcer disease excluding bleeding	0.0%	0.0%	0.0%	0.0%	<0.001
Liver disease	1.3%	1.1%	1.1%	1.1%	<0.001
Renal failure	17.5%	16.3%	16.0%	15.6%	<0.001
Other neurological disorders	6.0%	5.7%	5.6%	5.7%	<0.001
Paralysis	1.8%	1.5%	1.6%	1.5%	<0.001
Psychoses	2.3%	2.0%	1.9%	1.7%	<0.001
Rheumatoid arthritis/collagen vascular diseases	2.0%	2.1%	2.2%	2.3%	<0.001
Solid tumor without metastasis	1.4%	1.4%	1.4%	1.5%	<0.001
Metastatic cancer	0.8%	0.8%	0.9%	1.0%	<0.001
Lymphoma	0.4%	0.5%	0.5%	0.6%	<0.001
Fluid and electrolyte disorders	19.7%	18.8%	19.0%	18.5%	<0.001
Weekend admission	26.1%	26.0%	25.9%	25.6%	<0.001
Admission type (Elective vs. Non-elective)					<0.001
Elective	8.1%	7.5%	6.3%	6.1%	
Nonelective	91.9%	92.5%	93.7%	93.9%	
Primary expected payer					<0.001
Medicare	59.1%	58.3%	56.2%	55.3%	
Medicaid	8.7%	5.9%	4.7%	3.2%	
Private Insurance	21.0%	26.4%	30.7%	35.4%	
Self-pay	7.5%	6.0%	5.2%	3.6%	
No charge	0.7%	0.6%	0.6%	0.3%	
Other	3.0%	2.8%	2.6%	2.1%	
Bed size of hospital					<0.001
Small	8.8%	11.0%	11.2%	11.0%	

(*continued*)

Table 1 (***Continued***)

Variables	0th-25th (n = 1884699)	26th-50th (n = 1806775)	51st-75th (n = 1567720)	76th-100th (n = 1344515)	p value
Medium	23.4%	23.3%	24.6%	26.6%	
Large	67.9%	65.7%	64.1%	62.4%	
Hospital region					<0.001
Northeast	12.4%	15.8%	20.7%	32.9%	
Midwest	19.2%	29.1%	26.2%	18.2%	
South	57.1%	40.0%	32.1%	24.7%	
West	11.3%	15.1%	21.1%	24.2%	
Location/teaching status of hospital					<0.001
Rural	19.4%	13.5%	4.4%	1.1%	
Urban nonteaching	34.2%	42.6%	46.7%	46.0%	
Urban teaching	46.4%	43.9%	48.9%	52.9%	

Notes: Dyslipidemia indicates disorders of lipid metabolism and was defined by code 53 of the Clinical Classification Software.

Abbreviations: AIDS = acquired immunodeficiency syndrome; AMI = acute myocardial infarction; CABG = coronary artery bypass graft; CAD = coronary artery disease; CVA = cerebrovascular accidents; IHD = ischemic heart disease; IQR = interquartile range; PCI = percutaneous coronary intervention; SD = standard deviation; STEMI = ST-elevation myocardial infarction.

Table 2

Comparison of clinical outcomes and invasive management between the different Median Household Income groups

