Differences in Treatment Patterns and Outcomes of Acute Myocardial Infarction for Low- and High-Income Patients in 6 Countries: an analysis from the International Health Systems Research Collaborative

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Key Points

Question: How do treatment patterns and outcomes for elderly patients presenting with acute myocardial infarction differ for low versus high income individuals across six countries.

Findings: In this study of 289,376 patients aged 66 years and over hospitalized with STEMI and 843,046 hospitalized with NSTEMI across six health systems, adjusted 30-day mortality rates were higher for low-income patients while rates of cardiac catheterization and percutaneous coronary interventions were lower. High-income patients also had shorter length of stay and lower rates of readmissions.

Meaning: These results suggest that Income-based disparities were present even in countries with universal health insurance and robust social safety net systems.

Abstract (322 words)

Importance: Differences in the organization and financing of health systems may produce more or less equitable outcomes for advantaged versus disadvantaged populations. We compared treatments and outcomes of elderly high- and low-income patients across six countries.

Objective: To determine if treatment patterns and outcomes for patients presenting with acute myocardial infarction differ for low- versus high-income individuals across six countries.

Design/Setting/Participants: Serial cross sectional cohort study of all adults age $\geq$ 66 years hospitalized with acute myocardial infarction between 2013 and 2018 in the US, Canada, England, Netherlands, Taiwan, and Israel using population-representative administrative data.

Exposures: Being in the top and bottom quintile of income within and across countries.

Main Outcomes: 30-day mortality, rates of cardiac catheterization and revascularization, length of stay, and readmission rates.

Results: We studied 289,376 patients hospitalized with STEMI and 843,046 hospitalized with NSTEMI. Adjusted 30-day mortality generally was 1-3 percentage points lower for high-income patients. For instance, 30-day mortality for high- vs. low-income STEMI patients in the Netherlands was 10.2% vs. 13.1%, difference -2.8% [95% C.I. -4.1 to -1.5]. In all countries, rates of cardiac catheterization and PCI were higher among high- vs low-income populations, with absolute differences ranging from 1-6 percentage points (e.g., 73.6% v. 67.4%, difference 6.1 percentage points [95% C.I. 1.2 to 11.0] for PCI in England for STEMI). Rates of CABG for STEMI patients in low- vs high-income were similar, but for NSTEMI were generally 1-2 pp higher among high-income patients (e.g., 12.5% v. 11.0% in the US, difference 1.5 percentage points [95% C.I. 1.3 to 1.8]). Thirty-day readmission rates generally also were 1-3 pp lower and hospital length-of-stay (LOS) generally was 0.2-0.5 days shorter for high-income patients.

Conclusions and Relevance: High-income individuals had substantially better survival and were more likely to receive lifesaving revascularization and had shorter LOS and fewer readmissions across almost all countries. Our results suggest that Income-based disparities were present even in countries with universal health insurance and robust social safety net systems.

Key Words: acute myocardial infarction, international comparisons, disparities in care

Research comparing treatment approaches and outcomes across countries can illuminate policy efforts to optimize population health.[1–5] Many international comparisons, reliant on aggregated country-level data, have reported that the United States (US) spends more but has poorer health as measured by life expectancy and childbirth outcomes.[2,6] A small number of these comparisons have evaluated between-country differences for racial minorities or lower income individuals, reporting substantial disparities in care, which manifests as shorter lifespans for these populations in the US.[7,8]

These high-level analyses lack detailed information on how disease-specific processes of care and outcomes differ for patients presenting with a single illness or condition across different countries.[9] Such disease-specific studies could provide insights into the potential impact of health system factors on treatment and outcomes for specific conditions as distinct from other social factors, which consistently have been shown to be major factors influencing health.[8,10,11] There are reasons to believe that income-based disparities may be larger in the US than other countries, even for seniors who are all insured by Medicare, due to wealthier patients having the ability to seek care from higher quality physicians and hospitals.[8] Alternatively, income-based disparities could be smaller for seniors in the US than seniors in other countries thanks to Medicare's generous coverage of advanced therapies and wide availability of these services. Moreover, like health systems in other countries, the US Medicare program provides nearly universal insurance for people aged 65 and older, and those with low incomes and disabilities also qualify for Medicaid, which eliminates most Medicare cost-sharing.

