Race, Ethnicity, Neighborhood Characteristics, and In-Hospital COVID-19 Mortality

Jianhui Hu, PhD[#,1], **Christie M. Bartels, MD, MS**[#,2,3], **Richard A. Rovin, MD**[4], **Laura E. Lamb, PhD**[5,6], **Amy J. H. Kind, MD, PhD**[2,7,8], **David R. Nerenz, PhD**[1]

[1]Henry Ford Health System, Detroit MI

[2]Health Services and Care Research Program, University of Wisconsin School of Medicine and Public Health, Department of Medicine, Madison, WI

[3]Department of Medicine, Division of Rheumatology, University of Wisconsin School of Medicine and Public Health, Madison, WI

[4]Aurora St. Luke's Medical Center, Milwaukee, WI

[5]Beaumont Health System, Royal Oak, MI

[6]Oakland University William Beaumont School of Medicine, Rochester, MI

[7]Department of Medicine, Division of Geriatrics and Gerontology, University of Wisconsin School of Medicine and Public Health, Madison, WI

[8]Department of Veterans Affairs Geriatrics Research Education and Clinical Center, Madison, WI

[#] These authors contributed equally to this work.

Abstract

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

Objective: 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 via the national ADI neighborhood deprivation rank comparing

Corresponding Author: Christie Bartels, MD MS, 1685 Highland Ave, Rm 4132, Madison, WI USA 53705-2281, Phone: (608) 263-3457, Fax: (608) 263-7353, cb4@medicine.wisc.edu.

in-hospital mortality across ADI quintiles. Analyses used multivariable logistic regression with fixed site effects.

Results: Among 5,999 COVID-19 patients median age was 61 (IQR 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 (Adj. OR, 1.74; 95% CI, 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.

Keywords

Introduction

Racial and ethnic disparities in 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 (i.e., "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 two 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 (e.g., poverty, housing, education, 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 three 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 three 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 years old) 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 seven groups: 18 to 39, 10-year-age groups up to 89, and 90 years and above. BMI was classified as underweight, normal weight, overweight, and three 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, other race). Categorical variables were compared using the chi-squared test or Fisher's 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 Spearman's rank correlation and variance inflation factors (VIF). 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 two-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 5,999 patients with COVID-19 median age was 60 years (18–103, [interquartile range (IQR), 44–73]), 2,858 (47.7%) were male, 1,127 (18.8%) were Hispanic/ Latino, and 1,765 (29.4%) Black. Median ADI national rank was 55 (range 1–100, [IQR 33–83]). Overall, 645 (10.8%) died during hospitalization. Compared to 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 five times more likely and Hispanic/ Latino patients almost three times more likely to live in the most disadvantaged neighborhood quintile (921 of 1,765 [52.2%] Black and 270 of 1127 [24.0%] Hispanic/ Latino vs 204 of 2,392 [8.5% White]) as shown in Table 2. Overall in-hospital death occurred in 13.2% of White patients (316 of 2,392), 12.9% of Black patients (227 of 1,765), compared to 4.2% of (47 of 1,127) Hispanic/Latino patients (Table 1).

Table 3 shows the results of multivariable logistic regressions with fixed effects by site. Complete data on 4,767 patients were included in our final multivariable logistic regression (Models 1–4). Collinearity and multicollinearity were not demonstrated as Spearman's rho was 0.25 between race and ADI. The maximum VIF 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 OR, 0.64; 95% CI, 0.47-0.88) than White patients. Hispanic/Latino ethnicity did not predict any significant mortality difference compared to 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 five comorbid conditions was associated with death. Compared to 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 three 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 three to five-fold more likely to reside in such neighborhoods, ADI, but not race, predicted increased mortality. Our findings are consistent with an intensive care unit (ICU) based study that reported lower 28-day mortality in people of color, with no difference in in-hospital mortality, intubation, or ICU 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 US.

Limitations include generalizability beyond these Midwestern, academic centers. Missing data occurred in n=1,232 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.

Acknowledgments:

References

1. Kabarriti R, Brodin NP, Maron MI, et al.Association of Race and Ethnicity With Comorbidities and Survival Among Patients With COVID-19 at an Urban Medical Center in New York. JAMA Netw Open2020;3(9):e2019795. [PubMed: 32975574]

2. Munoz-Price LS, Nattinger AB, Rivera F, et al.Racial Disparities in Incidence and Outcomes Among Patients With COVID-19. JAMA Netw Open2020;3(9):e2021892. [PubMed: 32975575]

3. Selden TM, Berdahl TA. COVID-19 And Racial/Ethnic Disparities In Health Risk, Employment, And Household Composition. Health affairs (Project Hope)2020;39(9):1624–32. [PubMed: 32663045]

4. Yehia BR, Winegar A, Fogel R, et al.Association of Race With Mortality Among Patients Hospitalized With Coronavirus Disease 2019 (COVID-19) at 92 US Hospitals. JAMA Netw Open2020;3(8):e2018039. [PubMed: 32809033]

5. Thebault R, Ba Tran A, Williams V. The coronavirus is infecting and killing black Americans at an alarmingly high rate. The Washington Post47, 2020. https://www.washingtonpost.com/nation/2020/04/07/coronavirus-is-infecting-killing-black-americans-an-alarmingly-high-rate-post-analysis-shows/

6. Emeruwa UN, Ona S, Shaman JL, et al.Associations Between Built Environment, Neighborhood Socioeconomic Status, and SARS-CoV-2 Infection Among Pregnant Women in New York City. JAMA2020;324(4):390–92. doi: 10.1001/jama.2020.11370 [PubMed: 32556085]