Variables	0th-25th (n = 1884699)	26th-50th (n = 1806775)	51st-75th (n = 1567720)	76th-100th (n = 1344515)	p value
Receipt of CA					
Total cohort	63.4%	64.6%	65.7%	64.3%	<0.001
NSTEMI	59.7%	60.1%	60.1%	57.8%	<0.001
STEMI	70.5%	72.7%	76.0%	76.3%	<0.001
Receipt of PCI					
Total cohort	40.4%	42.7%	44.8%	44.3%	<0.001
NSTEMI	31.3%	32.8%	33.8%	32.7%	<0.001
STEMI	58.0%	60.7%	64.8%	65.5%	<0.001
Receipt of CABG					
Total cohort	8.9%	9.1%	8.9%	8.5%	<0.001
NSTEMI	9.5%	9.7%	9.5%	9.2%	<0.001
STEMI	7.7%	7.9%	7.8%	7.4%	<0.001
Receipt of thrombolysis					
Total cohort	0.4%	0.4%	0.5%	0.6%	<0.001
NSTEMI	0.2%	0.2%	0.2%	0.3%	<0.001
STEMI	0.8%	0.8%	0.9%	1.1%	<0.001
Use of assist device or IABP					
Total cohort	4.5%	4.8%	5.1%	5.5%	<0.001
NSTEMI	2.7%	2.7%	2.8%	3.0%	<0.001
STEMI	8.1%	8.6%	9.2%	10.0%	<0.001
In-hospital MACCE					
Total cohort	8.1%	7.8%	7.7%	7.7%	<0.001
NSTEMI	6.3%	6.2%	6.2%	6.3%	<0.001
STEMI	11.4%	10.9%	10.5%	10.3%	<0.001
In-hospital mortality					
Total cohort	6.0%	5.9%	5.7%	5.7%	<0.001
NSTEMI	4.3%	4.2%	4.1%	4.2%	<0.001
STEMI	9.4%	9.0%	8.5%	8.3%	<0.001
In-hospital all-cause bleeding					
Total cohort	5.0%	5.2%	5.5%	5.7%	<0.001
NSTEMI	5.2%	5.4%	5.6%	5.6%	<0.001
STEMI	4.7%	4.9%	5.5%	5.7%	<0.001
In-hospital ischemic stroke					
Total cohort	1.8%	1.7%	1.7%	1.7%	<0.001
NSTEMI	1.9%	1.8%	1.8%	1.8%	<0.001
STEMI	1.7%	1.5%	1.5%	1.4%	<0.001
In-hospital cardiac complications					
Total cohort	0.6%	0.7%	0.7%	0.7%	<0.001
NSTEMI	0.4%	0.5%	0.5%	0.5%	<0.001

(*continued*)

Table 2 (***Continued***)

Variables	0th-25th (n = 1884699)	26th-50th (n = 1806775)	51st-75th (n = 1567720)	76th-100th (n = 1344515)	p value
STEMI	0.9%	1.0%	1.1%	1.1%	<0.001
Length of stay (days)					
Total cohort	3 (2, 6)	3 (2, 6)	3 (2, 6)	3 (2, 6)	<0.001
NSTEMI	4 (2, 7)	4 (2, 6)	3 (2, 6)	3 (2, 6)	<0.001
STEMI	3 (2, 6)	3 (2, 5)	3 (2, 5)	3 (2, 5)	<0.001
Total charges, US Dollars					
Total cohort	40939 (20912, 71953)	41208 (21118, 71665)	44639 (23940, 77011)	47676 (25146, 82276)	<0.001
NSTEMI	34732 (18047, 62686)	34362 (17743, 62163)	37417 (19740, 67221)	39895 (20494, 71637)	<0.001
STEMI	41298 (20812, 68627)	42798 (23486, 69763)	47265 (28323, 76956)	51545 (30615, 83956)	<0.001

Abbreviations: CA = coronary angiography; CABG = coronary artery bypass graft; IABP = intra-aortic balloon pump; MACCE = major adverse cardiac and cerebrovascular events (composite of mortality, acute stroke/ transient ischemic attack and cardiac complications); PCI = percutaneous coronary intervention.