We developed the International Health System Research Collaborative (IHSRC) to facilitate population-level comparisons of treatment patterns and outcomes in the US, Canada, England, the Netherlands, Israel, and Taiwan; countries with highly developed healthcare systems and accessible administrative data, but significant differences in financing, organization, and performance in international rankings.[12–16] In this study, we compare differences in AMI treatment (e.g., cardiac catheterization, revascularization) and outcomes (mortality, readmissions) for high- and low-income patients across our six countries. AMI is an exemplar condition for cross-country comparison because it is common, has internationally agreed upon diagnostic criteria, and validated coding schemes in administrative data.[17–21] Moreover, patients with AMI are consistently hospitalized in high-income countries, so hospital data generally capture all cases. Thus, these data are ideal for comparing the differences in treatment processes and outcomes of high- versus low-income patients across countries. We hypothesized that despite each country offering universal insurance for older adults, there would be larger income-based disparities in treatment and outcomes in the US than other countries, notwithstanding the fact that low-income older adults would do worse in all countries.

Methods

Data and patients

Following prior work, we used population-representative administrative claims to identify all adults age 66 years and older hospitalized for at least one day (or who died on the day of admission) with a primary diagnosis of ST elevation or non-ST elevation myocardial infarction (STEMI or NSTEMI) between January 1, 2013 and December 31, 2018 in any of our six IHSRC countries (Canada was represented by data from the provinces of Ontario and Manitoba) using relevant ICD9 and ICD10 codes (see Appendix Table 1 for coding). We applied the same inclusion and exclusion criteria in the same order in each country, though we allowed for some variations to reflect local differences in data architecture. More detail is available elsewhere on the data sources used for each country.[22]

We excluded patients with an AMI admission during the year prior to avoid counting readmissions as new admissions. We also excluded patients with less than one year of preadmission or post-admission follow-up data except in the case of death. For patients who were transferred between hospitals as part of their admission, we evaluated the complete episode of care. We used data from 2012 for our one-year lookback and data from 2019 for one-year follow-up.

We recorded demographic information (age, sex) and comorbidities. Comorbid conditions present on the index admission and previous admissions during the 1-year lookback were captured using a Manitoba adaptation of the Elixhauser comorbidity index.[23,24] Following Agency for Healthcare Research and Quality convention, we excluded cardiovascular conditions identified in the index admission that could plausibly have arisen due to the AMI, but included other non-cardiovascular conditions from that admission.[25] In the Netherlands where comorbidities from hospital data were unavailable, we used medications related to chronic conditions to identify comorbidities (see Appendix Table 2 for each country's approach to identifying comorbidities).[26–28]

Ascertaining Income Status

We use "income" as a proxy measure of socioeconomic status. In most countries, we defined high-income patients as those living in an area (e.g., postal code) in the top 20% of the income distribution and low-income as those living in areas in the bottom 20% of the distribution such that we used a similar definition for each country that defined high- and low-income relative to the incomes in that particular country. The income distributions used to define high and low were based on regions within countries, except in Israel and England, where they were national (Sensitivity analyses by region in Israel showed similar results). Thus, these methods are subject to misclassification at the individual level and vary across countries based on the level of income mixing within the regions. In the Netherlands, household income was observed for individuals, rather than areas. More details on the country-specific approaches are available in Appendix Table 3.

Outcomes

The primary outcomes were age-, sex-, and comorbidity-adjusted 30-day and one-year mortality, which was available in the administrative data from each country. Secondary outcomes included use of cardiac catheterization, percutaneous coronary intervention (PCI), and coronary artery bypass grafting (CABG) during the index hospitalization and within 90 days of admission. These outcomes were selected because there is a strong body of evidence for the benefits of early PCI in patients with STEMI, but also concern about potential overuse of PCI in the NSTEMI population.[29–31] We also examined hospital length-of-stay [LOS] and readmission within 30 days of discharge.

