

Characteristics and Risk Factors for Mortality by Coronavirus Disease 2019 Pandemic Waves in Fulton County, Georgia: A Cohort Study March 2020–February 2021

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Background. We examined differences in mortality among coronavirus disease 2019 (COVID-19) cases in the first, second, and third waves of the COVID-19 pandemic.

Methods. A retrospective cohort study of COVID-19 cases in Fulton County, Georgia, USA, reported to a public health surveillance from March 2020 through February 2021. We estimated case-fatality rates (CFR) by wave and used Cox proportional hazards random-effects models in each wave, with random effects at individual and long-term-care-facility level, to determine risk factors associated with rates of mortality.

Results. Of 75 289 confirmed cases, 4490 (6%) were diagnosed in wave 1 (CFR 31 deaths/100 000 person days [pd]), 24 293 (32%) in wave 2 (CFR 7 deaths/100 000 pd), and 46 506 (62%) in wave 3 (CFR 9 deaths/100 000 pd). Compared with females, males were more likely to die in each wave: wave 1 (adjusted hazard ratio [aHR], 1.5; 95% confidence interval [CI], 1.2–1.8), wave 2 (aHR 1.5, 95% CI, 1.2–1.8), and wave 3 (aHR 1.7, 95% CI, 1.5–2.0). Compared with non-Hispanic whites, non-Hispanic blacks were more likely to die in each wave: wave 1 (aHR, 1.4; 95% CI, 1.1–1.8), wave 2 (aHR, 1.5; 95% CI, 1.2–1.9), and wave 3 (aHR, 1.7; 95% CI, 1.4–2.0). Cases with any disability, chronic renal disease, and cardiovascular disease were more likely to die in each wave compared with those without these comorbidities.

Conclusions. Our study found gender and racial/ethnic disparities in COVID-19 mortality and certain comorbidities associated with COVID-19 mortality. These factors have persisted throughout the COVID-19 pandemic waves, despite improvements in diagnosis and treatment.

Keywords. case fatality rate; cohort; COVID-19; mortality; risk factors.

Since the first case of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)—the novel coronavirus that causes coronavirus disease 2019 (COVID-19)—was detected in the United States in January 2020 [1, 2], there have been serial waves of the epidemic, with cases rising and falling during the summer and winter holiday weeks. Simultaneously, there have been substantial improvements in the diagnosis, treatment, and prevention of COVID-19, with several interventions demonstrating reduced morbidity and mortality [3]. However, key risk groups have remained disproportionately affected by COVID-19, despite these advances.

Early data from the United States demonstrated more severe disease occurring among older persons and those with comorbidities [4], including hypertension, diabetes, obesity, renal disease, lung disease, and immunosuppression [5–7]. In addition, persons who were non-Hispanic black represented 23% of COVID-19-related deaths [8], despite comprising 13.4% of the US population [9]. Although hospitalization rates have been reported as higher among non-Hispanic black patients, results were mixed when evaluating race and ethnicity as a risk factor for death after adjusting for covariates [10, 11]. Adults in the southern United States have higher rates of several medical comorbidities (eg, diabetes, obesity) than those in other parts of the United States, with even higher rates among racial and ethnic minorities [12], raising concerns for even poorer outcomes from COVID-19 in these populations.

Between March 2020 and March 2021, there were 3 COVID-19 pandemic waves in the United States. In the first wave (March through May 2020), limited knowledge of COVID-19 and lack of resources, including personal protective equipment and effective treatment, added to the severity of this first

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phase. Lessons learned from the first wave improved preventive measures and the management of patients in the second wave (June through September 2020). However, the number of COVID-19 cases was higher than the first wave, as were hospitalizations and deaths. By the third wave (October 2020 through January 2021), case counts and severity exceeded all prior waves. Given the cyclic and progressive nature of the COVID-19 pandemic, together with of the availability of vaccines for priority populations toward the end of the third wave, it remained critically important to monitor trends in severe disease among the most vulnerable groups. To explore changes in demographics of COVID-19 cases over time, including differential impact on severe disease and mortality by epidemic waves, we evaluated individuals with SARS-CoV-2 in Fulton County, Georgia, USA.

