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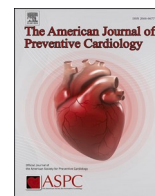
Association between vehicle ownership and disparities in mortality after myocardial infarction

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ABSTRACT

Background: Access to reliable transportation is fundamental in the management of chronic disease. The purpose of this study was to investigate the association between vehicle ownership at the neighborhood-level and long-term mortality after myocardial infarction (MI).

Methods: This is a retrospective observational study evaluating adult patients admitted for MI between January 1st, 2006, and December 31st, 2016. Neighborhoods were defined by census tract and household vehicle ownership data was obtained from the American Community Survey courtesy of the University of California, Los Angeles Center for Neighborhood Knowledge. Patients were divided into 2 groups: those living in neighborhoods with higher vehicle ownership, and those living in neighborhoods with lower vehicle ownership. The cutoff of 4.34% of households reporting not owning a vehicle was used to define a neighborhood as one with "higher" vs "lower" vehicle ownership as this was the median value for the cohort. The association between vehicle ownership and all-cause mortality after MI was assessed using Cox proportional hazards regression models.

Results: A total of 30,126 patients were included (age 68.1 +/- 13.5 years, 63.2% male). After adjusting for age, sex, race/ethnicity, and medical comorbidities, lower vehicle ownership was associated with increased all-cause mortality after MI (hazard ratio [HR] 1.10; 95% confidence interval [CI] 1.06–1.14; $p<0.001$). This finding remained significant after adjusting for median household income (HR 1.06; 95% CI 1.02–1.10; $p = 0.007$). Upon comparison of White and Black patients living in neighborhoods with lower vehicle ownership; Black patients were found to have an increased all-cause mortality after MI (HR 1.21, 95% CI 1.13–1.30, $p<0.001$), a difference which remained significant after adjusting for income (HR 1.20; 95% CI 1.12–1.29; $p<0.001$). There was no significant difference in mortality between White and Black patients living in neighborhoods with higher vehicle ownership.

Conclusion: Lower vehicle ownership was associated with increased mortality after MI. Black patients living in neighborhoods with lower vehicle ownership had a higher mortality after MI than White patients living in similar neighborhoods but Black patients living in neighborhoods with higher vehicle ownership had no worse mortality than their White counterparts. This study highlights the importance of transportation in determining health status after MI.

1. Introduction

Living with ischemic heart disease requires careful attention to many aspects of daily life. Medications, doctor visits, diet, exercise, and managing stress are all vital components in treating this progressive disease [1]. The ability to incorporate these elements into one's lifestyle is heavily dependent upon the ability to access reliable transportation. Lack of transportation has been associated with lower adherence to medication use [2–6], inability to make it to medical appointments [2,7,8], and limitations in accessing nutritious foods [9].

The neighborhoods in which people live are instrumental in determining transportation accessibility as well as in determining the extent to which the lack of transportation will impact one's health. People who live in neighborhoods with limited access to transportation have fewer employment opportunities and are more likely to endure hardships related to poverty [10]. Beyond financial difficulties, individuals who live in these neighborhoods have less access to fresh fruits and vegetables [10] and less access to safe outdoor spaces for exercise and recreation [11]. These individuals may also be more reliant on active forms of transportation, such as walking or riding a bike, and are more likely to engage in these activities in dangerous conditions due to substandard infrastructure for active transport in these communities [10].