Statistical Analyses

Our analyses were focused on comparison of low- versus high-income patients within each country and stratified by STEMI v. NSTEMI. We compared age, sex, and comorbidities of low and high-income patients hospitalized with AMI in each year and country. We calculated population-level AMI rates (hospitalizations per 1,000 population age $\geq$ 66 years per year) for each country and year and adjusted (via direct standardization) the results for the high-income patients to the age and sex distribution of the low-income patient in that country. We were not able to calculate adjusted AMI rates for England because we lacked denominator populations by income.

From prior work, we know that recording of comorbidities differs markedly across countries as a result of different incentives for coding.[22] As a result, adjusting for recorded comorbidities in between-country comparisons is likely biased. However, adjusting for comorbidities for within-country comparisons should not be a problem; therefore, within each country, we compared outcomes for high- and low-income patients by estimating 30-day mortality and readmissions after adjusting for age, sex, and comorbidities. In each country and for each outcome, we fit logistic regression models with indicators for age (in 5-year ranges), sex, and comorbidities. We interpreted the regression coefficient on the highest income quintile versus the lowest income quintile.

We then calculated age- and sex-standardized rates of in-hospital and 90-day cardiac interventions (cardiac catheterization [with or without PCI], PCI, and CABG) within each country for those in the top and bottom income quintiles. We did not adjust these comparisons for comorbid conditions because treatment approaches in AMI generally are dictated by the type of AMI rather than the presence or absence of comorbid conditions. We analyzed readmissions and length of stay in a similar manner.

Analyses were conducted for all the years pooled. . Our analyses were conducted locally by investigative teams from each of our six IHSRC countries and approved by the appropriate ethics oversight boards in each country. Analyses were conducted using SAS (US, Ontario, Manitoba, Taiwan), and R (Israel, England, Netherlands).

Results

Our study population consisted of 289,376 hospitalizations for STEMI and 843,046 for NSTEMI between 2013-2018 in the US, Canada (Ontario and Manitoba), England, Netherlands, Israel, and Taiwan. The average income in the lowest and highest income quintiles are presented in Table 1 in each country's native currency. Across the countries, the ratio of income (mean income for highest-income quintile/ lowest quintile) ranged from 1.35 for Taiwan to 4.36 for Israel (US 2.14). STEMI and NSTEMI incidence rates were higher for low-income (vs. high-income) populations in all countries. For instance, annual STEMI incidence in Canada was 1.55 per 1,000 among the low-income population versus 1.32 among the high-income population.

Average age was generally similar within countries for high- and low-income and between countries (Table 1). Similar data broken out by STEMI and NSTEMI is in Appendix Table 4. There were large differences between countries in rates of comorbid illness, which reflect known country-specific coding patterns. For example, rates of hypertension among patients in the lowest income quintile were 87% in the US compared to 67% in England and 10% in Netherlands. Looking across income quintiles within a given country, rates of comorbid conditions were much more similar though conditions such as diabetes and congestive heart failure (CHF) were generally more common in the lowest vs. the highest income quintile (e.g., diabetes in Israel was 71% vs. 40%; CHF in England was 8.6% v. 5.7%). A full listing of comorbidities is available in Appendix Tables 5 and 6.

Mortality

Adjusted 30-day and one-year mortality for both STEMI and NSTEMI were lower for the high-income patients in all countries except Taiwan (Figure 1). The largest differences in 30-day mortality were seen in Canada for STEMI (14.9% v. 17.8% for high vs. Low SES quintile respectively, difference –2.9 percentage points [95% C.I. -4.7 to -1.2]) and Israel for NSTEMI (8.8% v. 11.5%, difference -2.8% [95% C.I. -6.4 to 0.9]). One year mortality differences were even larger, with the highest difference being in Israel (16.2% v. 25.3%, difference -9.1% [95% C.I. -16.7 to –1.6] for STEMI and 22.2% v. 28.9%, difference -6.7% [95% C.I. -12.4 to –0.9] for NSTEMI). Age/sex standardized results are shown in Appendix Figure 1.

