Title

Differential Treatment and Outcomes for Patients With Heart Attacks in Advantaged and Disadvantaged Communities.

Journal

Journal of the American Heart Association, 12(17)

Authors

Shen, Yu-Chu
Sarkar, Nandita
Hsia, Renee

Publication Date

2023-09-05

DOI

10.1161/JAHA.122.030506

Peer reviewed

Journal of the American Heart Association

ORIGINAL RESEARCH

Differential Treatment and Outcomes for Patients With Heart Attacks in Advantaged and Disadvantaged Communities

Yu-Chu Shen, PhD; Nandita Sarkar, PhD; Renee Y. Hsia, MD, MSc

BACKGROUND: Racially and ethnically minoritized groups, people with lower income, and rural communities have worse access to percutaneous coronary intervention (PCI) than their counterparts, but PCI hospitals have preferentially opened in wealthier areas. Our study analyzed disparities in PCI access, treatment, and outcomes for patients with acute myocardial infarction based on the census-derived Area Deprivation Index.

METHODS AND RESULTS: We obtained patient-level data on 629 419 patients with acute myocardial infarction in California between January 1, 2006 and December 31, 2020. We linked patient data with population characteristics and geographic coordinates, and categorized communities into 5 groups based on the share of the population in low or high Area Deprivation Index neighborhoods to identify differences in PCI access, treatment, and outcomes based on community status. Risk-adjusted models showed that patients in the most advantaged communities had 20% and 15% greater likelihoods of receiving same-day PCI and PCI during the hospitalization, respectively, compared with patients in the most disadvantaged communities. Patients in the most advantaged communities also had 19% and 16% lower 30-day and 1-year mortality rates, respectively, compared with the most disadvantaged, and a 15% lower 30-day readmission rate. No statistically significant differences in admission to a PCI hospital were observed between communities.

CONCLUSIONS: Patients in disadvantaged communities had lower chances of receiving timely PCI and a greater risk of mortality and readmission compared with those in more advantaged communities. These findings suggest a need for targeted interventions to influence where cardiac services exist and who has access to them.

Key Words: acute myocardial infarction ■ Area Deprivation Index ■ cardiac outcomes ■ disadvantage ■ percutaneous coronary intervention

See Editorial by Mukaz and Cushman.

How does the overall level of disadvantage in the community in which one lives affect access to percutaneous coronary intervention (PCI) services, and is this level of disadvantage associated with treatment and outcome disparities? Prior literature has shown that racially and ethnically minoritized groups, as well as people with lower income and those in rural communities, have worse access to PCI than their counterparts.[1–3] Hospitals with PCI services have preferentially opened in areas with wealthier hospitals, higher rates of private insurance, and less state regulation of new cardiac catheterization laboratories.[1]

A significant limitation of existing studies is the identification of communities by a single dimension, such as income, race and ethnicity, or rurality, rather than a multidimensional understanding of disadvantage. Such measures extend beyond traditional variables, such as income and employment, to also include less traditional

Correspondence to: Renee Y. Hsia, MD, MSc, Department of Emergency Medicine, Box 1377, University of California, San Francisco, 1001 Potrero Ave., Building 5, Suite 6A, San Francisco, CA 94110. Email: renee.hsia@ucsf.edu

This article was sent to Jacquelyn Y. Taylor, PhD, PNP-BC, RN, FAHA, FAAN, Guest Editor, for review by expert referees, editorial decision, and final disposition.

Supplemental Material is available at https://www.ahajournals.org/doi/suppl/10.1161/JAHA.122.030506

For Sources of Funding and Disclosures, see page 10.

JAHA is available at: www.ahajournals.org/journal/jaha

CLINICAL PERSPECTIVE

What Is New?

- The results of our study show significant disparities in percutaneous coronary intervention access, treatment, and outcomes based on community level of disadvantage; patients in the most advantaged communities had a 20% higher likelihood of same-day percutaneous coronary intervention and a 16% to 19% lower likelihood of mortality compared with patients in the most disadvantaged communities.

What Are the Clinical Implications?

- These findings illuminate the association between neighborhood disadvantage status and the ability to access and receive timely percutaneous coronary intervention, as well as disparities in outcomes by neighborhood-level of disadvantage, suggesting a need for targeted public health interventions that distribute cardiac care more equitably across disadvantaged areas.

Nonstandard Abbreviations and Acronyms

ADI Area Deprivation Index

variables, such as housing (eg, median rent, percentage of owner-occupied housing units, percentage of units without complete plumbing), education, and household characteristics (eg, single-parent households, percentage of households without a motor vehicle). These additional measures are useful because they reflect the more complicated realities of the intersection of socioeconomic factors that affect people's lives.

These nuanced indices can also be helpful for more precisely understanding where disparities in PCI care exist, which is crucial, because timely PCI has been associated with better patient outcomes.[4,5] This study aimed to determine whether patients with acute myocardial infarction (AMI) in areas with high levels of deprivation experienced differences in PCI access, treatment, and outcomes compared with those in areas with lower levels of deprivation. A community-level approach was used to categorize communities based on the percentage of residents living in neighborhoods with a high or low Area Deprivation Index (ADI), a validated marker of neighborhood-level socioeconomic disadvantage that combines 17 measures of employment, income, housing, and education from the American Community Survey to create a score for each geographic unit in the United States.[6–12] Using all-payer nonpublic patient discharge data from California between 2006 and 2020, we compared differences in access to PCI facilities, treatment, and health outcomes among patients with AMI across the community disadvantage gradient, from those who lived in the most advantaged to most disadvantaged communities. In our secondary analysis, we further stratified our results by type of AMI, and explored whether the disadvantage gradient grew or reduced over time.

METHODS

Data Availability

Because of the sensitive nature of the data collected for this study, requests to access the data set from qualified researchers trained in human subject confidentiality protocols may be sent to the California Department of Health Care Access and Information at https://hcai.ca.gov/.