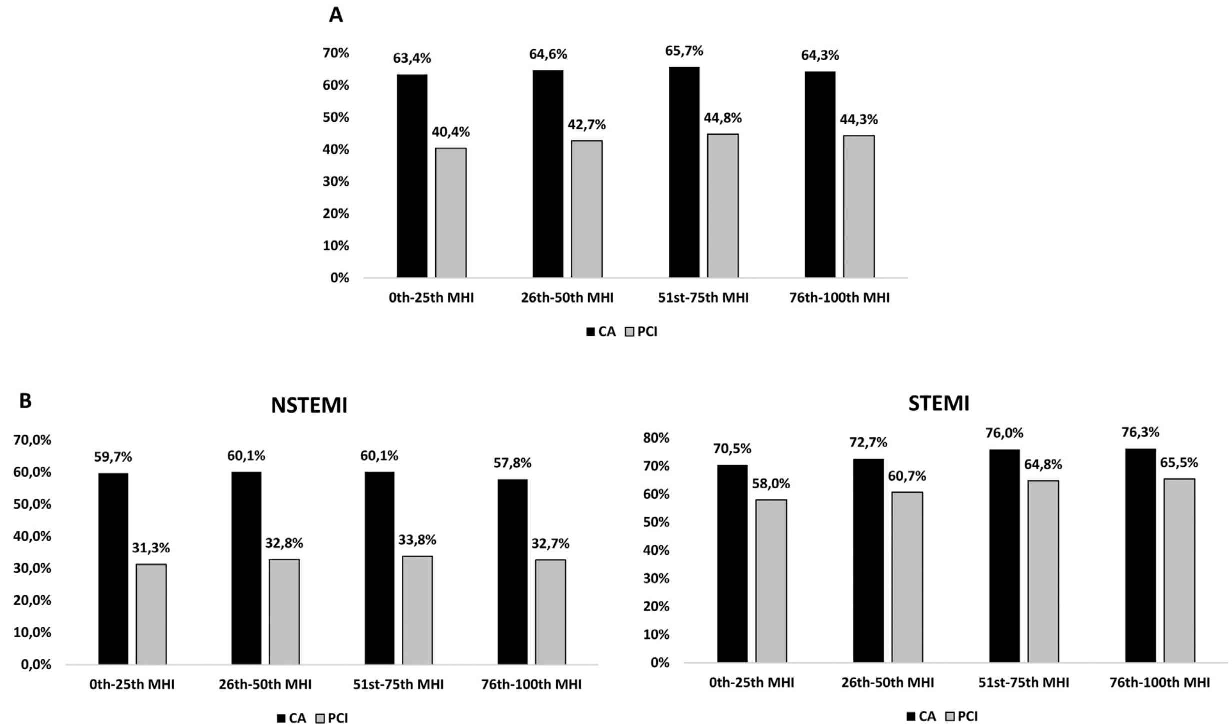

Figure 1. Receipt of CA and PCI according to the MHI: *(A)*. In total cohort; *(B)*. In AMI subtypes. CA = coronary angiography; NSTEMI = non-ST-elevation myocardial infarction; STEMI = ST-elevation myocardial infarction.

Table 3
Adjusted odds of in-hospital treatments and outcomes according to the Median Household Income group in total cohort*

Outcome	26th-50th (n = 1806775)		51st-75th (n = 1567720)		76th-100th (n = 1344515)	
	OR [95% CI]	p value	OR [95% CI]	p value	OR [95% CI]	p value
Treatments						
Receipt of CA	1.06 [1.06, 1.07]	<0.001	1.02 [1.02, 1.03]	<0.001	0.95 [0.95, 0.96]	<0.001
Receipt of PCI	1.09 [1.09, 1.10]	<0.001	1.14 [1.13, 1.14]	<0.001	1.10 [1.10, 1.11]	<0.001
Outcomes:						
MACCE	0.98 [0.97, 0.99]	<0.001	0.95 [0.95, 0.96]	<0.001	0.91 [0.91, 0.92]	<0.001
Mortality	0.97 [0.96, 0.98]	<0.001	0.94 [0.93, 0.95]	<0.001	0.88 [0.88, 0.89]	<0.001
Acute stroke/TIA	0.95 [0.93, 0.96]	<0.001	0.93 [0.92, 0.95]	<0.001	0.90 [0.88, 0.91]	<0.001
All-cause bleeding	1.04 [1.03, 1.05]	<0.001	1.06 [1.05, 1.07]	<0.001	1.08 [1.06, 1.09]	<0.001

* Reference group: 0th-25th (n=1884699) group.

Abbreviations: CA = coronary angiography; CI = confidence interval; MACCE = major adverse cardiac and cerebrovascular events (composite of mortality, acute stroke/transient ischemic attack and cardiac complications); OR = odds ratios; PCI = percutaneous coronary intervention; TIA = transitory ischemic attack.

Table 4
Adjusted odds of in-hospital outcomes according to the Median Household Income group in AMI subgroups*