Treatment patterns

Rates of cardiac catheterization and PCI within 90 days of admission for STEMI were higher for high-income patients than low-income patients in all countries (Figure 2). For instance, rates of catheterization in high- versus low-income STEMI patients in England were 85.3% v. 79.4% (difference 5.9 percentage points [95% C.I. 0.6 to 11.2]. Rates of catheterization for NSTEMI also were higher among high-income patients in all six countries (e.g., 50.7% v. 45.1%, difference 5.7 percentage points [95% C.I. 3.5 to 7.8] for the Netherlands. Rates of PCI showed similar patterns (higher rates of PCI for those in the highest income quintile). Rates of CABG within 90 days of STEMI were not uniformly higher or lower in the highest income quintile (Figure 2). Among NSTEMI patients, however, high-income patients had higher CABG rates in all countries except Israel and Taiwan. Taken together, rates of revascularization were substantially higher for high-income patients in all countries for STEMI and NSTEMI.

LOS and Readmissions

Length of stay was generally shorter for high versus low-income patients for both STEMI and NSTEMI except for Israel and Taiwan (Figure 3). Thirty-day readmission rates were consistently lower for higher income patients for both STEMI and NSTEMI. The difference among NSTEMI patients ranged from -0.7 percentage points in the US (15.7% v.16.4% , difference-.07 percentage points [95% C.I. -1.0 to -0.4] to -2.4 pp in Canada (13.8% v. 16.2%, difference -2.4 percentage points [95% C.I. -3.5 to -1.3]) Age/sex standardized readmission rates are shown in Appendix Figure 2.

Discussion

In this analysis of population-representative patient-level administrative data from six high-income countries, we observe several notable findings. First, despite vastly different healthcare systems, AMI mortality rates were generally higher for low-income patients, though this was not the case in Taiwan, which also had the smallest relative difference between the highest and lowest income quintiles. Second, low-income patients in all countries were less likely to receive cardiac catheterization and PCI than high income patients. Third, both per-capita AMI rates and

30-day hospital readmission rates were consistently higher for low-income patients. Taken together, these results suggest that for AMI, patients from low-income groups are subject to disparities in care processes and outcomes despite vastly different healthcare and social safety net systems.

Our study challenges an important and deeply held belief that income-based disparities in health and healthcare are larger in the US than other high-income countries, though with the caveat that we examine an elderly population that is eligible for Medicare coverage, which may be more similar to available coverage in other countries. There are very few studies that have directly addressed this issue using patient-level data for circumscribed diseases or conditions. Recent studies from the ICCONIC group found that persistently costly Medicare patients were more likely to be Medicaid eligible and to be members of racial and ethnic minority groups.[3,32] Reports from the OECD have documented similar findings.[33] A recent cohort study using survey and self-reported data from the US and England found larger income-based disparities in health outcomes in the US for adults age 55-64.[7] That study relied on self-report of adults who were not yet eligible for Medicare, so some of those observed differences in health outcomes may have been driven by higher under- or uninsurance rates in the US. Our study also builds upon a recent study that examined health outcomes of US residents from wealthier and poorer geographic regions compared to similar populations in other high-income countries, finding that outcomes for wealthy Americans were no better than average outcomes in other countries.[11] That study, however, used mostly aggregated data, which might obscure more substantial heterogeneity by income level within counties. Moreover, because health outcomes also are dependent on the availability of health system resources in an area, that study also might have been confounded by geographic differences in healthcare resources available in different areas of the country.[34]