Study Population and Data Sources

The study population included 629 419 patients with AMI between January 2006 and December 2020 residing in 1723 zip code communities in California. Data were merged from multiple sources. First, we obtained patient data from the California Department of Health Care Access and Information. We combined both nonpublic patient discharge data and nonpublic emergency department data to capture a complete cohort of AMI patients and linked these patient records to vital statistics via unique patient identifiers. Relevant data elements from the patient data included patients' resident zip code, admission date, source of admission, demographics (eg, age, sex, race, and ethnicity), insurance status at the time of admission, *International Classification of Diseases, Ninth and Tenth Revision* (*ICD-9* and *ICD-10*) diagnostic codes, treatments received (identified through *ICD-9* and *ICD-10* procedure codes), comorbidities, and date of death. Second, we procured the data to calculate the ADI at the Census block group level from the *Neighborhood Atlas*,[9,10] which ranks each neighborhood's socioeconomic well-being based on the following dimensions: income, education, employment, and housing quality.[6,10] Third, we obtained facility procedure volumes from the Office of Statewide Health Planning and Development facility use data to identify whether a hospital was PCI capable. Lastly, we linked the patient data with zip code–level population characteristics and geographic coordinates from the American Community Survey and the Census based on residential zip code.

Categorizing Zip Code Communities From Most Advantaged to Most Disadvantaged

Because we limited our study population to California, we used the state-specific ADI for this analysis. At the neighborhood (ie, census block group) level, state-specific ADI values ranged from 1 to 10 and represented 10 deciles of socioeconomic conditions, where the most advantaged neighborhoods (ie, most favorable, or least deprived socioeconomic condition) were given a value of 1, and the most disadvantaged (most deprived socioeconomic condition) were given a value of 10.

Although ADI was defined at the neighborhood level, our community was defined at the zip code level because the zip code was the smallest geographic unit available from our patient data. Following a strategy that maps neighborhood populations to zip code communities (described in more detail in Data S1), we determined the percentage of each community's population living in a high ADI neighborhood (ie, if the state-specific ADI value was 9 or 10) or a low ADI neighborhood (if the state-specific ADI value was 1 or 2). We then categorized communities into 5 groups based on the share of the population in low or high-ADI neighborhoods. Specifically, the most advantaged communities were defined as zip codes with >50% of the population living in low ADI neighborhoods; likewise, the most disadvantaged communities were defined as zip codes with >50% of the population in high ADI neighborhoods. Relatively advantaged communities had 25% to 50% of the population in low ADIs, and relatively disadvantaged communities had 25% to 50% of the population in high ADIs. The rest of the zip codes (those with <25% of the population in high and low ADIs) were defined as mixed communities. To track communities consistently over time, these community ADI categories were made time-invariant based on ADI values from 2015 (the earliest year available on the *Neighborhood Atlas* website). Our past experience working with these types of community-level measures showed that they were highly correlated over time.[13]

Defining a Hospital's PCI Capacity and Population Access

Following prior work,[13,14] we used a volume-based threshold to identify a hospital's PCI capability. A hospital was defined as PCI-capable if it performed at least 50 PCI procedures per year based on PCI volumes reported in the Office of Statewide Health Planning and Development facility data.[15] The advantage of using a volume-based definition is that it minimizes errors from self-reported measurements, such as those published in the American Hospital Association's annual surveys.

Once we identified PCI-providing hospitals, we measured the population's geographic access to these PCI hospitals using driving time. Specifically, for each zip code community, we identified whether there was a PCI hospital available to residents in that community within a 15-minute drive from the geographic center (as listed in the US census) of the community. We computed the actual driving time between each community–hospital pair using automation software from Stata that interfaced with HERE Technologies' web-based platform.[16,17] We chose a threshold of 15 minutes based on thresholds reported in other studies[18–20] and prior literature showing that the majority of hospital visits are within 15 minutes of a patient's residence.[21]

Statistical Analysis

The main outcomes of this study included: (1) admission to a PCI hospital, (2) receipt of PCI on the day of admission (subsequently referred to as same-day PCI), (3) receipt of PCI during the hospitalization, and (4) time-specific health outcomes (30-day and 1-year mortality, 30-day readmission rate). In our main analysis, we included receipt of coronary angiography as part of PCI treatment because this procedure represents a prelude to revascularization and accounts for clinical realities of failed PCI and/or anatomy that is not suitable for PCI. In our sensitivity analysis, we used a more conservative approach whereby we counted PCI only, rather than both PCI and coronary angiography. For health outcomes, we focused on time-specific mortality rather than in-hospital mortality so that results were not driven by variation across hospitals' discharge or other practices, and instead captured potential differences in longer-term health outcomes.

We implemented a linear probability model with county fixed effects to control for any unobserved time-invariant heterogeneity across counties. Our key independent variables were the 4 dummies used to capture each community's disadvantage status, from the most disadvantaged (reference community) to the most advantaged. In addition, we estimated robust standard errors that accounted for intracommunity correlation among patients from the same county.[22] All models controlled for patient demographics, including age groups, sex, race, and ethnicity, as well as health insurance (private, Medicare, Medicaid, indigent care, uninsured/self-pay, and others), the 22 Elixhauser patient comorbid indicators, and an indicator for ST-segment–elevation myocardial infarction (STEMI) to control for underlying individual patient health conditions.[23,24]

In addition to the main models discussed above, we implemented the following additional models to further explore differential experiences by patients in each type of community. First, we stratified the sample by patients with STEMI versus non-STEMI (NSTEMI). In general, treatment for patients with STEMI tends to be protocolized, and this stratified analysis allowed us to investigate whether standardization reduced or widened disparities across communities. Second, to test whether differences across the 5 types of communities changed over time, we implemented a set of models through which we interacted time trends with community disadvantage status. Third, we tested the robustness of our results by classifying patients into 5 community types using an alternative ADI index constructed directly at the zip code level (details described in Data S1).[6] Institutional review board approval for this study was provided by the University of California, San Francisco, and informed consent was not required because the study did not involve human subjects.

RESULTS

Figure 1 shows that in this study population of 629 419 patients with AMI, between January 2006 and December 2020, 15% of patients lived in each of relatively disadvantaged and most disadvantaged communities, 48% lived in mixed communities, 14% in relatively advantaged communities, and 8% in most advantaged communities. The percentage of patients who did not have a PCI hospital within 15 minutes increased across the community disadvantage gradient, from 17% in the most advantaged communities to 63% in the most disadvantaged communities.

