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Jianhui Hu
*Henry Ford Health*, jhu1@hfhs.org

Christie M. Bartels

Richard A. Rovin

Laura E. Lamb

Amy J.H. Kind

*See next page for additional authors*



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## Authors

Jianhui Hu, Christie M. Bartels, Richard A. Rovin, Laura E. Lamb, Amy J.H. Kind, and David R. Nerenz

# Race, Ethnicity, Neighborhood Characteristics, and In-Hospital Coronavirus Disease-2019 Mortality

*Jianhui Hu, PhD,* Christie M. Bartels, MD, MS,†‡ Richard A. Rovin, MD,§ Laura E. Lamb, PhD,∥¶ Amy J.H. Kind, MD, PhD,†#** and David R. Nerenz, PhD**

**Background:** Despite many studies reporting disparities in coronavirus disease-2019 (COVID-19) incidence and outcomes in Black and Hispanic/Latino populations, mechanisms are not fully understood to inform mitigation strategies.

**Objective:** The aim was to test whether neighborhood factors beyond individual patient-level factors are associated with in-hospital mortality from COVID-19. We hypothesized that the Area Deprivation Index (ADI), a neighborhood census-block-level composite measure, was associated with COVID-19 mortality independently of race, ethnicity, and other patient factors.

**Research Design:** Multicenter retrospective cohort study examining COVID-19 in-hospital mortality.

**Subjects:** Inclusion required hospitalization with positive SARS-CoV-2 test or COVID-19 diagnosis at three large Midwestern academic centers.

**Measure(s):** The primary study outcome was COVID-19 in-hospital mortality. Patient-level predictors included age, sex, race, insurance, body mass index, comorbidities, and ventilation. Neighborhoods were examined through the national ADI neighborhood deprivation rank comparing in-hospital mortality across ADI quintiles. Analyses used multivariable logistic regression with fixed site effects.

**Results:** Among 5999 COVID-19 patients median age was 61 (interquartile range: 44–73), 48% were male, 30% Black, and 10.8% died. Among patients who died, 32% lived in the most disadvantaged quintile while 11% lived in the least disadvantaged quintile; 52% of Black, 24% of Hispanic/Latino, and 8.5% of White patients lived in the most disadvantaged neighborhoods. Living in the most disadvantaged neighborhood quintile predicted higher mortality (adjusted odds ratio: 1.74; 95% confidence interval: 1.13–2.67) independent of race. Age, male sex, Medicare coverage, and ventilation also predicted mortality.

**Conclusions:** Neighborhood disadvantage independently predicted in-hospital COVID-19 mortality. Findings support calls to consider neighborhood measures for vaccine distribution and policies to mitigate disparities.

**Key Words:** health disparities, epidemiology, health policy, socioeconomic factors, housing and health

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From the *Henry Ford Health System, Detroit; †Department of Medicine, Health Services and Care Research Program; ‡Division of Rheumatology, Department of Medicine, University of Wisconsin School of Medicine and Public Health, Madison, WI; §Aurora St. Luke's Medical Center, Milwaukee, WI; ∥Beaumont Health System, Royal Oak, MI; ¶Oakland University William Beaumont School of Medicine, Rochester, MI; #Division of Geriatrics and Gerontology, Department of Medicine, University of Wisconsin School of Medicine and Public Health; and **Department of Veterans Affairs Geriatrics Research Education and Clinical Center, Madison, WI.

J.H. and C.M.B. contributed equally as co-first authors.

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Correspondence to: Christie M. Bartels, MD, MS, 1685 Highland Avenue, Room 4132, Madison, WI 53705-2281. E-mail: cb4@medicine.wisc.edu.