Outcome	26th-50th (n = 1806775)		51st-75th (n = 1567720)		76th-100th (n = 1344515)	
	OR [95% CI]	p value	OR [95% CI]	p value	OR [95% CI]	p value
Treatments						
Receipt of CA						
NSTEMI	1.05 [1.05, 1.06]	<0.001	0.99 [0.98, 0.99]	<0.001	0.91 [0.90, 0.91]	<0.001
STEMI	1.06 [1.05, 1.07]	<0.001	1.08 [1.07, 1.09]	<0.001	1.04 [1.03, 1.05]	<0.001
Receipt of PCI						
NSTEMI	1.08 [1.07, 1.09]	<0.001	1.09 [1.08, 1.10]	<0.001	1.04 [1.03, 1.05]	<0.001
STEMI	1.08 [1.07, 1.09]	<0.001	1.17 [1.16, 1.18]	<0.001	1.17 [1.16, 1.18]	<0.001
Outcomes						
MACCE						
NSTEMI	0.98 [0.97, 0.99]	<0.001	0.96 [0.95, 0.97]	<0.001	0.93 [0.92, 0.94]	<0.001
STEMI	0.98 [0.96, 0.99]	<0.001	0.95 [0.94, 0.97]	<0.001	0.90 [0.89, 0.91]	<0.001
Mortality						
NSTEMI	0.97 [0.96, 0.98]	<0.001	0.94 [0.92, 0.95]	<0.001	0.90 [0.88, 0.91]	<0.001
STEMI	0.97 [0.95, 0.98]	<0.001	0.94 [0.93, 0.96]	<0.001	0.88 [0.87, 0.89]	<0.001
Acute stroke/TIA						
NSTEMI	0.95 [0.93, 0.97]	<0.001	0.93 [0.91, 0.95]	<0.001	0.90 [0.88, 0.92]	<0.001
STEMI	0.95 [0.92, 0.98]	0.001	0.96 [0.93, 0.99]	0.006	0.90 [0.87, 0.93]	<0.001
All-cause bleeding						
NSTEMI	1.05 [1.04, 1.06]	<0.001	1.05 [1.04, 1.06]	<0.001	1.07 [1.05, 1.08]	<0.001
STEMI	1.02 [1.00, 1.03]	0.043	1.09 [1.07, 1.11]	<0.001	1.11 [1.09, 1.13]	<0.001

* Reference group: 0th-25th (n=1884699) group.

Abbreviations: AMI = acute myocardial infarction; CA = coronary angiography; CI = confidence interval; MACCE = major adverse cardiac and cerebrovascular events (composite of mortality, acute stroke/transient ischemic attack and cardiac complications); NSTEMI = non-ST-elevation myocardial infarction; OR = odds ratios; PCI = percutaneous coronary intervention; STEMI = ST-elevation myocardial infarction; TIA = transitory ischemic attack.

the NSTEMI subgroup for the MACCE outcome, but remained in other outcomes irrespective of the AMI subtype. Differences were generally more pronounced in the STEMI subgroup (Table 2).

The findings persisted in multivariable analysis, in which the highest MHI group had the lowest odds of MACCE (aOR 0.91 [0.91, 0.92]), mortality (aOR 0.88 [0.88, 0.89]) and acute stroke/ transient ischemic attack (aOR 0.90 [0.88, 0.91]; Table 3). This pattern was found in both STEMI and NSTEMI subgroups (Table 4).

Overall receipt of coronary angiography or PCI steadily increased over the years, irrespective of MHI (Table 5). Graphical analysis of adjusted odds for invasive management has shown a constant pattern of MHI-related disparity in coronary angiography and PCI receipt, but recent years suggest alleviation of such inequalities. This tendency has been observed for PCI in both AMI subgroups, while receipt of coronary angiography has shown a convergent trend only in STEMI patients (Figure 2, Supplementary Tables S3 to S5). Likewise, outcome inequalities among different MHI groups exist but generally tended to decrease in recent years, except for mortality which maintains a divergent trend in both AMI subgroups (Figure 3, Supplementary Tables S3 to S5). Trend analysis revealed a significant decrease in all adverse outcomes across the years, except all-cause bleeding which showed a steady increase, in all MHI groups (Table 5).

Discussion

The present study of >6.5 million hospitalizations is by far the largest to examine the trends of management strategies and in-hospital clinical outcomes of AMI according to SES over an 11-year period. Several key findings can be noted. First, we show that SES is associated with co-morbidity burden, with a lower overall co-morbidity burden found in the higher SES groups. Second, we observe a direct relationship between SES and invasive management, with higher SES patients more likely to receive coronary angiography and PCI. Patients with higher SES had better outcomes, including MACCE, mortality and acute stroke, but not bleeding. Notwithstanding, these inequalities have considerably improved over the study period, although not fully resolved.