Table 1 shows that patient characteristics differed significantly between the most advantaged and most disadvantaged communities (patient characteristics for the other 3 types of communities are included in Table S1). Communities that were classified as most disadvantaged had a higher proportion of Black residents (8%) compared with the most advantaged communities (3%), as well as a substantially higher percentage of Hispanic residents (25% in the most disadvantaged, compared with 6% in the most advantaged communities). Residents of these disadvantaged communities also tended to be younger, with a larger proportion of residents <65 years of age (43% in disadvantaged communities, compared with 33% in advantaged communities) and a smaller proportion of residents ≥85 years of age (12% in disadvantaged compared with 20% in advantaged communities). Disadvantaged communities also had a higher proportion of patients with diabetes (41%, compared with 28% in advantaged communities), chronic pulmonary disease (24% versus 15% in advantaged communities), and obesity (18% versus 11% in advantaged communities).

When examining admission to a PCI-capable hospital, patients in the most disadvantaged communities were less likely to be admitted to a PCI hospital (74% admitted) compared with patients in the most advantaged communities (88% admitted). Patients in the most disadvantaged communities were also more likely to be admitted to a PCI hospital with low PCI volume (32% of patients in disadvantaged versus 26% in advantaged communities) and less likely to receive same-day PCI (34% compared with 40% in advantaged communities). Furthermore, 30-day readmissions were more likely among patients in disadvantaged

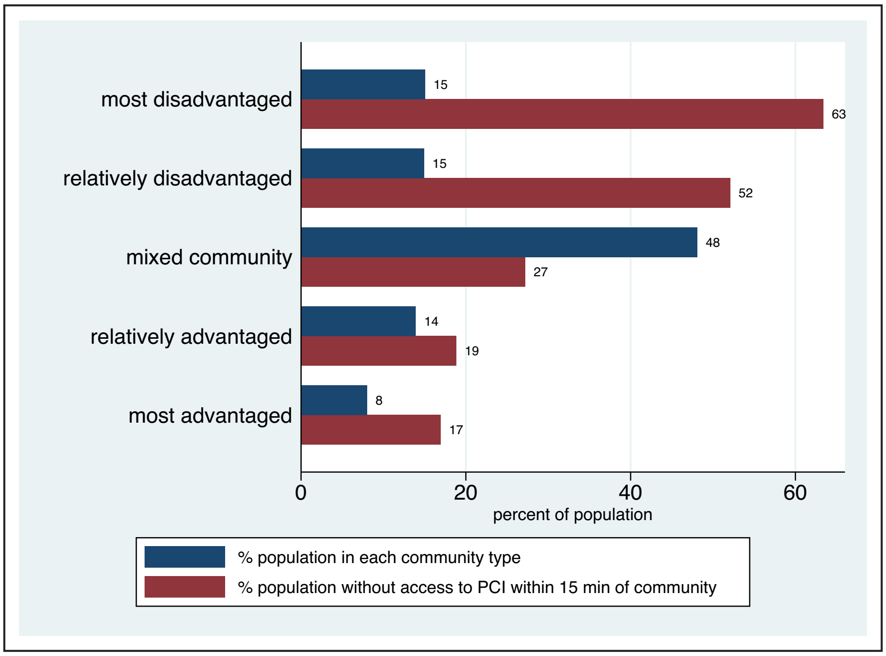

Figure 1. California's population and PCI access distribution by community disadvantage status.
Blue bars represent the percentage of patients in each of the 5 community types. Red bars represent the percentage of patients who did not have a PCI hospital within a 15-minute drive of their community. PCI indicates percutaneous coronary intervention.

Table 1. Descriptive Statistics of Patient Characteristics (2006–2020)

Characteristic	Total population		Most advantaged community		Most disadvantaged community	
	N	%	N	%	N	%
Patient demographics						
Race and ethnicity						
Asian	62 832	10%	6797	14%	4103	4%
Black	47 507	8%	1302	3%	7423	8%
Hispanic	122 727	19%	3099	6%	23 886	25%
White	363 133	58%	34 143	71%	56 785	59%
Other non-White races[†]	33 342	5%	2712	6%	4089	4%
Women	240 005	38%	16 818	35%	38 380	40%
Age distribution at time of admission, y						
<65	248 349	39%	15 715	33%	41 411	43%
65–69	76 030	12%	5220	11%	12 257	13%
70–74	73 001	12%	5289	11%	11 569	12%
75–79	70 630	11%	5736	12%	10 578	11%
80–84	66 916	11%	6181	13%	9135	9%
85+	93 176	15%	9741	20%	11 187	12%
Patient conditions						
STEMI	168 563	27%	14 319	30%	24 252	25%
Peripheral vascular disease	84 169	13%	6966	15%	11 218	12%
Pulmonary circulation disorders	24 266	4%	1874	4%	3760	4%
Diabetes (uncomplicated+complicated)	236 429	38%	13 650	28%	39 755	41%
Renal failure	157 860	25%	10 923	23%	22 907	24%
Liver	15 414	2%	1010	2%	2557	3%
Cancer	19 094	3%	1881	4%	2497	3%
Dementia	24 471	4%	2007	4%	3172	3%
Valvular disease	75 009	12%	6673	14%	10 479	11%
Hypertension (uncomplicated+complicated)	487 208	77%	34 900	73%	75 908	79%
Chronic pulmonary disease	122 832	20%	7108	15%	23 417	24%
Rheumatoid arthritis/collagen vascular	14 266	2%	1211	3%	2078	2%
Coagulation deficiency	35 707	6%	2895	6%	4585	5%
Obesity	102 449	16%	5473	11%	17 393	18%
Substance use	39 429	6%	2068	4%	7928	8%
Depression	38 629	6%	2975	6%	6024	6%
Psychosis	34 946	6%	2607	5%	5029	5%
Hypothyroidism	72 020	11%	5937	12%	10 584	11%
Paralysis and other neurological disorder	49 528	8%	3867	8%	7234	8%
Ulcer	2041	0%	142	0%	316	0%
Weight loss	22 299	4%	1275	3%	3265	3%
Fluid and electrolyte disorders	139 871	22%	9720	20%	21 127	22%
Anemia (blood loss and deficiency)	130 039	21%	9023	19%	18 725	19%
Admission status and treatment received						
Admitted to PCI hospital	478 841	76%	42 372	88%	71 388	74%
Admitted to low-volume PCI hospital	189 045	30%	12 415	26%	30 388	32%

(*Continued*)

Table 1. Continued

Characteristic	Total population		Most advantaged community		Most disadvantaged community	
	N	%	N	%	N	%
Received same-day PCI	219306	35%	19255	40%	32745	34%
Received PCI during hospitalization	400830	64%	32226	67%	61652	64%
Health outcomes						
30-d mortality	54041	9%	4196	9%	8631	9%
1-y mortality	110016	17%	8047	17%	17686	18%
30-d readmission	159850	25%	10327	21%	24715	26%
Total patients (N)	629419	100%	48033	8%	96272	15%

PCI indicates percutaneous coronary intervention; and STEMI, ST-segment–elevation myocardial infarction.
†American Indian or Alaskan Native; Native Hawaiian or Other Pacific Islander; Non-Black and Non-White and Non-Hispanic; or Other

communities (26% compared with 21% in advantaged communities).