METHODS

Design, Participants, and Setting

We conducted a retrospective cohort study analysis of surveillance data of individuals diagnosed with laboratory-confirmed SARS-CoV-2 infection from March 2, 2020 when the first case

of COVID-19 was notified in Georgia [13] to February 28, 2021. A laboratory confirmation of SARS-CoV-2 infection was defined as having a positive result on a real-time reverse-transcriptase polymerase chain reaction. We included residents of Fulton County, Georgia, which includes 90% of the city of Atlanta. The population in Fulton County is 1.06 million people and represents 10% of the state of Georgia's population [14]. During this study period, we identified 3 waves of the COVID-19 pandemic that were used in our analyses: the first wave was 90 days from March 2, 2020 to May 30, 2020; the second wave was 119 days from May 31, 2020 to September 26, 2020; and the third wave was 155 days from September 27, 2020 to February 28, 2021 (Figure 1). These time periods correspond with the overall peaks and troughs for the United States, as reported by the Centers for Disease Control and Prevention [15].

Data Source

Data were extracted from the State Electronic Notifiable Disease Surveillance System (SENDSS), an electronic database used by the Georgia Department of Public Health to track patients with notifiable diseases, including COVID-19 cases. The extracted data for

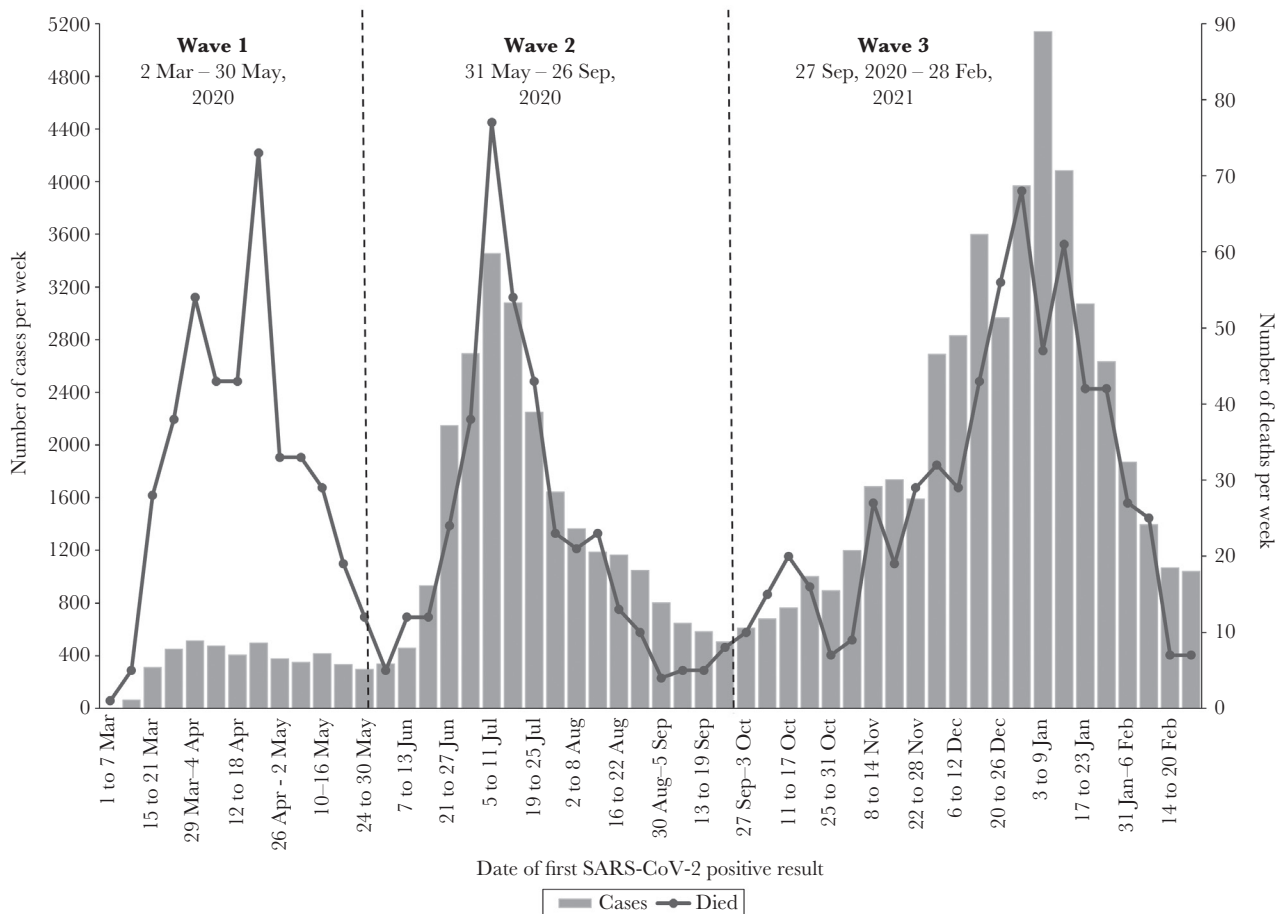


Figure 1. Weekly counts of confirmed coronavirus disease 2019 cases by Waves in Fulton County, Georgia (March 2020–February 2021). SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

each case included in this study were as follows: date of first SARS-CoV-2 positive specimen collection, age, gender, race and ethnicity, medical comorbidities, residence in a long-term care facility (LTCF), hospitalization, intensive care unit (ICU) admission, and death. Where applicable, dates related to hospitalization, discharge, death, and the length of hospital stay were also extracted and used to determine hospitalization status for records with missing data. To have complete case investigations and reporting to the surveillance system, we included cases that tested positive for COVID-19 up to and including February 28, 2021. Given known delays in disease progression and case investigation for individuals diagnosed in the latter portion of the study period, we allowed for a 4-week lag to March 31, 2021, for extraction of data from SENDSS.

Outcomes