Our analysis reveals that AMI patients with low SES generally have more co-morbidities compared with their high SES counterparts, consistent with previous reports.[6,7,12–14] Whilst significant differences among AMI patients based on SES in terms of management and outcomes were observed, these substantially lessened over time. An improvement in mortality with an increase in bleeding rates was observed in all MHI groups over the study period. These trends could partly be attributable to higher overall use of invasive management, but other factors like potent antithrombotic therapy could presumably also affect bleeding rates.[15] Previous studies that have evaluated the impact of SES on outcomes of AMI are smaller,[16] included only STEMI patients[7] or elderly patients[8] or occurred in healthcare settings outside of the US.[6,12] Yong et al evaluated acute coronary syndrome patients (N = 835,070) and found that low SES patients were least likely to get timely revascularization and DES.[16] Agarwal et al analyzed NIS data of STEMI patients (2003 to 2011) reporting that lower SES patients had decreased timely reperfusion and increased in-hospital mortality.[7] Rao et al

Table 5
Trend of in-hospital outcomes and invasive management from 2004 to 2014

Outcome/Year	2004-2006	2007-2009	2010-2012	2013-2014	p value (for trend)
MACCE					
0th-25th MHI	9.0%	8.2%	7.5%	7.1%	<0.001
26th-50th MHI	8.6%	8.2%	7.2%	7.1%	<0.001
51st-75th MHI	8.4%	8.1%	7.1%	7.0%	<0.001
76th-100th MHI	8.3%	7.8%	7.2%	7.1%	<0.001
Mortality					
0th-25th MHI	7.1%	6.1%	5.5%	5.1%	<0.001
26th-50th MHI	6.8%	6.0%	5.2%	4.9%	<0.001
51st-75th MHI	6.5%	5.9%	5.1%	4.8%	<0.001
76th-100th MHI	6.5%	5.6%	5.2%	5.0%	<0.001
Acute stroke/TIA					
0th-25th MHI	2.0%	1.9%	1.7%	1.6%	<0.001
26th-50th MHI	1.7%	1.8%	1.5%	1.7%	<0.001
51st-75th MHI	1.8%	1.8%	1.5%	1.6%	<0.001
76th-100th MHI	1.7%	1.7%	1.6%	1.6%	<0.001
Cardiac complications					
0th-25th MHI	0.4%	0.7%	0.7%	0.7%	<0.001
26th-50th MHI	0.5%	0.7%	0.8%	0.8%	<0.001
51st-75th MHI	0.5%	0.8%	0.8%	0.9%	<0.001
76th-100th MHI	0.5%	0.8%	0.8%	0.9%	<0.001
All-cause bleeding					
0th-25th MHI	3.9%	4.8%	5.7%	6.1%	<0.001
26th-50th MHI	4.1%	5.0%	5.9%	6.4%	<0.001
51st-75th MHI	4.6%	5.4%	6.0%	6.7%	<0.001
76th-100th MHI	5.1%	5.7%	5.8%	6.5%	<0.001
CA					
0th-25th MHI	56.5%	62.2%	66.8%	70.7%	<0.001
26th-50th MHI	59.2%	64.0%	67.2%	70.5%	<0.001
51st-75th MHI	61.4%	64.8%	68.2%	70.7%	<0.001
76th-100th MHI	61.1%	63.2%	66.5%	69.0%	<0.001
PCI					
0th-25th MHI	34.6%	39.6%	43.3%	46.2%	<0.001
26th-50th MHI	37.8%	42.1%	45.3%	47.9%	<0.001
51st-75th MHI	40.9%	44.2%	47.0%	49.1%	<0.001
76th-100th MHI	41.0%	43.7%	46.4%	48.4%	<0.001

Abbreviations: CA = coronary angiography; MACCE = major adverse cardiac and cerebrovascular events (composite of mortality, acute stroke/transient and cardiac complications); MHI = median household income; PCI = percutaneous coronary intervention; TIA = transitory ischemic attack.

evaluated elderly American Medicare beneficiaries in the angioplasty era concluding that there were significant disparities in management and outcomes based on SES.[8] Interestingly, studies performed in countries offering universal healthcare systems have shown less disparity in delivery of healthcare based on SES.[6,12,17] An Australian study of STEMI patients (2005 to 2015) treated at 6 government funded hospitals (N = 5,665) reported that even though lower SES was associated with more co-morbidities and slightly longer reperfusion times, there was no difference in in-hospital and 1-year mortality and MACE (composite of death, AMI, and target vessel revascularization).[6] However a Swiss