Figure 2 (full results shown in Table S2) shows the risk-adjusted results of the association between community disadvantage status and the 6 treatment and outcomes measures. Figure 2A shows that although the probability of admission to a PCI hospital was 7.0 percentage points higher in the most advantaged communities

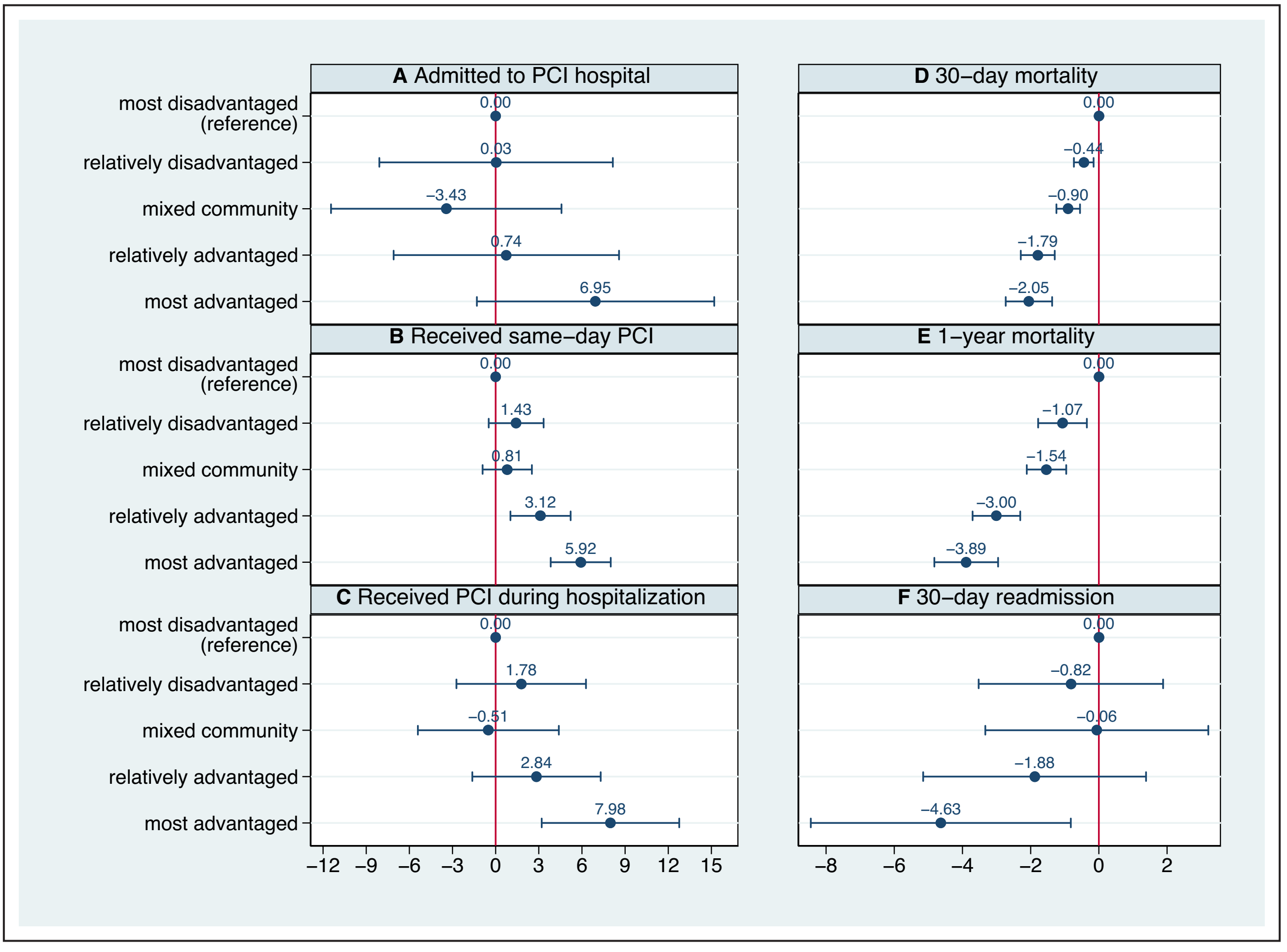

Figure 2. Risk-adjusted treatment and outcome differences by community disadvantage status.
Risk-adjusted probability differences in admission to a PCI hospital (**A**), receipt of same-day PCI (**B**), receipt of PCI during hospitalization (**C**), 30-day mortality (**D**), 1-year mortality (**E**), and 30-day readmission (**F**) for each of the 4 community types, when compared with the most disadvantaged communities. Outcomes are controlled for county fixed effects, patient demographics, health insurance status, 22 Elixhauser patient comorbid indicators, and an indicator for ST-segment–elevation myocardial infarction. Error bars represent 95% CIs. PCI indicates percutaneous coronary intervention.

compared with the most disadvantaged communities, this coefficient was estimated with a wide 95% CI (95% CI, −1.3 to 15.2); thus, there were no statistically significant differences across the 5 community types (all four 95% CIs included 0) for this outcome. Figure 2B shows that the risk-adjusted probability of receiving same-day PCI was higher for patients in advantaged communities than in disadvantaged communities. Patients in relatively and most advantaged communities had a 3.1 (95% CI, 1.0–5.2) and 5.9 (95% CI, 3.8–8.0) percentage point greater likelihood of receiving same-day PCI, respectively, representing a 10% and 20% relative increase, compared with patients in the most disadvantaged communities. Similarly, Figure 2C shows that patients in the most advantaged communities were 8.0 percentage points more likely to receive PCI during the hospitalization (95% CI, 3.2–12.8) compared with the most disadvantaged communities. Given the base rate of 54% in the most disadvantaged communities for this outcome, the 8.0 percentage point increase represents a 15% relative difference between the 2 communities.