The association between the neighborhood in which a person lives and health outcomes has been described for a variety of disease states [12–14], including ischemic heart disease [15–17]. Previously validated indices for evaluating neighborhood socioeconomic status include metrics to evaluate transportation access because of the significant role transportation plays in determining health status [18,19]. Despite broad
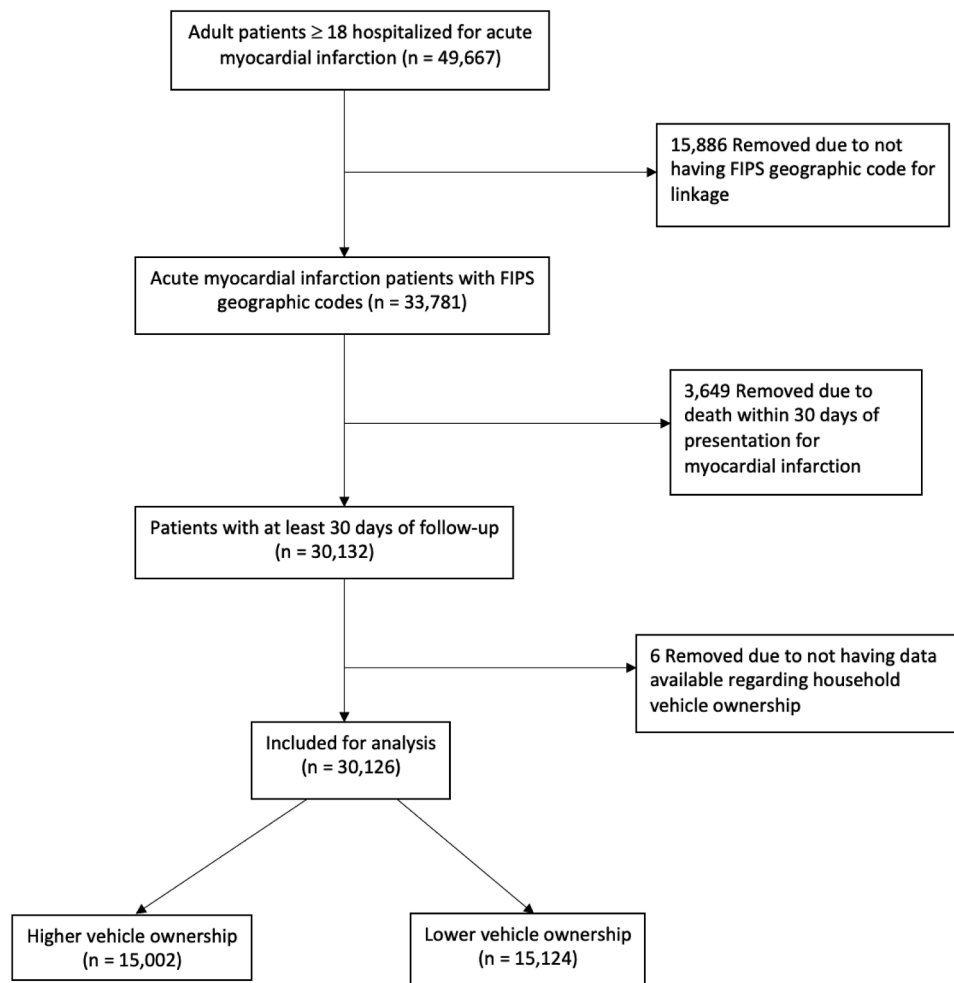

Fig. 1. (page 21): flowchart of patient eligibility and inclusion.

acknowledgement that transportation is one of the fundamental social determinants of health, the existing literature regarding the association between transportation disparities and outcomes after myocardial infarction is very limited. This study is intended to explore the association between disparities in household vehicle ownership and mortality after myocardial infarction (MI).

2. Methods

2.1. Study population

This is a retrospective observational study utilizing data from the Kaiser Permanente Southern California (KPSC) Health System. KPSC is an integrated health system that serves over 4.5 million members. KPSC members receive comprehensive healthcare insurance via enrollment through the Kaiser Foundation Health Plan. KPSC provides care to a population of members that represent the racial and ethnic diversity of the Southern California region. Member information is prospectively captured through a centralized electronic data warehouse and available electronic datasets contain information pertaining to demographics, pharmacy records, laboratory records, and healthcare utilization from both ambulatory visits and hospitalizations. The present study has been approved by the KPSC Institutional Review Board and given the observational nature of the study; a waiver of informed consent was obtained.

Adult patients ($\geq$ 18 years old) admitted to the hospital with a principal diagnosis of acute MI between January 1st, 2006, and December 31st, 2016, were identified using International Classification

of Diseases (ICD) 9 or 10 codes 412.x, 414.12, I21.x, I22.x, I23.x, or I25.42. Each patient was included in the study only once with the date of the first diagnosis of acute MI during the study period used as the index date. The one-year period prior to the index date was defined as the baseline window. Covariates were identified according to the following categories: demographics, medical comorbidities, cardiac risk factors, and use of cardiac medications. Medical comorbidities and cardiac risk factors were collected from the one-year prior to the index date. Use of cardiac medications was identified using outpatient pharmacy records.