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Racial and ethnic disparities in coronavirus disease-2019 (COVID-19) incidence and outcomes have been extensively documented.[1–4] Black and Hispanic/Latino populations have been particularly hard-hit.[5] Mechanisms responsible for these disparities are not fully understood, although disproportionate risks borne by these populations as a reflection of long-standing structural and systemic inequities likely play a large role.[3,5–7] Increasing awareness of such structural factors has driven calls for new approaches to mitigate disparities, including the use of small area-level indices of socioeconomic disadvantage (ie, "neighborhood disadvantage") as a means to identify, respond to and, ultimately, equitably allocate COVID-19-related resources.[8]

However, it remains unclear if neighborhood-level factors are themselves a risk factor for COVID-19 mortality.[4,7] Patient-level characteristics have been well studied, but less attention has been paid to neighborhood characteristics as reasons for higher COVID-19 mortality rates. Experiences of 2 identical individuals with COVID-19 might differ depending on where they live. For example, high-density housing,[6] or more frequent or crowded grocery trips,[9] affect the likelihood of coronavirus exposure for low-income neighborhoods separate from the living conditions of any individual. Accuracy and timeliness of information about COVID-19,[10] and the ability to be screened and take appropriate precautions,[3] could also be influenced by neighborhood characteristics. Ethical justification of using neighborhood-level metrics for COVID-19 resource allocation to mitigate disparities would be strengthened if neighborhood disadvantage itself independently predicted risk of COVID-19 mortality.

Neighborhoods can be characterized many ways using census and other publicly available data. One potentially useful metric is the Area Deprivation Index (ADI),[11] a measure that combines 17 specific indicators (eg, poverty, housing, education, and employment) into an index of disadvantage. The ADI is freely available to the public through the Neighborhood Atlas[11,12] and has been proposed by thought leaders as a candidate metric for COVID-19 resource allocation.[8] The ADI has proven useful in a range of health disparities studies.[13,14]

In this study, we used data from 3 large diverse health systems in Michigan and Wisconsin to examine the effects of ADI on in-hospital mortality of COVID-19 patients.

## METHODS

This retrospective, observational, cohort study used electronic health record data from 3 large hospital systems: Aurora Health (Milwaukee, WI), Henry Ford Health Systems (Detroit, MI), and University of Wisconsin Hospital and Clinics (Madison, WI). Adult patients (18 y old or above) who were hospitalized with confirmed SARS-CoV-2 or diagnosis of COVID-19 between February and June 2020 were included. National ADI data were obtained through the Neighborhood Atlas,[12] from University of Wisconsin-Madison School of Medicine and Public Health. IRB approvals or exemptions were obtained for each entity for pooled analysis of limited data.

Data included patient sociodemographics (age, sex, self-reported race/ethnicity Black, White, or Hispanic/Latino from the electronic health record), primary insurance (Medicare, Medicaid, commercial, other, or uninsured), comorbidities, body mass index (BMI) at admission, mechanical ventilator use, and discharge disposition. Age was divided into 7 groups: 18–39, 10-year-age groups up to 89, and 90 years and above. BMI was classified as underweight, normal weight, overweight, and 3 classes of obesity. Comorbidities including hypertension, lung disease, heart disease, diabetes, and neurological disease were assessed at admission and any encounters the prior year. Patient addresses were geocoded and assigned an ADI national rank according to their residential census block group. Higher ADI rank indicates more disadvantage. Analyses used ADI rank quintiles.

Our outcome, in-hospital mortality, was defined by patient status at discharge or last hospital observation.

We first compared patient characteristics between those who did and did not die during hospitalization. We also compared patient characteristics and in-hospital mortality by race and ethnicity (Black, White, Hispanic/Latino, and other race). Categorical variables were compared using the $\chi^2$ test or the Fisher exact test. Logistic regressions with site fixed effects were used to evaluate the association between patient characteristics and in-hospital mortality. Variables in bivariate analyses with $P<0.1$ were included in multivariate logistic regression models to determine independent predictors of mortality. Collinearity and multicollinearity were assessed using the Spearman rank correlation and variance inflation factors. To examine how relationships between mortality and predictors changed with additional variables, we report a series of "stepwise" regression models. Significance was set at $P<0.05$; all tests were 2-sided. Sensitivity analysis compared patients who died to those discharged alive. Analyses were conducted using STATA/SE version 16.1 (StataCorp, LLC, College Station, TX).