The mortality differences we identified were substantial, including differences in 30-day mortality for STEMI in the almost all countries that were 2-3 percentage points higher (absolute difference) for low-income patients (a 10-20% relative difference). For context, a 2%-3% absolute difference in mortality is similar to the mortality benefits afforded by treatment innovations such as primary PCI or thrombolytic therapy.[31,32] We also observed that low-income patients were treated less aggressively, with lower rates of both cardiac catheterization and revascularization, which might be one potential explanation for worse outcomes. Our finding that lower income patients received less aggressive treatment in all countries builds on prior studies suggesting that lower income patients are less likely to receive many types of both evidence-based and non-evidence-based care.[35–37]

It also is possible that factors beyond revascularization may contribute to the higher mortality for lower income patients. For instance, smoking rates are higher among low income vs. higher income populations in most countries.[33,38] In addition, geography and differential access for lower income patients to facilities with advanced cardiovascular services might explain lower rates of PCI and CABG. Though we controlled for measured comorbidities in each country in our mortality analyses, there also may be higher rates of other unmeasured comorbidities among lower income populations that might also influence short term outcomes.[39] Irrespective of the cause, our finding of increased mortality of a similar magnitude for lower income patients in all countries suggest that poverty and disadvantage are problems that afflicts all countries irrespective of history, culture, healthcare system, and social safety net.[8,40–42]

Readmission rates were universally higher among lower income patients in all countries, though the magnitude of this difference varied. The largest difference was in Israel for STEMI, but differences across the countries were relatively similar. Readmission rates have been an area of intense scrutiny in the US since the publication of a landmark 2009 study that found readmission rates approaching 20% for Medicare patients.[43] The Hospital Readmission

Reduction Program (HRRP) has been one of the signature value-based purchasing programs for hospital by the US Medicare program. The HRRP penalizes Medicare payments for hospitals with higher readmission rates and has been associated with reductions in readmissions over time.[44,45] Perhaps related to the HRRP, but also potentially due to other factors, readmission rates we observed in the US were among the lowest of the 6 countries studied.[46–48] More recently, there also has been a widespread recognition in the US that readmissions are strongly related to social factors.[44,49–51] As a result, the HRRP has adopted a new methodology for determining penalties that compares hospitals to peer hospitals that care for similar proportions of disadvantaged populations.[52] Our finding of higher readmission rates for patients with low income in all countries provides important new information that the challenges of reducing hospital readmissions for disadvantaged populations are not easily rectified.

Our study has several limitations that warrant mention. First, our study relied upon administrative claims data and lacked detailed clinical information about myocardial infarction severity or treatments so we cannot stratify subgroups of patients (e.g. by severity) beyond the STEMI-NSTEMI dichotomy, age and gender. We also lacked information on potentially important confounders such as smoking rates. Second, there is no universal method for identifying low- and high-income populations across countries and most existing methods may not account for assets or consumption.[53] Moreover, rates of misclassification might vary as a result of differential rates of income mixing within geographic regions in each country. Using area-level measures as we did also leads to misclassification, but this misclassification biases our results towards the null and would not explain the results we observed. Third, we did not adjust for race or ethnicity as race and ethnicity data were not available for all countries and populations considered to be disadvantaged also differed across the countries. Fourth, our study was limited to adults aged 66 years and older who were hospitalized for AMI and may not apply to younger patients or those with private insurance or enrolled in Medicare managed care in the US. Moreover, by focusing on American seniors insured by Medicare, we were not able to evaluate whether income-based disparities in the US might be magnified relative to other countries in younger populations where US uninsurance rates approach 10% and underinsurance 20%. Fifth, some of our results might be explained by variation in the availability of hospitals that perform PCI and/or CABG or the quality of hospitals within an area. Thus, further research is warranted to explore the contribution of supply side factors to the outcomes we observed.

In this analysis of disparities in treatment and outcome for AMI across six different countries, we found relatively consistent disparities in both treatment and outcomes by income. Our results suggest that in contrast to findings from other studies, the US is not an outlier in terms of the care provided to and outcomes of low vs. high income patients for the population of elderly patients admitted with an acute myocardial infarction.