Patients were excluded if they were not KPSC members and if they did not have continuous one-year membership prior to the index date to allow for adequate assessment of baseline covariates. Patients who died within 30 days of admission were excluded as the intent of the study was to examine the effect of transportation access on long-term outcomes. Patients without a permanent address on file that could be used to determine the census tract in which the patient lived were also excluded. Race and ethnicity were based on self-reported data and were categorized as White, Black, Hispanic (which included Hispanic people of any race), Asian (which included Pacific Islanders), and other (which included mixed race, Native American/Alaska Native, and unknown).

2.2. Vehicle ownership

Neighborhoods were defined by the census tract where each patient resided according to their address at the time of the index hospitalization. Household vehicle ownership data for each patient's neighborhood was obtained from the 2014–2018 American Community Survey

Table 1

: Baseline characteristics according to neighborhood vehicle ownership and race.

	Higher Vehicle Ownership (n = 15,002)	Lower Vehicle Ownership (n = 15,124)	P value	White Patients Lower Vehicle Ownership (n = 7257)	Black Patients Lower Vehicle Ownership (n = 2305)	P value	White Patients Higher Vehicle Ownership (n = 9267)	Black Patients Higher Vehicle Ownership (n = 1069)	P value
Demographics									
Age	67.8 (+/- 13.2)	68.5 (+/- 13.7)	<0.01	71.2 (+/- 13.1)	68.2 (+/- 13.5)	<0.01	69.6 (+/- 12.9)	66.6 (+/- 13.2)	<0.01
Male	9857 (65.7)	9197 (60.8)	<0.01	4435 (61.1)	1131 (49.1)	<0.01	6017 (64.9)	601 (56.2)	<0.01
Race/Ethnicity									
Asian	1263 (8.4)	1145 (7.6)	<0.01						
Black	1069 (7.1)	2305 (15.2)	<0.01						
Hispanic	2957 (19.7)	3934 (26.0)	<0.01						
White	9267 (61.8)	7257 (48.0)	<0.01						
Other	446 (3.0)	483 (3.2)	0.28						
Income									
< $45,000	1278 (8.5)	6752 (44.6)	<0.01	2599 (35.8)	1361 (59.0)	<0.01	659 (7.1)	115 (10.8)	<0.01
$45,000-$80,000	7886 (52.6)	6775 (44.8)	<0.01	3619 (49.9)	823 (35.7)	<0.01	4492 (48.5)	654 (61.2)	<0.01
>$80,000	5838 (38.9)	1597 (10.6)	<0.01	1039 (14.3)	121 (5.2)	<0.01	4116 (44.4)	300 (28.1)	<0.01
Insurance									
Commercial	5953 (39.7)	6035 (39.9)	0.70	2420 (33.3)	974 (42.3)	<0.01	3263 (35.2)	478 (44.7)	<0.01
Medicaid	280 (1.9)	522 (3.5)	<0.01	101 (1.4)	101 (4.4)	<0.01	88 (0.9)	33 (3.1)	<0.01
Medicare	5047 (33.6)	5108 (33.8)	0.82	2851 (39.3)	743 (32.2)	<0.01	3475 (37.5)	292 (27.3)	<0.01