## RESULTS

Table 1 shows that among 5999 patients with COVID-19 median age was 60 years (18–103; interquartile range (IQR): 44–73), 2858 (47.7%) were male, 1127 (18.8%) were

**TABLE 1.** Characteristics of COVID-19 Patients by Discharge or Last Hospital Status

| | Patients, n (%) | | | |
|---|---|---|---|---|
| Patient Characteristics* | All (n = 5999) | Alive (n = 5354) | Died (n = 645) | *P* |
| Age, years | | | | < 0.001 |
| 18–39 | 1157 (19.3) | 1145 (21.4) | 12 (1.9) | |
| 40–49 | 761 (12.7) | 741 (13.8) | 20 (3.1) | |
| 50–59 | 1047 (17.5) | 1000 (18.7) | 47 (7.3) | |
| 60–69 | 1172 (19.5) | 1051 (19.6) | 121 (18.8) | |
| 70–79 | 916 (15.3) | 736 (13.8) | 180 (27.9) | |
| 80–89 | 654 (10.9) | 483 (9.0) | 171 (26.5) | |
| 90+ | 292 (4.9) | 198 (3.7) | 94 (14.6) | |
| Sex: male | 2858 (47.7) | 2486 (46.5) | 372 (57.8) | < 0.001 |
| Race and ethnicity | | | | < 0.001 |
| Non-Hispanic White | 2392 (39.9) | 2076 (38.8) | 316 (49.0) | |
| Black | 1765 (29.4) | 1538 (28.7) | 227 (35.2) | |
| Hispanic/Latino | 1127 (18.8) | 1080 (20.2) | 47 (7.3) | |
| Other | 447 (7.5) | 410 (7.7) | 37 (5.7) | |
| Missing | 268 (4.5) | 250 (4.7) | 18 (2.8) | |
| ADI national rank: quintile | | | | < 0.001 |
| First (1–20): least disadvantaged | 629 (10.5) | 556 (10.4) | 73 (11.3) | |
| Second (21–40) | 1204 (20.1) | 1112 (20.8) | 92 (14.3) | |
| Third (41–60) | 1152 (19.2) | 1029 (19.2) | 123 (19.1) | |
| Fourth (61–80) | 996 (16.6) | 921 (17.2) | 75 (11.6) | |
| Fifth (81–100) | 1495 (24.9) | 1289 (24.1) | 206 (31.9) | |
| Missing | 523 (8.7) | 447 (8.4) | 76 (11.8) | |
| Primary insurance | | | | < 0.001 |
| Medicare | 2433 (40.6) | 1916 (35.9) | 517 (80.2) | |
| Medicaid | 821 (13.7) | 773 (14.5) | 48 (7.4) | |
| Commercial | 1500 (25.0) | 1435 (26.9) | 65 (10.1) | |
| Other | 306 (5.1) | 298 (5.6) | 8 (1.2) | |
| Uninsured | 930 (15.5) | 923 (17.3) | 7 (1.1) | |
| Ventilator use: any | 872 (14.5) | 514 (9.6) | 358 (55.5) | < 0.001 |
| BMI | | | | < 0.001 |
| Underweight (< 18.5) | 135 (2.3) | 105 (2.0) | 30 (4.7) | |
| Normal (18.5–25) | 1126 (18.8) | 955 (17.8) | 171 (26.5) | |
| Overweight (25–30) | 1537 (25.6) | 1362 (25.4) | 175 (27.1) | |
| Class 1 obesity (30–35) | 1150 (19.2) | 1059 (19.8) | 91 (14.1) | |
| Class 2 obesity (35–40) | 696 (11.6) | 631 (11.8) | 65 (10.1) | |
| Class 3 obesity (≥ 40) | 675 (11.3) | 619 (11.6) | 56 (8.7) | |
| Missing | 680 (11.3) | 623 (11.6) | 57 (8.8) | |
| Comorbidities | | | | |
| Hypertension | 2368 (39.5) | 1999 (37.3) | 369 (57.2) | < 0.001 |
| Lung disease | 1399 (23.3) | 1166 (21.8) | 233 (36.1) | < 0.001 |
| Heart disease | 2189 (36.5) | 1883 (35.2) | 306 (47.4) | < 0.001 |
| Diabetes | 1468 (24.5) | 1237 (23.1) | 231 (35.8) | < 0.001 |
| Neurological disease | 1418 (23.6) | 1241 (23.2) | 177 (27.4) | 0.016 |