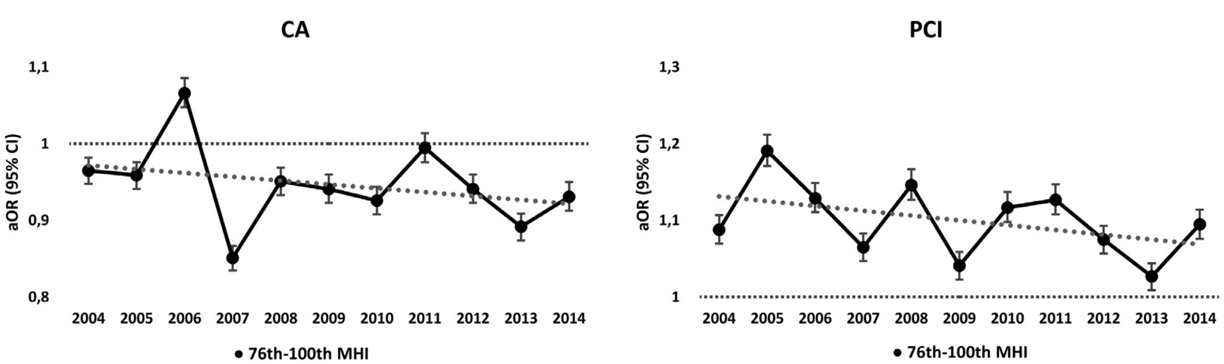

Figure 2. The trend of adjusted odds for invasive management according to the MHI from 2004 to 2014.
*Reference group: 0th-25th (n=1884699) group; $p<0.001$ for all trends. CA = coronary angiography.

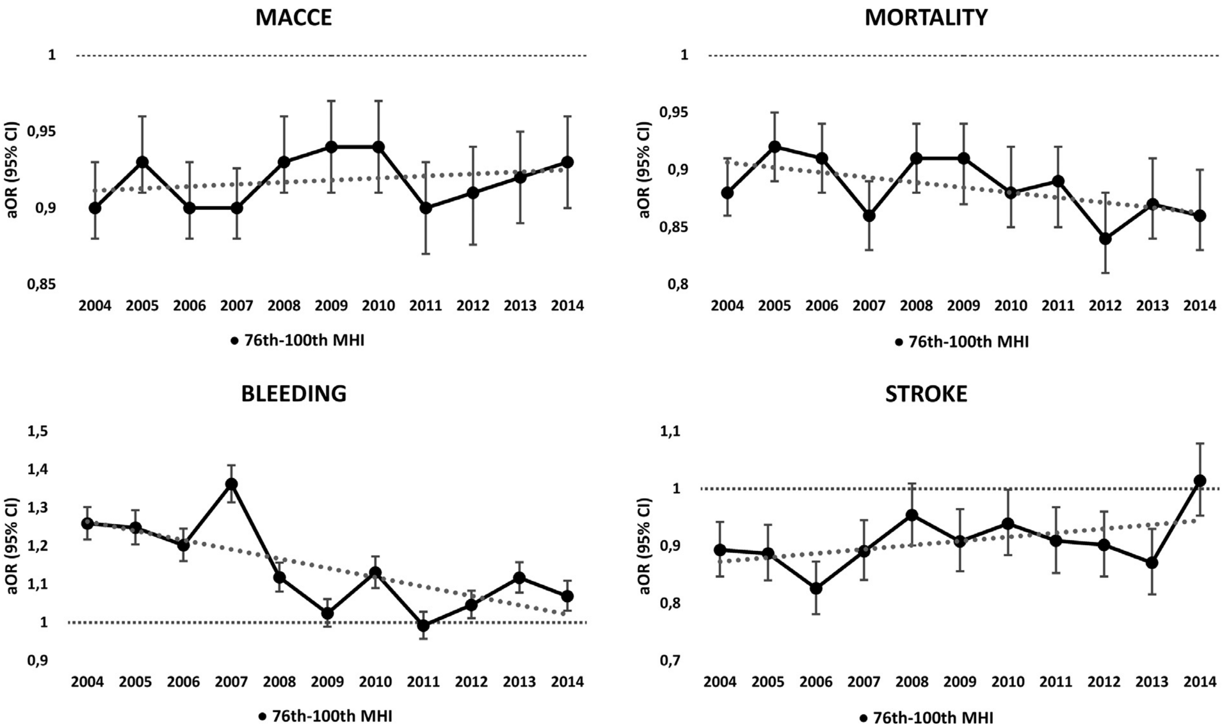

Figure 3. The trend of adjusted odds for different clinical outcomes according to the MHI from 2004 to 2014.
*Reference group: 0th-25th (n=1884699) group; $p<0.001$ for all trends. MACCE = major adverse cardiovascular and cerebrovascular events.