The disadvantage status gradient was also evident when examining mortality outcomes of comparable patients with similar comorbidities. Figure 2D and 2E reveal that mortality was lowest in the most advantaged communities and highest in the most disadvantaged communities. For example, 30-day mortality rates in the most advantaged communities were 2.1 (95% CI, −2.7 to −1.4) percentage points below the most disadvantaged communities. With an average 30-day mortality likelihood of 11% in the most disadvantaged community, this difference represents a 19% relative gap between the most advantaged and most disadvantaged communities. Compared with the most disadvantaged communities, the 1-year mortality gap ranged from a 1.1 (95% CI, −1.8 to −0.4) percentage point decrease for relatively disadvantaged communities to a 3.9 (95% CI, −4.8 to −3.0) percentage point decrease for the most advantaged communities. Given the average 1-year mortality of 24% in the reference community, the relative difference between the most disadvantaged communities and the most advantaged communities was 16%. When examining 30-day all-cause readmissions, patients in the most advantaged communities had a 4.6 (95% CI, −8.5 to −0.8) percentage point lower readmission rate (15% relative decrease) compared with the most disadvantaged communities.

Table 2 shows that the disparity gradient was smaller for patients with STEMI than for those with NSTEMI in terms of probability of receiving same-day PCI. A 6.3 (95% CI, 4.8–7.7) and 4.9 (95% CI, 0.6–9.3) percentage point gap was observed for patients with NSTEMI and STEMI, respectively, in the most advantaged communities compared with the most disadvantaged communities. These differences represent a 37% and 9% relative increase in likelihood of same-day PCI for patients with NSTEMI and STEMI, respectively, in the most advantaged communities, given the baseline same-day PCI rates of 17% for NSTEMI and 53% for STEMI.

The disparities across communities observed in Figure 2 were persistent and stable over time. In our interaction models looking at time trends and outcomes by community disadvantage status (Table S3), interaction terms were not statistically significant for any of the models, meaning that the disparities across the 5 types of communities did not shrink or widen over time.

We performed several robustness checks. First, our sensitivity analysis showed a similar disparity gradient across all outcomes pertaining to the 5 community types when we used the alternative ADI definition constructed directly at the zip code-level (Table S4). Second, our results remained the same after using a more restrictive PCI definition (by excluding receipt of coronary angiography). Third, the disparity gradient in health outcomes persisted even after controlling for the site of admission and treatment received, albeit at a smaller magnitude (Table S5). In other words, having received the same treatment did not eliminate health disparities. Finally, the disadvantage gradient persisted when our analysis was restricted to only urban communities (Table S6), suggesting that our findings were not driven entirely by rural communities, which represented 8% of patients in this population (rural designation was based on the Federal Office of Rural Health Policy).[25] Almost half of the patients in rural areas were in the most disadvantaged communities, whereas only about 100 patients in rural areas lived in communities classified as most or relatively advantaged.

DISCUSSION

In this analysis of 629 419 patients with AMI from 2006 to 2020, we observed significant disparities across the 5 community types for 5 out of the 6 outcomes examined. Compared with the most disadvantaged communities, patients in the most advantaged communities had a 20% higher likelihood of same-day PCI, 15% higher likelihood of PCI during the hospitalization, 19% and 16% decreases in 30-day and 1-year mortality rates, respectively, and a 15% decrease in 30-day readmission rates. The 3 different time-specific health outcomes all displayed a disparity gradient from the most advantaged to most disadvantaged communities, illustrating both a dose response and the severity of the observed disparity.

Previous literature has shown that Black patients with AMI are less likely to be admitted to revascularization programs than White patients,[26] are less likely to receive PCI during a hospital admission,[13,27,28] and have significantly higher 1- and 5-year mortality rates when compared with White patients.[29–31] Our findings

Table 2. Risk-Adjusted Process and Outcome Differences by Community Disadvantage Status, Stratified by STEMI and NSTEMI

Community disadvantage status	Admitted to PCI hospital	Same-day PCI	PCI during hospitalization	30-d mortality	1-y mortality	30-d readmission
Patients with NSTEMI						
Outcome base rate in most disadvantaged community	57%	17%	46%	11%	27%	34%
Most disadvantaged (reference)	0.00	0.00	0.00	0.00	0.00	0.00
Relatively disadvantaged	−0.19 (−9.21 to 8.83)	1.52* (0.11 to 2.92)	1.97 (−2.81 to 6.75)	−0.49* (−0.87 to −0.11)	−1.22† (−2.12 to −0.33)	−0.84 (−3.85 to 2.17)
Mixed community	−3.91 (−12.97 to 5.14)	1.04 (−0.15 to 2.23)	−0.52 (−5.90 to 4.86)	−0.72† (−1.13 to −0.30)	−1.53† (−2.38 to −0.69)	−0.28 (−3.88 to 3.31)
Relatively advantaged	1.25 (−7.85 to 10.35)	3.28† (1.75 to 4.81)	3.24 (−1.62 to 8.11)	−1.65† (−2.25 to −1.05]	−3.05† (−4.02 to −2.07)	−2.26 (−5.82 to 1.29)
Most advantaged	8.75 (−0.88 to 18.38)	6.27† (4.80 to 7.74)	9.44† (4.16 to 14.71)	−1.80† (−2.54 to −1.07)	−4.09† (−5.26 to −2.93)	−5.06* (−9.09 to −1.03)
N	459 262	459 262	459 262	431 263	431 263	459 262
Patients with STEMI						
Outcome base rate in most disadvantaged community	71%	53%	68%	11%	18%	28%
Most disadvantaged (reference)	0.00	0.00	0.00	0.00	0.00	0.00
Relatively disadvantaged	0.30 (−5.15 to 5.76)	0.99 (−2.54 to 4.53)	1.19 (−2.62 to 5.00)	−0.34 (−0.79 to 0.10)	−0.63† (−1.08 to −0.17)	−0.76 (−2.67 to 1.15)
Mixed community	−2.33 (−7.33 to 2.67)	0.08 (−3.61 to 3.76)	−0.42 (−4.02 to 3.18)	−1.36† (−1.97 to −0.76)	−1.48† (−2.04 to −0.92)	0.60 (−2.17 to 3.38)
Relatively advantaged	−0.49 (−5.21 to 4.24)	2.49 (−1.77 to 6.75)	1.92 (−1.60 to 5.44)	−2.19† (−2.89 to −1.49)	−2.87† (−3.57 to −2.18)	−0.90 (−3.92 to 2.13)
Most advantaged	2.75 (−2.32 to 7.82)	4.94* (0.61 to 9.26)	4.36* (0.72 to 8.00)	−2.77† (−3.74 to −1.80)	−3.44† (−4.30 to −2.57)	−3.52 (−7.35 to 0.30)
N	168 103	168 103	168 103	159 129	159 129	168 103

Other control variables include age, sex, race and ethnicity, insurance status, comorbid conditions, and time trend. Values are coefficient (95% CI). NSTEMI indicates non–ST-segment–elevation myocardial infarction; PCI, percutaneous coronary intervention; and STEMI, ST-segment–elevation myocardial infarction.