*All categorical variables were compared using the $\chi^2$ test or the Fisher exact test.

ADI indicates area deprivation index; BMI, body mass index; COVID-19, coronavirus disease-2019.

**TABLE 2.** Characteristics of COVID-19 Patients by Race and Ethnicity

| Patient Characteristics | Non-Hispanic White [n (%)] (n = 2392) | Black [n (%)] (n = 1765) | Hispanic/Latino [n (%)] (n = 1127) | Other [n (%)] (n = 447) | *P* |
|---|---|---|---|---|---|
| Age, years | | | | | < 0.001 |
| 18–39 | 362 (15.1) | 264 (15.0) | 354 (31.4) | 93 (20.8) | |
| 40–49 | 198 (8.3) | 219 (12.4) | 259 (23.0) | 54 (12.1) | |
| 50–59 | 341 (14.3) | 347 (19.7) | 236 (21.0) | 74 (16.6) | |
| 60–69 | 439 (18.4) | 422 (23.9) | 170 (15.1) | 92 (20.6) | |
| 70–79 | 449 (18.8) | 318 (18.0) | 55 (4.9) | 61 (13.7) | |
| 80–89 | 389 (16.3) | 163 (9.2) | 41 (3.6) | 43 (9.6) | |
| 90+ | 214 (9.0) | 32 (1.8) | 12 (1.1) | 30 (6.7) | |
| Sex: male | 1124 (47.0) | 839 (47.6) | 555 (49.3) | 223 (49.9) | 0.495 |
| ADI national rank: quintile | | | | | < 0.001 |
| First (1–20) least disadvantaged | 404 (16.9) | 56 (3.2) | 50 (4.4) | 91 (20.4) | |
| Second (21–40) | 699 (29.2) | 147 (8.3) | 191 (17.0) | 114 (25.5) | |
| Third (41–60) | 574 (24.0) | 174 (9.9) | 267 (23.7) | 86 (19.2) | |
| Fourth (61–80) | 334 (14.0) | 262 (14.8) | 308 (27.3) | 64 (14.3) | |
| Fifth (81–100) | 204 (8.5) | 921 (52.2) | 270 (24.0) | 64 (14.3) | |
| Missing | 177 (7.4) | 205 (11.6) | 41 (3.6) | 28 (6.3) | |
| Primary Insurance | | | | | < 0.001 |
| Medicare | 1250 (52.3) | 818 (46.4) | 142 (12.6) | 152 (34.0) | |
| Medicaid | 177 (7.4) | 305 (17.3) | 230 (20.4) | 83 (18.6) | |
| Commercial | 554 (23.2) | 464 (26.3) | 334 (29.7) | 100 (22.4) | |
| Other | 4 (5.0) | 49 (2.8) | 105 (9.3) | 29 (6.5) | |
| Uninsured | 289 (12.1) | 126 (7.2) | 314 (27.9) | 83 (18.6) | |
| Ventilator use: any | 312 (13.0) | 351 (19.9) | 123 (10.9) | 59 (13.2) | < 0.001 |
| BMI | | | | | < 0.001 |
| Underweight (< 18.5) | 72 (3.0) | 31 (1.8) | 8 (0.7) | 18 (4.0) | |
| Normal (18.5–25) | 544 (22.7) | 268 (15.2) | 148 (13.1) | 135 (30.2) | |
| Overweight (25–30) | 643 (26.9) | 395 (22.4) | 321 (28.5) | 134 (30.0) | |
| Class 1 obesity (30–35) | 439 (18.4) | 366 (20.7) | 252 (22.4) | 58 (13) | |
| Class 2 obesity (35–40) | 243 (10.2) | 268 (15.2) | 142 (12.6) | 28 (6.3) | |
| Class 3 obesity (≥ 40) | 223 (9.3) | 298 (16.9) | 110 (9.8) | 24 (5.4) | |
| Missing | 228 (9.5) | 139 (7.9) | 146 (13.0) | 50 (11.2) | |
| Comorbidities | | | | | |
| Hypertension | 959 (40.1) | 985 (55.8) | 218 (19.3) | 146 (32.7) | < 0.001 |
| Lung disease | 610 (25.5) | 606 (34.3) | 91 (8.1) | 69 (15.4) | < 0.001 |
| Heart disease | 1064 (44.5) | 633 (35.9) | 301 (26.7) | 151 (33.8) | < 0.001 |
| Diabetes | 540 (22.6) | 598 (33.9) | 191 (17.0) | 105 (23.5) | < 0.001 |
| Neurological disease | 738 (30.9) | 358 (20.3) | 225 (20.0) | 84 (18.8) | < 0.001 |