The primary outcome measure was mortality, measured as the case-fatality rate (CFR), rate ratio, and adjusted hazard ratio (aHR). The CFR was defined as the number of deaths per follow-up time in days (person-days) among cases in each wave [16]. The rate ratio was defined as the ratio of the CFRs between risk groups among confirmed cases in each wave. The aHR was defined as the ratio of the hazard rates of mortality between risk groups among confirmed cases in each wave while accounting for covariates. The secondary outcomes, measured among hospitalized cases only, were the proportion admitted to the ICU, hospital length of stay, and hospital discharge disposition in each wave.

Statistical Analysis

We described demographic characteristics of all cases as medians and interquartile ranges (IQRs) for continuous variables, or frequencies and proportions (%) for categorical variables. Differences in the distributions of the baseline characteristics across the 3 waves were assessed using Kruskal-Wallis test for continuous variables and Pearson χ^2 test for categorical variables. Missing data on covariates were shown in the descriptive table and excluded in the analyses. In each wave, there were <1% of cases with missing age or gender, and <11% of cases with missing race and ethnicity combined. Cases with missing data are included in the descriptive analysis (Table 1) but excluded from models.

In the primary outcome analyses, we used Kaplan-Meier curves (1) to compare mortality by the COVID-19 pandemic waves and (2) to compare mortality by gender and race/ethnicity groups in each wave. To determine factors associated with mortality, we obtained crude (unadjusted) rate ratios by gender groups, race/ethnicity groups, and by medical comorbidity (any disability, immunocompromised, chronic renal disease, cardiovascular disease, diabetes mellitus, chronic lung disease, and chronic liver disease). In the adjusted analyses, we fit multivariable Cox proportional hazards regression random effects models by wave, with individuals and LTCFs as random

effects (shared frailty models) that contained age, gender, race, and ethnicity (combined), and all the recorded medical comorbidities. We included random effects for clustering at individual and LTCF level in the adjusted models. Cases from LTCFs have been shown to contribute high proportions of COVID-19-related hospitalizations and deaths [17]. We anticipated a nonlinear association between age and mortality over time and found the association between age and mortality to be squared and cubic across the 3 waves for all models ($P > .05$ for all models). We therefore added these fractional polynomials for age to the adjusted models [18]. In each of the adjusted Cox models, we used the likelihood ratio test to test the proportional hazards assumption for potential interaction between each variable and time.