*P<0.05.

†P<0.01.

add to this literature by showing that disparities exist not only when evaluating outcomes based on a single dimension, such as race or income, but also on a larger level of overall community disadvantage. The widening geographic disparities in PCI shown by prior literature,[32] therefore, may also be related to a community's level of disadvantage and where financial incentives do or do not exist for providing these services.

This is even more sobering given that the demand for PCI care is likely higher in disadvantaged communities compared with advantaged communities, because incidence of AMI is higher in communities with a greater proportion of racially and ethnically minoritized residents.[33,34] Taken together, our findings suggest that the observed disparities in patient access are not driven by lower demand for care in disadvantaged communities, but instead that patients who need care are not receiving the same level of care as their advantaged counterparts.

Notably, when evaluating differences in disparities in our stratified analyses of patients with NSTEMI versus STEMI, the probability of admission to a PCI hospital and receipt of PCI (both same-day and PCI during hospitalization) showed greater disparities across communities when looking at NSTEMI versus STEMI. One interpretation of these findings is that standardized protocols that exist for STEMI may improve access to timely PCI for disadvantaged populations and could potentially be applied to other conditions. This is consistent with prior literature showing that disparities in receiving critical AMI treatment between Black and White individuals are more pronounced in patients with NSTEMI compared with STEMI.[35] Our findings elucidate and expand on this previously observed relationship by showing that disparities in NSTEMI treatment exist beyond singular measures such as race, and persist even when looking more broadly at community disadvantage.

Given the multidimensional factors underlying structural discrimination in the US health care system, it is crucial to include several social determinants of health when studying cardiac care disparities at the community level. Furthermore, it is notable that the observed disparities did not change over the study period, despite reports by *Healthy People 2030* that eliminating health disparities is one of the highest priorities of the federal government[36]; the observed disparities across all 5 groups persisted to the same degree year after year.

To our knowledge, this is the first study to use the 17-component census-derived ADI to evaluate community-level disparities in PCI hospital expansion and patient access and outcomes. Previous studies have used the ADI in models evaluating cardiovascular disease risk and chronic disease management[37–40]; however, less is known about how, or if, area deprivation affects access to and outcomes of cardiac care, particularly for patients with AMI. By analyzing disparities in access to cardiac care not only by 1 or 2 factors, but instead across several social determinants of health, this study reveals broader structural forces at play impacting patient care in the cardiac care system. The observed association between neighborhood disadvantage level and access, treatment, and outcome disparities suggests that the social determinants of health included in the ADI are important contributors to poor cardiac health in disadvantaged areas. These findings could inform future research on the mechanisms underlying this relationship and help target public health interventions that distribute cardiac care, such as opening PCI-capable hospitals more equitably across disadvantaged areas.

At a broader level, these findings reveal that fundamentally, structural discrimination within the cardiac care system is motivated and reinforced by financial incentives for equipped hospitals to open in more advantaged areas with a higher proportion of affluent, nonminoritized residents. This is likely influenced by the fact that 25% to 40% of a hospital's net revenue is derived from cardiac services alone,[41] suggesting that a community's potential profitability is a significant factor considered in deciding whether or not to open a PCI hospital. Our findings suggest that there may be an opportunity for more targeted interventions to influence where services exist and who has access to them. Initiatives such as certificate-of-need laws and changing reimbursement mechanisms, for example, could serve as potential levers to encourage care where it is most needed.[1,42] Further research examining how these types of policy interventions, as well as others, could affect access to cardiac care is vital.

Limitations

Our study has several important limitations. First, our analysis is limited to California. Although California has the largest population of all 50 states (12% of the US population), and the population is diverse, our results are not generalizable to the rest of the United States. Second, our analyses rely on an administrative database rather than clinical data or medical charts. We therefore do not have granularity on the severity of patient illness beyond comorbidities nor time-to-treatment metrics. However, using administrative data is critical for this type of population-based study; the alternative of using hospital-based or patient registries, such as the American College of Cardiology/American Heart Association's Acute Coronary Treatment and Intervention Outcomes Network Registry-Get With The Guidelines and catheterization percutaneous coronary intervention Registry, would result in a biased sample, because we would not be able to capture patients with AMI who did not receive treatment in these registries. Third, health disparities across community disadvantage types might be driven by differences in underlying population health. We addressed this concern by controlling for patients' comorbid conditions. Moreover, our descriptive statistics showed that the age distribution was younger in the most disadvantaged communities, and younger age is usually associated with lower mortality among the AMI population. However, we cannot completely eliminate the possibility that the disparity gradient is driven by underlying health differences, especially because individuals from disadvantaged communities tend to have greater difficulty accessing a usual source of care.[43] Finally, although we were able to show a clear disparity gradient in access, treatment, and outcomes among the AMI population by community disadvantage status, our data do not contain information such as lifestyle, care-seeking behaviors, or other environmental factors that would allow us to fully explore why this disparity gradient exists. We partially explored other potential factors by comparing patients who were admitted to similar sites and received treatment, but access to, and receipt of, cardiac technology only reduced the disparity gradient by a small amount.

CONCLUSIONS

When using the multidimensional ADI to define community disadvantage status, patients living in disadvantaged communities were less likely to be admitted to a PCI hospital, had a lower chance of receiving same-day PCI and PCI during the hospitalization, and experienced poorer health outcomes than those living in advantaged communities, including a higher likelihood of hospital readmission and increased 30-day and 1-year mortality rates.