ADI indicates area deprivation index; BMI, body mass index.

Hispanic/Latino, and 1765 (29.4%) Black. Median ADI national rank was 55 (range: 1–100, IQR: 33–83]). Overall, 645 (10.8%) died during hospitalization. Compared with those alive, more of those who died were older [median (IQR) age, 76 (67–85) vs. 58 (42–70)], male (57.8% vs. 46.5%), Black (35.2% vs. 28.7%), or White non-Hispanic (49.0% vs. 38.8%). Hispanic/Latino ethnicity was less common among those who died (7.3% vs. 20.2%). Among patients who died, 32% lived in the most disadvantaged quintile while 11% lived in the least disadvantaged quintile. A larger proportion also had comorbid conditions, or required mechanical ventilation during hospitalization [358 (55.5%) vs. 514 (9.6%)].

Compared with White patients, Black patients were 5 times more likely and Hispanic/Latino patients almost 3 times more likely to live in the most disadvantaged neighborhood quintile [921 of 1765 (52.2%) Black and 270 of 1127 (24.0%) Hispanic/Latino vs. 204 of 2392 (8.5% White)] as shown in Table 2. Overall in-hospital death occurred in 13.2% of White patients (316 of 2392), 12.9% of Black patients (227 of 1765), compared with 4.2% of (47 of 1127) Hispanic/Latino patients (Table 1).

Table 3 shows the results of multivariable logistic regressions with fixed effects by site. Complete data on 4767 patients were included in our final multivariable logistic regression (Models 1–4). Collinearity and multicollinearity were not demonstrated as the Spearman ρ was 0.25 between race and ADI. The maximum variance inflation factors quantifying any multicollinearity was 3.16 for all right-hand variables. Race did not initially predict mortality (Table 3 Model 2), and after adding ADI, Black patients had lower mortality (Model 4 odds ratio (OR): 0.64; 95% confidence interval (CI): 0.47–0.88) than White patients. Hispanic/Latino ethnicity did not predict any significant mortality difference compared with White non-Hispanic patients. However, patients who lived in the most disadvantaged neighborhood quintile were more likely (OR: 1.74; 95% CI: 1.13–2.67) to die during hospitalization than patients living in the least disadvantaged neighborhoods. Age greater than 60 years (OR range: 2.76–28.85, male sex (OR: 1.34; 95% CI: 1.06–1.69), and ventilator use (OR: 17.38; 95% CI: 13.34–22.66) all consistently associated with in-hospital death. None of 5

 