Other Insurance	3722 (24.8)	3459 (22.9)	<0.01	1885 (26.0)	487 (21.1)	<0.01	2441 (26.3)	266 (24.9)	0.32
Comorbidities									
Hypertension	10,042 (66.9)	10,659 (70.5)	<0.01	5123 (70.6)	1850 (80.3)	<0.01	6197 (66.9)	845 (79.0)	<0.01
Hyperlipidemia	9304 (62.0)	9510 (62.9)	0.12	4560 (62.8)	1445 (62.7)	0.92	5684 (61.3)	680 (63.6)	0.16
Diabetes	5099 (34.0)	5756 (38.1)	<0.01	2332 (32.1)	983 (42.6)	<0.01	2730 (29.5)	414 (38.7)	<0.01
Obesity	2965 (19.8)	3103 (20.5)	0.11	1386 (19.1)	602 (26.1)	<0.01	1795 (19.4)	284 (26.6)	<0.01
CAD	2673 (17.8)	2727 (18.0)	0.64	1419 (19.6)	425 (18.4)	0.25	1784 (19.3)	180 (16.8)	0.06
PVD	4214 (28.1)	4478 (29.6)	<0.01	2308 (31.8)	767 (33.3)	0.20	2771 (29.9)	315 (29.5)	0.80
Atrial Fibrillation	1571 (10.5)	1609 (10.6)	0.65	950 (13.1)	231 (10.0)	<0.01	1148 (12.4)	102 (9.5)	<0.01
CHF	2213 (14.8)	2641 (17.5)	<0.01	1275 (17.6)	539 (23.4)	<0.01	1405 (15.2)	205 (19.2)	<0.01
Stroke	2404 (16.0)	2591 (17.1)	0.01	1347 (18.6)	429 (18.6)	0.98	1568 (16.9)	210 (19.6)	0.03
Lung Disease	3180 (21.2)	3467 (22.9)	<0.01	1905 (26.3)	571 (24.8)	0.17	2129 (23.0)	240 (22.5)	0.73
Liver Disease	573 (3.8)	664 (4.4)	0.01	264 (3.6)	117 (5.1)	<0.01	318 (3.4)	38 (3.6)	0.90
Kidney Disease	3989 (26.6)	4642 (30.7)	<0.01	2142 (29.5)	920 (39.9)	<0.01	2405 (26.0)	342 (32.0)	<0.01
Prior Medications									
Statin	7751 (51.7)	7968 (52.7)	0.08	3891 (53.6)	1223 (53.1)	0.66	4781 (51.6)	558 (52.2)	0.73
P2Y12	1419 (9.5)	1431 (9.5)	1.00	735 (10.1)	223 (9.7)	0.55	887 (9.6)	115 (10.8)	0.23
Beta Blocker	6338 (42.2)	6589 (43.6)	0.02	3277 (45.2)	1126 (48.9)	<0.01	3991 (43.1)	506 (47.3)	<0.01
ACEi/ARB	7692 (51.3)	7964 (52.7)	0.02	3790 (52.2)	1308 (56.7)	<0.01	4676 (50.5)	608 (56.9)	<0.01
Nitrate	1133 (7.6)	1249 (8.3)	0.02	590 (8.1)	246 (10.7)	<0.01	664 (7.2)	87 (8.1)	0.27
Smoking History									
Active	1376 (9.2)	1615 (10.7)	<0.01	789 (10.9)	284 (12.3)	0.06	892 (9.6)	123 (11.5)	0.06
Passive	56 (0.4)	71 (0.5)	0.23	31 (0.4)	16 (0.7)	0.15	28 (0.3)	6 (0.6)	0.16
Quit	4837 (32.2)	4852 (32.1)	0.77	2559 (35.3)	771 (33.4)	0.12	3173 (34.2)	358 (33.5)	0.65
Never	5650 (37.7)	5559 (36.8)	0.11	2372 (32.7)	815 (35.4)	0.02	3197 (34.5)	408 (38.2)	0.02
Missing Information	3083 (20.6)	3027 (20.0)	0.25	1506 (20.8)	419 (18.2)	<0.01	1977 (21.3)	174 (16.3)	<0.01
Treatment for MI									
Medical Therapy	8970 (59.8)	9142 (60.4)	0.25	4485 (61.8)	1563 (67.8)	<0.01	5649 (61.0)	742 (69.4)	<0.01
PCI	4804 (32.0)	4754 (31.4)	0.28	2210 (30.5)	602 (26.1)	<0.01	2894 (31.2)	265 (24.8)	<0.01
CABG	1562 (10.4)	1528 (10.1)	0.39	710 (9.8)	169 (7.3)	<0.01	920 (9.9)	78 (7.3)	<0.01