7. Egede LE, Walker RJ, Garacci E, et al.Racial/Ethnic Differences In COVID-19 Screening, Hospitalization, And Mortality In Southeast Wisconsin. Health Aff (Millwood)2020;39(11):1926–34. doi: 10.1377/hlthaff.2020.01081 [PubMed: 33136498]

8. Schmidt H, Gostin LO, Williams MA. Is It Lawful and Ethical to Prioritize Racial Minorities for COVID-19 Vaccines?Jama2020;324(20):2023. doi: 10.1001/jama.2020.20571 [PubMed: 33052391]

9. Chang S, Pierson E, Koh PW, et al.Mobility network models of COVID-19 explain inequities and inform reopening. Nature. 2021; 589: 82–7. [PubMed: 33171481]

10. Chiu WA, Fischer R, Ndeffo-Mbah ML. State-level needs for social distancing and contact tracing to contain COVID-19 in the United States. Nature Human Behaviour2020;4(10):1080–90. doi: 10.1038/s41562-020-00969-7

11. Kind AJH, Buckingham WR. Making Neighborhood-Disadvantage Metrics Accessible - The Neighborhood Atlas. N Engl J Med2018;378(26):2456–58. doi: 10.1056/NEJMp1802313 [PubMed: 29949490]

12. University of Wisconsin School of Medicine Public Health. 2018Area Deprivation Index v2.4 [Available from: ttps://www.neighborhoodatlas.medicine.wisc.edu/ accessed September 2020.]

13. Hu J, Kind AJH, Nerenz D. Area Deprivation Index Predicts Readmission Risk at an Urban Teaching Hospital. Am J Med Qual2018;33(5):493–501. doi: 10.1177/1062860617753063 [PubMed: 29357679]

14. Kind AJ, Jencks S, Brock J, et al.Neighborhood socioeconomic disadvantage and 30-day rehospitalization: a retrospective cohort study. Ann Intern Med2014;161(11):765–74. doi: 10.7326/M13-2946 [published Online First: 2014/12/02] [PubMed: 25437404]

15. Lazar MH, Fadel R, Gardner-Gray J, et al.Racial Differences in a Detroit, MI, ICU Population of Coronavirus Disease 2019 Patients. Critical Care Medicine2021;49(3):482–89. doi: 10.1097/ccm.0000000000004735 [PubMed: 33372746]

Table 1.

Characteristics of COVID-19 patients by discharge or last hospital status

Patient Characteristics[a]	Patients, No. (%)			
	All	Alive	Died	
	(N=5999)	(n=5354)	(n=645)	P value
Age, years				<.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)	<.001
Race and ethnicity				<.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				<.001
1st (1–20): least disadvantaged	629 (10.5)	556 (10.4)	73 (11.3)	
2nd (21–40)	1204 (20.1)	1112 (20.8)	92 (14.3)	
3rd (41–60)	1152 (19.2)	1029 (19.2)	123 (19.1)	
4th (61–80)	996 (16.6)	921 (17.2)	75 (11.6)	
5th (81–100)	1495 (24.9)	1289 (24.1)	206 (31.9)	
missing	523 (8.7)	447 (8.4)	76 (11.8)	
Primary Insurance				<.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)	<.001
BMI				<.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)	

| Patient Characteristics[a] | Patients, No. (%) | | | |
	All (N=5999)	Alive (n=5354)	Died (n=645)	P value
Comorbidities				
Hypertension	2368 (39.5)	1999 (37.3)	369 (57.2)	<.001
Lung disease	1399 (23.3)	1166 (21.8)	233 (36.1)	<.001
Heart disease	2189 (36.5)	1883 (35.2)	306 (47.4)	<.001
Diabetes	1468 (24.5)	1237 (23.1)	231 (35.8)	<.001
Neurological disease	1418 (23.6)	1241 (23.2)	177 (27.4)	0.016

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

[a]All categorical variables were compared using the χ^2 test or Fisher's exact test.

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 value
Age, years					*<.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					*<.001*
1st (1–20) least disadvantaged	404 (16.9)	56 (3.2)	50 (4.4)	91 (20.4)	
2nd (21–40)	699 (29.2)	147 (8.3)	191 (17.0)	114 (25.5)	
3rd (41–60)	574 (24.0)	174 (9.9)	267 (23.7)	86 (19.2)	
4th (61–80)	334 (14.0)	262 (14.8)	308 (27.3)	64 (14.3)	
5th (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					*<.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)	*<.001*
BMI					*<.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)	*<.001*
Lung disease	610 (25.5)	606 (34.3)	91 (8.1)	69 (15.4)	*<.001*
Heart disease	1064 (44.5)	633 (35.9)	301 (26.7)	151 (33.8)	*<.001*
Diabetes	540 (22.6)	598 (33.9)	191 (17.0)	105 (23.5)	*<.001*
Neurological disease	738 (30.9)	358 (20.3)	225 (20.0)	84 (18.8)	*<.001*

Abbreviations: ADI, area deprivation index; BMI, body mass index.

Table 3.

Odds associating race, ethnicity, neighborhood, patient characteristics & 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				
1st (1–20) least disadvantaged			1 [Reference]	1 [Reference]
2nd (21–40)			0.99 (0.66–1.50)	0.99 (0.65–1.49)
3rd (41–60)			1.38 (0.92–2.05)	1.37 (0.92–2.04)
4th (61–80)			1.15 (0.75–1.78)	1.21 (0.78–1.88)

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)*
5th (81–100)			1.44 (0.97–2.15)	1.74 (1.13–2.67)

Abbreviations: ADI, area deprivation index; BMI, body mass index