**TABLE 3.** Odds Associating Race, Ethnicity, Neighborhood, Patient Characteristics, and In-hospital Death

| Patient Characteristics (n = 4767) | Model 1 Adj. OR (95% CI) | Model 2 Adj. OR (95% CI) | Model 3 Adj. OR (95% CI) | Model 4 Adj. OR (95% CI) |
|---|---|---|---|---|
| Age, years | | | | |
| 18–39 | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| 40–49 | 1.16 (0.48–2.84) | 1.16 (0.47–2.82) | 1.17 (0.48–2.87) | 1.19 (0.48–2.92) |
| 50–59 | 1.88 (0.89–3.97) | 1.85 (0.87–3.89) | 1.92 (0.91–4.05) | 1.89 (0.90–4.01) |
| 60–69 | 2.73 (1.32–5.65) | 2.64 (1.28–5.48) | 2.82 (1.36–5.84) | 2.76 (1.33–5.74) |
| 70–79 | 5.74 (2.69–12.22) | 5.49 (2.58–11.72) | 6.00 (2.81–12.78) | 5.75 (2.70–12.29) |
| 80–89 | 12.98 (5.99–28.14) | 12.09 (5.56–26.29) | 13.64 (6.27–29.65) | 12.71 (5.83–27.70) |
| 90+ | 26.19 (11.70–58.66) | 23.86 (10.59–53.77) | 28.66 (12.72–64.58) | 28.85 (11.42–58.51) |
| Sex: male | 1.33 (1.05–1.68) | 1.33 (1.05–1.67) | 1.34 (1.07–1.70) | 1.34 (1.06–1.69) |
| Ventilator use | 16.96 (13.05–22.05) | 17.31 (13.29–22.54) | 16.87 (12.97–21.94) | 17.38 (13.34–22.66) |
| BMI | | | | |
| Normal (18.5–25) | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| Underweight (< 18.5) | 1.08 (0.61–1.90) | 1.08 (0.61–1.90) | 1.07 (0.61–1.89) | 1.07 (0.61–1.89) |
| Overweight (25–30) | 0.86 (0.64–1.15) | 0.84 (0.63–1.14) | 0.85 (0.63–1.14) | 0.83 (0.62–1.12) |
| Class 1 obesity (30–35) | 0.59 (0.42–0.85) | 0.58 (0.41–0.83) | 0.60 (0.42–0.85) | 0.59 (0.41–0.84) |
| Class 2 obesity (35–40) | 0.78 (0.52–1.19) | 0.77 (0.50–1.17) | 0.77 (0.50–1.17) | 0.76 (0.50–1.16) |
| Class 3 obesity (≥ 40) | 0.81 (0.52–1.26) | 0.80 (0.52–1.25) | 0.79 (0.51–1.23) | 0.79 (0.51–1.23) |
| Comorbidities | | | | |
| Hypertension | 0.96 (0.73–1.26) | 0.98 (0.75–1.30) | 0.94 (0.71–1.24) | 0.98 (0.74–1.29) |
| Lung disease | 1.08 (0.84–1.40) | 1.07 (0.83–1.39) | 1.08 (0.83–1.39) | 1.06 (0.82–1.38) |
| Heart disease | 1.05 (0.79–1.38) | 1.02 (0.77–1.35) | 1.05 (0.80–1.39) | 1.02 (0.77–1.35) |
| Diabetes | 1.14 (0.89–1.46) | 1.17 (0.91–1.50) | 1.12 (0.87–1.45) | 1.16 (0.90–1.49) |
| Neurological disease | 1.30 (0.98–1.73) | 1.27 (0.96–1.69) | 1.29 (0.97–1.71) | 1.24 (0.93–1.65) |
| Primary insurance | | | | |
| Medicare | 1 [Reference] | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| Medicaid | 0.61 (0.37–0.99) | 0.63 (0.38–1.03) | 0.58 (0.36–0.95) | 0.58 (0.35–0.96) |
| Commercial | 0.56 (0.37–0.84) | 0.56 (0.37–0.84) | 0.57 (0.38–0.86) | 0.57 (0.38–0.87) |
| Other | 0.47 (0.20–1.12) | 0.47 (0.19–1.12) | 0.44 (0.19–1.06) | 0.43 (0.18–1.05) |
| Uninsured | 0.39 (0.16–0.95) | 0.40 (0.16–0.97) | 0.38 (0.15–0.94) | 0.39 (0.16–0.97) |
| Race and ethnicity | | | | |
| Non-Hispanic White | | 1 [Reference] | | 1 [Reference] |
| Black | | 0.78 (0.59–1.03) | | 0.64 (0.47–0.88) |
| Hispanic/Latino | | 0.84 (0.55–1.29) | | 0.75 (0.48–1.16) |
| Other | | 0.62 (0.38–1.02) | | 0.63 (0.38–1.03) |
| ADI national rank: quintile | | | | |
| First (1–20) least disadvantaged | | | 1 [Reference] | 1 [Reference] |
| Second (21–40) | | | 0.99 (0.66–1.50) | 0.99 (0.65–1.49) |
| Third (41–60) | | | 1.38 (0.92–2.05) | 1.37 (0.92–2.04) |
| Fourth (61–80) | | | 1.15 (0.75–1.78) | 1.21 (0.78–1.88) |
| Fifth (81–100) | | | 1.44 (0.97–2.15) | 1.74 (1.13–2.67) |