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<u>Table</u> 1: Study population by jurisdiction for SES quintiles across all study years (2013-2018)

	Canada		England		Israel		Netherlands		Taiwan		US	
	1st (poorest) quintile	5th (wealthiest) quintile	1st (poorest) quintile	5th (wealthiest) quintile	1st (poorest) quintile	5th (wealthiest) quintile	1st (poorest) quintile	5th (wealthiest) quintile	1st (poorest) quintile	5th (wealthiest) quintile	1st (poorest) quintile	5th (wealthiest) quintile
Sample size												
Overall N(a)	17,367	12,412	6,829	10,056	715(n)	1,833(n)	17,483	13,216	11,507	10,242	194,462	142,104
STEMI N(a)	4,398	3,586	1,803	3,044	217	554	5,603	5,072	4,444	3,888	42,585	35,956
STEMI incidence per 1000(b)	1.55	1.32	—(i)	—(i)	2.11	1.08	1.64	1.54	1.65	1.46	1.24	1.08
NSTEMI N(a)	12,969	8,826	5,026	7,012	498	1,279	11,880	8,144	7,063	6,354	151,877	106,148
NSTEMI incidence per 1000(b)	4.57	3.41	—(i)	—(i)	4.83	2.26	3.48	2.64	2.58	2.38	4.36	3.25
Income metrics												
Average income, local currency	44,160(c)	113,920(c)	27,913(d)	51,116(d)	102,360(e)	446,076(e)	17,149(f)	50,783(f)	549,600(g)	676,800(g)	35,525(h)	75,989(h)
Ratio of average incomes(o)	1.00	2.58	1.00	1.83	1.00	4.36	1.00	2.96	1.00	1.23	1.00	2.14
Gini index of income inequality		33.3(j)		35.1(j)(k)		38.6(l)		29.2(m)		n/a		41.1(m)
Demographics												
Age	78.7	78.0	78.6	79.9	76.3	80.5	79.1	75.2	78.1	77.7	79.1	79.8
Female	47.4	38.2	44.1	40.9	42.0	39.0	50.5	29.6	40.8	36.8	49.3	45.1
Male	52.6	61.8	55.9	59.1	58.0	61.0	49.5	70.4	59.2	63.2	50.7	54.9
Comorbidities(p)												
Hypertension	53.1	50.7	66.7	62.8	73.0	66.3	10.3	7.3	63.0	64.5	87.3	85.0
Diabetes	37.0	29.6	36.3	25.4	70.9	40.4	10.7	4.9	39.3	40.4	43.7	35.8
Congestive Heart Failure	6.3	4.8	8.6	5.7	14.8	12.7	0.2	0.1	13.1	11.7	15.5	12.4
Hypothyroidism	2.1	1.9	9.3	8.6	6.4	13.2	0.3	0.1	0.6	0.5	18.7	20.4

(a) Number of admissions
(b) Age and sex standardized number of admissions per year during study period
(c) Median neighborhood income of STEMI sample, Canadian dollars
(d) Mean net income by SES quintile, not based on study sample, British pounds. Data from English Indices of Deprivation 2019 and the UK Office of National Statistics

(e) Mean net household income by SES quintile for 2018 only, not based on study sample, Shekels
(f) Median household income of STEMI sample, Euros
(g) Median household income of STEMI sample, New Taiwan Dollars
(h) Median neighborhood income of STEMI sample, U.S. dollars. Data from US Census.
(i) Data not available.
(j) As of 2017 (World Bank)
(k) Data is for whole United Kingdom
(l) As of 2018 (World Bank)
(m) As of 2019 (World Bank)
(n) Israel reflects cases from 2011 to 2018 to accrue additional sample.
(o) The income quintiles we empirically defined differ from other available reports of income disparities for at least two different reasons. First, our use of area levels measures serves to dampen the disparity between the highest and lowest quintile. Second, our study focuses on the elderly population and for those at the high end of the income spectrum, the use of income may underestimate differences in underlying wealth.
(p) Listed comorbidities were selected for parsimony and relevance to AMI. Additional details are in Appendix Tables 4 and 5