We examined whether having additional comorbidities to an already existing comorbidity further increased the risk of mortality. We therefore fit Kaplan-Meier curves to determine survival functions by no comorbidity, 1 comorbidity, 2 comorbidities, and 3 or more comorbidities at COVID-19 diagnosis. We used the log-rank test to examine statistical difference among these groups.

In the secondary outcome analyses, we examined the proportions and median times among hospitalized cases and compared them across waves. A 2-sided $P < .05$ was considered statistically significant. Statistical analyses were performed in Stata software version 15.1 (StataCorp, College Station, TX).

Patient Consent Statement

As a public health surveillance activity in response to the COVID-19 emergency, this activity was determined to be exempt by Georgia Department of Public Health Institutional Review Board (IRB). The Emory University IRB approved this activity with a waiver of informed consent.

RESULTS

Between March 2, 2020 and February 28, 2021, there were 75 289 confirmed cases of COVID-19 in Fulton County, Georgia. Of these, 29 360 (39%) were non-Hispanic black persons, 35 264 (47%) were males, and the median age was 36 years (IQR, 25–52). Overall, 1426 (2%) confirmed COVID-19 cases died during follow-up, with a median time to death of 22 days (IQR, 13–41 days). Of these 75 289 confirmed cases, 4490 (6%) were diagnosed in wave 1; 24 293 (32%) in wave 2, and 46 506 (62%) in wave 3. The median number of cases diagnosed per week increased in each wave, from 378 cases/week (IQR, 310–450) in wave 1, 1166 cases/week (IQR, 646–2146) in wave 2, and 2114 cases/week (IQR, 1047–2933) in wave 3. The total number of deaths were 411 in wave 1, 377 in wave 2, and 637 in wave 3. The rate of reported deaths varied in each wave from a median of 33 deaths/week (IQR, 19–43) in wave 1 to 13 deaths/week (IQR, 8–24) in wave 2, and 27 deaths/week (IQR, 15–42) in wave 3 (Figure 1).

Table 1. Case-Fatality Rate and Rate Ratio by Pandemic Waves According to Gender, Race/Ethnicity, and Medical Comorbidities in Fulton County, Georgia (March 2020–February 2021)