ARTICLE INFORMATION

Received April 10, 2023; accepted June 15, 2023.

Affiliations

Department of Defense Management, Naval Postgraduate School, Monterey, CA (Y.-C.S.); National Bureau of Economic Research, Cambridge, MA (Y.-C.S., N.S.); Department of Emergency Medicine (R.Y.H.), and Philip R. Lee Institute for Health Policy Studies (R.Y.H.), University of California, San Francisco, CA.

Acknowledgments

The authors thank the California Department of Health Care Access and Information for the data used in this project. The authors also thank M. Feldmeier for editorial assistance.

Sources of Funding

The authors would like to acknowledge support of this project through the Pilot Project Award from the National Bureau of Economic Research Center for Aging and Health Research, funded by the National Institute on Aging grant (P30AG012810); the National Institute on Minority Health and Health Disparities (R01MD017482); and the National Heart, Lung, and Blood Institute (R01HL114822 and R01HL134182). The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the article; or decision to submit the article for publication.

Disclosures

All authors received grants from the National Institute of Aging, the National Institute on Minority Health and Health Disparities, and the National Heart, Lung, and Blood Institute.

Supplemental Material

Data S1
Tables S1–S6

REFERENCES

1. Concannon TW, Nelson J, Kent DM, Griffith JL. Evidence of systematic duplication by new percutaneous coronary intervention programs. *Circ Cardiovasc Qual Outcomes*. 2013;6:400–408. doi: 10.1161/CIRCOUTCOMES.111.000019
2. Nallamothu BK, Bates ER, Wang Y, Bradley EH, Krumholz HM. Driving times and distances to hospitals with percutaneous coronary intervention in the United States. *Circulation*. 2006;113:1189–1195. doi: 10.1161/CIRCULATIONAHA.105.596346
3. Hsia RY, Shen Y-C. Percutaneous coronary intervention in the United States: risk factors for untimely access. *Health Serv Res*. 2016;51:592–609. doi: 10.1111/1475-6773.12335
4. Stone GW, Kappetein AP, Sabik JF, Pocock SJ, Morice M-C, Puskas J, Kandzari DE, Karmpaliotis D, Brown WM, Lembo NJ, et al. Five-year outcomes after PCI or CABG for left main coronary disease. *N Engl J Med*. 2019;381:1820–1830. doi: 10.1056/NEJMoa1909406
5. Bhatt DL. Timely PCI for STEMI—still the treatment of choice. *N Engl J Med*. 2013;368:1446–1447. doi: 10.1056/NEJMe1302670
6. Singh GK. Area deprivation and widening inequalities in US mortality, 1969–1998. *Am J Public Health*. 2003;93:1137–1143. doi: 10.2105/AJPH.93.7.1137
7. Singh GK, Lin C-CC. Area deprivation and inequalities in health and health care outcomes. *Ann Intern Med*. 2019;171:131–132. doi: 10.7326/M19-1510
8. Singh GK, Siahpush M. Increasing inequalities in all-cause and cardiovascular mortality among US adults aged 25–64 years by area socioeconomic status, 1969–1998. *Int J Epidemiol*. 2002;31:600–613. doi: 10.1093/ije/31.3.600
9. Kind AJH, Jencks S, Brock J, Yu M, Bartels C, Ehlenbach W, Greenberg C, Smith M. Neighborhood socioeconomic disadvantage and 30-day rehospitalization: a retrospective cohort study. *Ann Intern Med*. 2014;161:765–774. doi: 10.7326/M13-2946
10. Kind AJH, Buckingham WR. Making neighborhood-disadvantage metrics accessible—the neighborhood atlas. *N Engl J Med*. 2018;378:2456–2458. doi: 10.1056/NEJMp1802313
11. Jencks SF, Schuster A, Dougherty GB, Gerovich S, Brock JE, Kind AJH. Safety-net hospitals, neighborhood disadvantage, and readmissions under Maryland's all-payer program: an observational study. *Ann Intern Med*. 2019;171:91–98. doi: 10.7326/M16-2671
12. Wadhera RK, Bhatt DL, Kind AJH, Song Y, Williams KA, Maddox TM, Yeh RW, Dong L, Doros G, Turchin A, et al. Association of outpatient practice-level socioeconomic disadvantage with quality of care and outcomes among older adults with coronary artery disease: implications for value-based payment. *Circ Cardiovasc Qual Outcomes*. 2020;13:e005977. doi: 10.1161/CIRCOUTCOMES.119.005977
13. Hsia RY, Krumholz H, Shen Y-C. Evaluation of STEMI regionalization on access, treatment, and outcomes among adults living in nonminority and minority communities. *JAMA Netw Open*. 2020;3:e2025874. doi: 10.1001/jamanetworkopen.2020.25874
14. Concannon TW, Nelson J, Goetz J, Griffith JL. A percutaneous coronary intervention lab in every hospital? *Circ Cardiovasc Qual Outcomes*. 2012;5:14–20. doi: 10.1161/CIRCOUTCOMES.111.963868
15. Fanaroff AC, Zakroysky P, Dai D, Wojdyla D, Sherwood MW, Roe MT, Wang TY, Peterson ED, Gurm HS, Cohen MG, et al. Outcomes of PCI in relation to procedural characteristics and operator volumes in the United States. *J Am Coll Cardiol*. 2017;69:2913–2924. doi: 10.1016/j.jacc.2017.04.032
16. Weber S, Péclat M. A simple command to calculate travel distance and travel time. *Stata J*. 2017;17:962–971. doi: 10.1177/1536867X1801700411
17. Developer guide—HERE routing API. HERE Developer. Accessed April 30, 2022. https://developer.here.com/documentation/routing-api/dev_guide/index.html.