Abbreviations: CAD, coronary artery disease; PVD, peripheral vascular disease; CHF, congestive heart failure; P2Y12, P2Y12 inhibiting medications; ACEi, angiotensin converting enzyme inhibitor; ARB, angiotensin receptor blocker; MI, myocardial infarction; PCI, percutaneous coronary intervention; CABG, coronary artery bypass surgery.

courtesy of the University of California, Los Angeles Center for Neighborhood Knowledge [20]. The transportation metric utilized was the percentage of households in a neighborhood (census tract) that do not own a vehicle.

Patients were divided into 2 groups based on their neighborhood of residence: those living in neighborhoods with higher vehicle ownership, and those living in neighborhoods with lower vehicle ownership. Lower vehicle ownership is defined as neighborhoods with $\geq$ 4.34% of households reporting not owning a vehicle and higher vehicle ownership is defined as neighborhoods with < 4.34% of households reporting not owning a vehicle. The cutoff for determining if a neighborhood would be considered one with "higher" vs "lower" vehicle ownership was obtained by taking the median for the percentage of households with no vehicle for the entire cohort of patients included in the study.

2.3. Mortality

Mortality data was obtained from a mortality data file maintained at KPSC, with integrated death information derived from multiple sources including insurance enrollment records, hospital death records, and death master files from the State of California and the Social Security Administration.

2.4. Statistical analysis

All-cause mortality was analyzed according to the percentage of households without a vehicle in a neighborhood as well as race/ethnicity. Descriptive statistics were used to analyze covariate distribution. Continuous variables were reported as means with standard deviations and compared using the independent *t*-test. Categorical variables were reported as counts and percentages and were compared using the chi-square test.
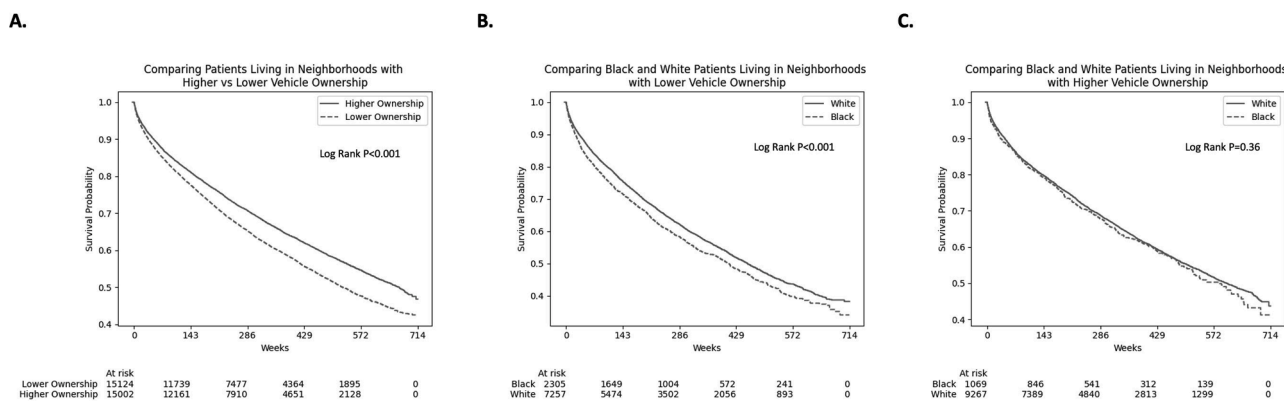
A.   **B.**   **C.**

Fig. 2. (page 22): Kaplan-Meier curves.
A. Comparing all-cause death according to neighborhood vehicle ownership.
B. Comparing all-cause death between White and Black patients living in neighborhoods with lower vehicle ownership.
C. Comparing all-cause death between White and Black patients living in neighborhoods with higher vehicle ownership.
Central illustration (page 23): Mortality disparities according to neighborhood and race.

Kaplan-Meier cumulative incidence plots were generated to show time to events for the primary endpoint of all-cause mortality. The association between living in a neighborhood with a higher percentage of households with no vehicle and all-cause mortality after myocardial infarction was assessed using Cox proportional hazards regression models. Multivariable models adjusted for age, sex, race/ethnicity, neighborhood median income, and medical comorbidities were used to estimate hazard ratios with 95% confidence intervals. P-values of less than 0.05 for association were used to indicate statistical significance. Statistical analyses were performed using Python 3.11 (Python Software Foundation, Wilmington, DE).

3. Results

3.1. Study population

Between January 1, 2006, and December 31, 2016, a total of 49,667 patients were admitted to the hospital with a principal diagnosis of acute MI (Fig. 1). From this initial cohort, 33,781 had an address on file from which a Federal Information Processing Standard (FIPS) geographic code was available for determination of census tract, 30,132 survived beyond 30 days from the admission date of the index hospitalization, and 30,126 had data available regarding the percentage of households with no vehicle for their census tract and were ultimately included for analysis.

Patients were separated into 2 groups based on percentage of households with no vehicle for their census tract: those living in neighborhoods with higher vehicle ownership ($<$ 4.34% of households with no vehicle, $n = 15,002$ [49.8%]) and those living in neighborhoods with lower vehicle ownership ($\geq$ 4.34% of households with no vehicle, $n = 15,124$ [50.2%]). White and Black patients were further separated

into groups according to whether they lived in a neighborhood with higher or lower vehicle ownership: White patients living in neighborhoods with lower vehicle ownership ($n = 7257$), Black patients living in neighborhoods with lower vehicle ownership ($n = 2305$), White patients living in neighborhoods with higher vehicle ownership ($n = 9267$), and Black patients living in neighborhoods with higher vehicle ownership ($n = 1069$). Asian and Hispanic patients were also separated into groups according to neighborhood and descriptive statistics for these groupings can be found in Tables S1 and S2 of the supplemental appendix.