ADI indicates area deprivation index; BMI, body mass index; CI, confidence interval; OR, odds ratio.

comorbid conditions was associated with death. Compared with normal BMI, class 1 obesity predicted less mortality (OR: 0.59; 95% CI: 0.41–0.84). Patients with Medicaid (OR: 0.58; 95% CI: 0.35–0.96) and commercial plans (OR: 0.57; 95% CI: 0.38–0.87) and those uninsured (OR: 0.39; 95% CI: 0.16–0.97) were less likely to die during hospitalization than Medicare patients.

Sensitivity analysis comparing patients who died and patients who were discharged alive yielded similar estimates for all covariates.

## DISCUSSION

In this analysis of COVID-19 patients hospitalized at 3 diverse, large Midwestern centers, patients residing in the highest ADI (most disadvantaged) neighborhoods were significantly more likely to die, even after accounting for individual-level risk factors. As others have noted,[1–4] individual-level factors of age, race, sex, and several specific comorbidities were associated with in-hospital mortality on univariable analyses. In the multivariable analyses, age, sex, and ADI most significantly associated with in-hospital mortality, even accounting for other factors.

The effect of ADI was significant, with residents in the most disadvantaged neighborhoods being at highest risk of death. While Black and Hispanic/Latino patients were 3–5-fold more likely to reside in such neighborhoods, ADI, but not race, predicted increased mortality. Our findings are consistent with an intensive care unit-based study that reported lower 28-day mortality in people of color, with no difference in in-hospital mortality, intubation, or intensive care unit days.[15] Moreover, separating ADI from race or ethnicity as predictors of COVID mortality is informative. This critically important finding provides additional scientific weight to the increasing calls to use neighborhood disadvantage metrics reflective of structural inequities, like the ADI, for COVID-19 resource allocation.[1] Granular geographic metrics of disadvantage, like the ADI, are a cornerstone of many global health systems, guiding efficient, effective allocation of scarce resources. Consideration could be given to using ADI for a similar purpose in the United States.

Limitations include generalizability beyond these Midwestern, academic centers. Missing data occurred in n = 1232 observations; missing ADI (n = 523) was more common in Black patients. Among other factors, this could represent homelessness which would most likely bias toward null findings. Findings should be re-examined in other cohorts with controls for individual income and education beyond neighborhood disadvantage. Fixed effects models likewise limit analysis of hospital factors or clustering effects.

## CONCLUSION

This study adds to the growing body of science and policy focused on neighborhood contextual factors, like ADI, and their independent association with key health outcomes. Finding 50% greater mortality in the most disadvantaged neighborhood quintile builds upon evidence supporting ADI as a readily available, policy-applicable means to allocate COVID-19 vaccine and to implement other strategies toward mitigating COVID-19 disparities.

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