study of 10,895 AMI patients (1995 to 2013) revealed that patients residing in low SES areas had worse outcomes with differences persisting even after adjusting for traditional risk factors.[18]

The reasons for lower adoption of evidence-based management and the poor outcomes among low SES AMI patients are complex and multifactorial. Lack of education and social awareness, poor access to transport and specialized care hospitals and lack of insurance places low SES patients at a disadvantage.[5] Even when they do receive invasive therapy low SES patients with AMI have longer reperfusion times,[7] and are less likely to receive DES[16] and to be prescribed guideline directed medical therapy at follow-up.[6]

This is the largest study to date to analyze in-hospital outcomes of AMI patients based on SES from a national perspective. Our analysis emphasizes the importance of continued public health measures to aid screening and prevention in low SES groups. The World Health Organization's "25by25" initiative aims to reduce cardiovascular mortality by 25% by year 2025 irrespective of any socioeconomic, racial or gender-based differences.[19] Universal health care, which will enable equal access to primary care services, has been recognized as a step towards sustainable development and diminishing inequalities.[20] In the absence of universal health care other measures such as the US Federal Government's Healthy People initiative are imperative. This initiative aims to provide data and tools to eliminate disparities in healthcare access and delivery based on sex, age, race, region, and SES. A 5-step framework for public health intervention called MAP-IT (mobilize, assess, plan, implement, and track) has been recommended as a path to the establishment of a healthy community.[21] Additionally at a physician-level, outreach services to lower SES communities, mass screening initiatives, and raising public awareness through media campaigns should be considered.

We acknowledge several limitations of our study, including the utilization of zip code based MHI as a surrogate for SES. Although we do not take into account other SES components such as education and employment as has been defined in expert documents,[5] the sole utilization of zip code based income is a well-established method within healthcare systems.[22,23] Secondly, some limitations like coding errors, hospitalization-based data, under-reporting of secondary diagnoses, and lack of formal adjudication of outcomes are inherent to the NIS database itself.[15] The NIS also does not capture the exact cause of death, and long-term outcomes thereby limiting us to just in-hospital events. Finally, the NIS does not capture antithrombotic strategies or drug therapies that may confound our findings.

In conclusion, using zip-code based SES, patients with low SES have more cardiovascular and noncardiovascular co-morbidities than their high SES counterparts with low SES patients receiving less coronary angiography and PCI associated with higher in-hospital mortality, MACCE, and ischemic stroke, especially in the STEMI patients. Over an 11-year study period significant differences in terms of management and in-hospital clinical outcomes were observed which were largely mitigated towards the end of the study period (2013 to 2014). Our findings underscore the importance of a continued multilevel, collaborative approach with easy access to healthcare particularly in low SES zip codes.

Author Contribution

Andrija Matetic: Software, Data curation, Methodology, Formal analysis, Visualization, Writing - Reviewing and

Editing; *Aditya Bharadwaj*: Methodology, Writing - Original draft preparation, Writing - Reviewing and Editing, Validation; *Mohamed Mohamed*: Conceptualization, Methodology, Data curation, Formal analysis, Writing - Reviewing and Editing; *Yashasvi Chugh*: Validation, Writing - Reviewing and Editing; *Sanjay Chugh*: Validation, Writing - Reviewing and Editing; *Margot Minissian*: Validation, Writing - Reviewing and Editing; *Amit Amin*: Validation, Writing - Reviewing and Editing; *Harriette Van Spall*: Validation, Writing - Reviewing and Editing; *David L. Fischman*: Validation, Writing - Reviewing and Editing; *Michael Savage*: Validation, Writing - Reviewing and Editing; *Annabelle Santos Volgman*: Validation, Writing - Reviewing and Editing; *Mamas A. Mamas*: Supervision, Conceptualization, Methodology, Resources, Project administration, Validation, Writing - Reviewing and Editing.

Declaration of Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this study.

Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.amjcard.2020.05.025.

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