Compared to the higher vehicle ownership group, the lower vehicle ownership group had a higher percentage of women, Black, and Hispanic patients (Table 1). The lower vehicle ownership group had more patients living in neighborhoods with a median household income of $<$ \$45,000 per year and more patients insured through Medicaid. There were higher rates of hypertension, diabetes, congestive heart failure, stroke, lung disease, liver disease, kidney disease, and active smoking among patients in the lower vehicle ownership group.

White and Black patients had significantly different baseline demographics and comorbidity profiles, irrespective of whether they lived in a neighborhood with higher or lower vehicle ownership. Black patients were more likely to be younger, female, living in a neighborhood with a median household income of $<$ \$45,000 per year, and to be insured through commercial insurance or Medicaid. White patients were more likely to be insured through Medicare. Black patients had higher rates of hypertension, diabetes, obesity, congestive heart failure, and kidney disease. White patients had higher rates of atrial fibrillation. Black patients were more likely to have previously been prescribed beta blockers, angiotensin-converting enzyme inhibitors (ACEi) or angiotensin II receptor blockers (ARB). Black patients were more likely to have never smoked. Black patients were less likely to receive reperfusion therapy (percutaneous coronary intervention or coronary artery bypass

Table 2
: Hazard ratios for all-cause death according to neighborhood vehicle ownership and race.

	Higher Vehicle Ownership	Lower Vehicle Ownership	P value	White Patients Lower Vehicle Ownership	Black Patients Lower Vehicle Ownership	P value
Unadjusted	Reference	1.22 (1.17–1.26)	$<$0.001	Reference	1.13 (1.05–1.20)	$<$0.001
Model 1		1.13 (1.09–1.17)	$<$0.001		1.35 (1.26–1.44)	$<$0.001
Model 2		1.10 (1.06–1.14)	$<$0.001		1.21 (1.13–1.30)	$<$0.001
Model 3		1.06 (1.02–1.10)	0.007		1.20 (1.12–1.29)	$<$0.001

Model 1: adjusted for age, gender, and race/ethnicity (not adjusted for race/ethnicity in comparison of White and Black patients).
Model 2: adjusted for age, gender, race/ethnicity (not adjusted for race/ethnicity in comparison of White and Black patients), and medical comorbidities (hypertension, hyperlipidemia, diabetes, atrial fibrillation, heart failure, stroke, kidney disease, lung disease, liver disease, rheumatic disease, hypothyroidism, and obesity).
Model 3: adjusted for age, gender, race/ethnicity (not adjusted for race/ethnicity in comparison of White and Black patients), medical comorbidities, and median household income for neighborhood.

surgery) compared to White patients.

Among White and Black patients living in neighborhoods with lower vehicle ownership; Black patients were more likely to have a prior history of liver disease and to have been prescribed nitrates. Among White and Black patients living in neighborhoods with higher vehicle ownership; Black patients were more likely to have a history of stroke.

3.2. Association between vehicle ownership and mortality

Patients were followed for 6.2 +/- 3.8 years. Kaplan-Meier survival curves comparing all-cause mortality between patients living in neighborhoods with higher vs lower vehicle ownership demonstrate significantly higher mortality among patients living in neighborhoods with lower vehicle ownership (Fig. 2A, log rank *p*<0.001). Kaplan-Meier survival curves comparing all-cause mortality between White and Black patients living in neighborhoods with lower vehicle ownership demonstrate significantly higher mortality among Black patients (Fig. 2B, log rank *p*<0.001). Kaplan-Meier survival curves comparing all-cause mortality between White and Black patients living in neighborhoods with higher vehicle ownership demonstrate no significant mortality difference (Fig. 2C, log rank *p* = 0.36).

Table 2 shows the association between vehicle ownership and all-cause mortality. After adjusting for age, gender, race/ethnicity, and medical comorbidities, living in a neighborhood with lower vehicle ownership was associated with significantly higher all-cause mortality when compared to living in a neighborhood with higher vehicle ownership (hazard ratio [HR] 1.10; 95% confidence interval [CI] 1.06–1.14; *p*<0.001). This difference remained significant after adjusting for neighborhood median household income (HR 1.06; 95% CI 1.02–1.10; *p* = 0.007).