18. Goodman DC, Fisher E, Stukel TA, Chang C. The distance to community medical care and the likelihood of hospitalization: is closer always better? *Am J Public Health*. 1997;87:1144–1150. doi: 10.2105/AJPH.87.7.1144
19. Lam O, Broderick B, Toor S. *How far Americans live from the closest hospital differs by community type*. Pew Research Center; 2018. Accessed December 13, 2021. https://www.pewresearch.org/fact-tank/2018/12/12/how-far-americans-live-from-the-closest-hospital-differs-by-community-type/
20. The importance of rural hospitals. Center for Healthcare Quality and Payment Reform. Accessed December 13, 2021. https://ruralhospitals.chqpr.org/Importance.html
21. Jia P, Wang F, Xierali IM. Differential effects of distance decay on hospital inpatient visits among subpopulations in Florida, USA. *Environ Monit Assess*. 2019;191:381. doi: 10.1007/s10661-019-7468-2
22. Stock JH, Watson MW. Heteroskedasticity-robust standard errors for fixed effects panel data regression. *Econometrica*. 2008;76:155–174. doi: 10.1111/j.0012-9682.2008.00821.x
23. Henry TD, Unger BT, Sharkey SW, Lips DL, Pedersen WR, Madison JD, Mooney MR, Flygenring BP, Larson DM. Design of a standardized system for transfer of patients with ST-elevation myocardial infarction for percutaneous coronary intervention. *Am Heart J*. 2005;150:373–384. doi: 10.1016/j.ahj.2005.01.059
24. Yeh RW, Sidney S, Chandra M, Sorel M, Selby JV, Go AS. Population trends in the incidence and outcomes of acute myocardial infarction. *N Engl J Med*. 2010;362:2155–2165. doi: 10.1056/NEJMoa0908610
25. Federal Office of Rural Health Policy (FORHP) data files. Human Resources & Services Administration. Accessed November 22, 2022. https://www.hrsa.gov/rural-health/about-us/what-is-rural/data-files
26. Popescu I, Cram P, Vaughan-Sarrazin MS. Differences in admitting hospital characteristics for black and white Medicare beneficiaries with acute myocardial infarction. *Circulation*. 2011;123:2710–2716. doi: 10.1161/CIRCULATIONAHA.110.973628
27. Li S, Chen A, Mead K. Racial disparities in the use of cardiac revascularization: does local hospital capacity matter? *PLOS One*. 2013;8:e69855. doi: 10.1371/journal.pone.0069855
28. Subramaniam AV, Patlolla SH, Cheungpasitporn W, Sundaragiri PR, Miller PE, Barsness GW, Bell MR, Holmes DR, Vallabhajosyula S. Racial and ethnic disparities in management and outcomes of cardiac arrest complicating acute myocardial infarction. *J Am Heart Assoc*. 2021;10:e019907. doi: 10.1161/JAHA.120.019907
29. Popescu I, Vaughan-Sarrazin MS, Rosenthal GE. Differences in mortality and use of revascularization in black and white patients with acute MI admitted to hospitals with and without revascularization services. *JAMA*. 2007;297:2489–2495. doi: 10.1001/jama.297.22.2489
30. Graham GN, Jones PG, Chan PS, Arnold SV, Krumholz HM, Spertus JA. Racial disparities in patient characteristics and survival after acute myocardial infarction. *JAMA Netw Open*. 2018;1:e184240. doi: 10.1001/jamanetworkopen.2018.4240
31. Virani SS, Alonso A, Aparicio HJ, Benjamin EJ, Bittencourt MS, Callaway CW, Carson AP, Chamberlain AM, Cheng S, Delling FN, et al. Heart disease and stroke statistics—2021 update. *Circulation*. 2021;143:e254–e743. doi: 10.1161/CIR.0000000000000950
32. Yeh RW, Normand S-LT, Wang Y, Barr CD, Dominici F. Geographic disparities in the incidence and outcomes of hospitalized myocardial infarction: does a rising tide lift all boats? *Circ Cardiovasc Qual Outcomes*. 2012;5:197–204. doi: 10.1161/CIRCOUTCOMES.111.962456
33. Graham G. Disparities in cardiovascular disease risk in the United States. *Curr Cardiol Rev*. 2015;11:238–245. doi: 10.2174/1573403X11666141122220003
34. Chi GC, Kanter MH, Li BH, Qian L, Reading SR, Harrison TN, Jacobsen SJ, Scott RD, Cavendish JJ, Lawrence JM, et al. Trends in acute myocardial infarction by race and ethnicity. *J Am Heart Assoc*. 2020;9:e013542. doi: 10.1161/JAHA.119.013542
35. Anstey D e, Li S, Thomas L, Wang TY, Wiviott SD. Race and sex differences in management and outcomes of patients after ST-elevation and non–ST-elevation myocardial infarct: results from the NCDR. *Clin Cardiol*. 2016;39:585–595. doi: 10.1002/clc.22570
36. Healthy People 2030. Health.gov. Accessed October 7, 2022. https://health.gov/healthypeople
37. Shirey TE, Hu Y, Ko Y-A, Nayak A, Udeshi E, Patel S, Morris AA. Relation of neighborhood disadvantage to heart failure symptoms and hospitalizations. *Am J Cardiol*. 2021;140:83–90. doi: 10.1016/j.amjcard.2020.10.057
38. Berman AN, Biery DW, Ginder C, Hulme OL, Marcusa D, Leiva O, Wu WY, Singh A, Divakaran S, Hainer J, et al. Study of lipoprotein(a) and its impact on atherosclerotic cardiovascular disease: design and rationale of the Mass General Brigham Lp(a) Registry. *Clin Cardiol*. 2020;43:1209–1215. doi: 10.1002/clc.23456
39. Miller A, Pohlig RT, Reisman DS. Social and physical environmental factors in daily stepping activity in those with chronic stroke. *Top Stroke Rehabil*. 2021;28:161–169. doi: 10.1080/10749357.2020.1803571
40. Durfey SNM, Kind AJH, Buckingham WR, DuGoff EH, Trivedi AN. Neighborhood disadvantage and chronic disease management. *Health Serv Res*. 2019;54:206–216. doi: 10.1111/1475-6773.13092
41. Casalino LP, Devers KJ, Brewster LR. Focused factories? Physician-owned specialty facilities. *Health Aff (Millwood)*. 2003;22:56–67. doi: 10.1377/hlthaff.22.6.56
42. Popescu I, Vaughan-Sarrazin MS, Rosenthal GE. Certificate of need regulations and use of coronary revascularization after acute myocardial infarction. *JAMA*. 2006;295:2141–2147. doi: 10.1001/jama.295.18.2141
43. National Academies of Sciences, Engineering, and Medicine; Health and Medicine Division; Board on Health Care Services; Committee on Health Care Utilization and Adults with Disabilities. *Factors that Affect Health-Care Utilization*. National Academies Press (US); 2018. Accessed October 17, 2022. https://www.ncbi.nlm.nih.gov/books/NBK500097/