Upon comparison between White and Black patients living in neighborhoods with lower vehicle ownership, after adjusting for age, gender, and medical comorbidities, being Black was associated with significantly higher all-cause mortality when compared to being White (HR 1.21; 95% CI 1.13–1.30; *p*<0.001). This difference remained significant after adjusting for neighborhood median household income (HR 1.20; 95% CI 1.12–1.29; *p*<0.001). Both the Asian and Hispanic cohorts were found to have lower mortality than White patients regardless of neighborhood, but this finding was not significant after adjusting for age and gender (see Figure S1 and Tables S3 and S4 for the survival analyses for these groups).

4. Discussion

Transportation is recognized as a fundamental social determinant of health but research investigating transportation disparities among patients with ischemic heart disease is lacking. The present study demonstrates that patients living in neighborhoods with lower vehicle ownership have a higher mortality after acute myocardial infarction compared to patients living in neighborhoods with higher vehicle ownership, even after accounting for median household income. Additionally, among those living in neighborhoods with lower vehicle ownership, Black patients had a higher mortality after acute myocardial infarction compared to White patients. There was no mortality difference between Black and White patients living in neighborhoods with higher vehicle ownership, suggesting that transportation serves as a key mediator in the disparities in health outcomes between Black and White patients after myocardial infarction.

Transportation inequities are increasingly recognized as significant contributors to disparities in healthcare access [21]. Despite this recognition, there is limited research into which patients are at the greatest risk for adverse health outcomes due to inadequate transportation [21] and this is especially true for patients with ischemic heart disease. This lack of research may explain why transportation intervention programs have failed to demonstrate a significant impact on medical outcomes [7,21-24].

The one study that was found which specifically investigated the association between transportation barriers and outcomes in patients with ischemic heart disease is a 2018 paper by Erskine et al. This study utilized survey data of 2008 patients who suffered an acute MI to determine the association between transportation barriers, financial barriers, and lack of usual source of medical care with all-cause mortality. The authors found that patients who reported difficulty accessing healthcare due to transportation issues the year prior to MI had increased mortality at 2-years post-MI. However, there were only 239 patients who reported transportation to be an issue with accessing medical care and the increased mortality among these patients appears to be due entirely to the 44 patients who reported having all three of the healthcare access barriers present: transportation barriers, financial barriers, and lack of usual source of medical care [25].

The study presented in this manuscript is unique in that the patients included were all well-insured, had equal access to primary and subspecialty care, and received their in-hospital and follow-up care in very similar medical centers because of their membership with the KPSC Health System. Even with these variables controlled for and after adjusting for median household income, there was still a significantly higher mortality among patients living in neighborhoods with lower vehicle ownership. The present study also included a very large and diverse patient cohort, which allowed for a thorough assessment of outcomes based on racial and ethnic differences. The fact that this study was able to control for treatment setting is particularly important in this regard as racial/ethnic differences in outcomes after MI have previously been demonstrated to be associated with racial and ethnic minorities being treated in lower performing medical centers compared to their White counterparts [26,27].

The utilization of an area-based metric of transportation disparities likely captures patients with additional socioeconomic risks but these risks cannot be ignored. On the contrary, the additional risk factors a patient has due to living in a neighborhood with lower vehicle ownership are likely magnified among those patients with unreliable transportation and an area-based transportation assessment helps to put these risks into context. It is notable that this study demonstrated increased mortality among patients living in neighborhoods with lower vehicle ownership even after adjusting for income. This is consistent with prior research demonstrating that living in a disadvantaged neighborhood can have detrimental health effects that are independent of a person's socioeconomic status [12,28,29] and the present findings suggest that transportation disparities may be a contributing factor.
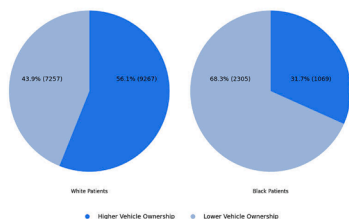
Access to a motor vehicle is vitally important to chronic disease management and lack of adequate transportation has been associated with inability to make it to medical appointments [2,8,30-33], delays in receiving medical therapy [2,34-36], increased reliance on emergency departments to receive care [2,37,38], and decreased likelihood to fill prescriptions [2–6]. Beyond difficulties in receiving medical care, lack of vehicle ownership has been associated with increased food insecurity [39], which itself is a risk for cardiovascular disease [40].

Socioeconomically deprived neighborhoods are less likely to have access to safe green outdoor spaces [11], which have been associated with increased physical activity, reduced levels of stress, and increased longevity [41]. Individuals who lack the transportation needed to escape to outdoor recreation areas may endure increased environmental stress in the form of neighborhood violence, noise, and pollution, all of which predispose these individuals to poor health outcomes [42,43]. These environmental stressors can also combine to diminish a person's ability to sustain health-promoting behaviors [44], which can be particularly harmful for patients with existing ischemic heart disease.
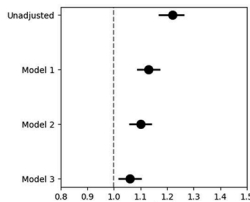
Decades of exclusionary housing practices, along with other forms of institutional racism, have created racially and ethnically segregated neighborhoods that persist throughout the United States [45]. Black Americans are more likely to live in neighborhoods with fewer employment opportunities, lower household income, worse access to quality education, and worse housing quality [46]. It has been well

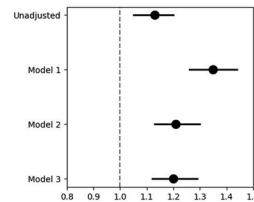**Central Illustration:** Disparities in Mortality Among Patients Living in Neighborhoods with Lower Vehicle Ownership
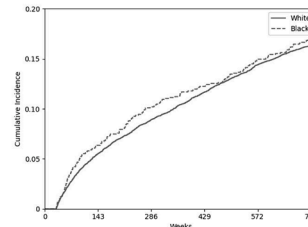
Model 1: adjusted for age, gender, and race/ethnicity *
Model 2: adjusted for age, gender, race/ethnicity *, and medical comorbidities
Model 3: adjusted for age, gender, race/ethnicity *, medical comorbidities, and median household income
for neighborhood

* Not adjusted for race/ethnicity in comparison of White and Black patients

Medical comorbidities: hypertension, hyperlipidemia, diabetes, atrial fibrillation, heart failure, stroke, kidney disease, lung disease, liver disease, rheumatic disease, hypothyroidism, and obesity

established that Black Americans are at increased risk for cardiovascular disease as well as for worse outcomes after MI [42,47,48]. This increased risk has been found to be largely attributable to the presence of greater cardiovascular disease risk factors [48,49] that are directly related to disparities in socioeconomic status [42,47,48]. The finding that Black patients living in neighborhoods with lower vehicle ownership had higher mortality than White patients living in similar neighborhoods but that there was no mortality difference between Black and White patients living in neighborhoods with higher vehicle ownership is consistent with these prior findings. This study suggests that providing certain high-risk patients with transportation after MI can have a meaningful impact on patient outcomes and additional research to identify these high-risk patients is certainly needed.

This study is inherently limited by the potential for confounding variables given its observational design. This study is also limited by needing to exclude patients who did not have a permanent address on file at the time of hospitalization. The inclusion of only KPSC members may reduce the overall generalizability of the study but it is reasonable to believe that these findings would be amplified in a less-well-insured cohort. Additionally, grouping patients into White, Black, Hispanic, and Asian subgroups does not account for the broad spectrum of ancestral diversity within each of these groups but limitations as to how data is captured within the electronic health record prevented a more thorough assessment of ancestry.

5. Conclusion

Living in a neighborhood with lower vehicle ownership was associated with increased mortality after myocardial infarction, even after adjusting for differences in household income. Black patients living in neighborhoods with lower vehicle ownership had a higher mortality after myocardial infarction than White patients living in neighborhoods with lower vehicle ownership. However, Black patients living in neighborhoods with higher vehicle ownership had no worse mortality than their White counterparts. These findings highlight the important role that transportation plays in determining health status among individuals with ischemic heart disease, particularly among Black individuals.

Statement of authorship

Jesse J Goitia Jr MD: Designed the study, performed statistical analysis, drafted the manuscript. **James Onwuzurike MD:** edited and revised the manuscript. **Aiyu Chen MPH:** performed statistical analysis. **Yi-Lin Wu MS:** performed statistical analysis. **Albert Yuh-Jer Shen MD:** edited and revised the manuscript. **Ming-Sum Lee MD, PhD:** collected data, performed statistical analysis, provided final review.

Declaration of Competing Interest

Supplementary materials

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