	Wave 1				Wave 2				Wave 3			
	Cases	Deaths	Case-Fatality Rate/100 000 Person-Days		Cases	Deaths (N = 377)	Case Fatality Rate/100 000 Person-Days		Cases	Deaths	Case Fatality Rate/100 000 Person-Days	
			Rate Ratio (95% CI) ^a	Rate Ratio (95% CI) ^a			Rate Ratio (95% CI) ^a	Rate Ratio (95% CI) ^a				
Overall	4490	411	31	24 293	377	7	46 506	638	19			
Age Groups Years, n (%)												
<25	382 (8)	2	1.7	6619 (27)	4	0.3	1	3	0.4	1	1	
25–34	666 (15)	4	1.9	6320 (26)	9	0.6	2.3 (0.6–10.2)	5	0.6	1.6 (0.3–10.5)		
35–44	720 (16)	4	1.7	3980 (16)	19	2.1	7.8 (2.6–31.4)	13	2.4	6.1 (1.7–33.2)		
45–54	707 (16)	21	9.5	3387 (14)	29	3.8	14.1 (5.0–55.2)	28	5.5	13.8 (4.3–71.2)		
55–64	725 (16)	44	19.9	2134 (9)	49	10.4	38.5 (14.1–146.9)	94	25.1	63.8 (21.2–314.8)		
≥65	1280 (29)	336	105.1	1821 (8)	267	74	272.7 (105.2–1008.3)	495	147.6	374.6 (127.4–1822.5)		
Unknown ^b	10 (<1)			32 (<1)			70 (<1)	1				
Median age (IQR)	51 (35–67)			33 (24–48)			37 (25–53)					
Gender, n (%)												
Female	2316 (52)	202	29.5	12 610 (52)	181	6.4	1	304	44.3	1	1	
Male	2173 (48)	209	32.7	11 494 (47)	196	7.7	1.2 (0.9–1.4)	333	52.2	1.2 (1.1–1.5)		
Unknown	1 (<1)			189 (1)			250 (1)	1				
Race/Ethnicity, n (%)												
White	1017 (23)	83	27.2	7363 (30)	123	7.6	1	266	22.8	1	1	
Black	2490 (55)	313	43.7	10 070 (41)	220	9.7	1.3 (1.0–1.6)	329	28.3	1.2 (1.1–1.5)		
Hispanic	410 (9)	9	7.3	2945 (12)	24	3.6	0.5 (0.3–0.7)	25	8.2	0.4 (0.2–0.5)		
Other	211 (5)	6	9	1424 (6)	10	3.2	0.4 (0.2–0.8)	14	4.6	0.2 (0.1–0.3)		
Unknown	362 (8)			2491 (10)			5104 (11)	4				
Any Disability, n (%)												
None	4281 (95)	307	23.8	24 100 (99)	348	6.5	1	584	178	1	1	
Yes	209 (5)	104	284.2	193 (1)	29	74.6	11.5 (7.6–16.9)	54	171	9.6 (7.1–12.7)		
Immunocompromised, n (%)												
None	4320 (96)	366	28.6	23 910 (98)	354	6.6	1	611	18.7	1	1	
Yes	170 (4)	45	105.7	383 (2)	23	28	4.2 (2.6–6.4)	27	60.4	3.2 (2.1–4.7)		
Chronic Renal Disease, n (%)												
None	4316 (96)	336	26.1	24 135 (99)	333	6.2	1	585	177	1	1	
Yes	174 (4)	75	209.3	158 (1)	44	153.1	24.8 (17.7–34.0)	53	374.9	21.1 (15.6–28.0)		
Cardiovascular Disease, n (%)												
None	3941 (88)	263	22.1	23 453 (97)	266	5.1	1	536	16.6	1	1	
Yes	549 (12)	148	109.3	840 (3)	111	64.9	12.8 (10.2–16.1)	102	1273	7.7 (6.1–9.5)		
Diabetes, n (%)												
None	4092 (91)	331	27.2	23 274 (96)	305	5.9	1	559	174	1	1	
Yes	398 (9)	80	75.3	1019 (4)	72	33.2	5.7 (4.3–7.3)	79	74.3	4.3 (3.3–5.4)		

Table 1. Continued

	Wave 1			Wave 2			Wave 3					
	Cases	Deaths	Case-Fatality Rate/100 000 Person-Days	Rate Ratio (95% CI) ^a	Cases	Deaths (N = 377)	Case Fatality Rate/100 000 Person-Days	Rate Ratio (95% CI) ^a	Cases	Deaths	Case Fatality Rate/100 000 Person-Days	Rate Ratio (95% CI) ^a
Chronic Lung Disease, n (%)												
None	4183 (93)	359	29	1	22 932 (94)	337	6.6	1	44 385 (95)	582	18.4	1
Yes	307 (7)	52	61.1	2.1 (1.5–2.8)	1361 (6)	40	13.4	2.0 (1.4–2.8)	2121 (5)	56	37.9	2.1 (1.5–2.7)
Chronic Liver Disease, n (%)												
None	4470 (100)	406	30.8	1	24 241 (100)	371	6.9	1	46 439 (100)	634	19.2	1
Yes	20 (<1)	5	102.5	3.3 (1.1–7.8)	52 (<1)	6	56.4	8.2 (3.0–18.1)	67 (<1)	4	80.5	4.2 (1.1–10.8)

Abbreviations: CI, confidence interval; IQR, interquartile range.

^aRate ratio is the ratio of the case-fatality rates.

^bUnknown were missing data in each covariate.

Case-Fatality Rates, Rate Ratios, and Risk Factors for Mortality

Of 75 289 cases at risk, 1426 died during 57 352 patient-days of follow-up (CFR 14.2 deaths per 100 000 person-days; 95% CI, 13.5–14.9). Compared to wave 1, the cumulative proportion of cases dying decreased in the subsequent waves. Non-Hispanic black persons comprised 55% (2490 of 4490) of all confirmed COVID-19 cases in the first wave, and 76% (313 of 411) of those that died in the first wave.

The overall CFR per 100 000 person-days decreased from 31 in the first wave to 7 in the second wave but increased to 19 in wave 3 (Table 1). Compared to wave 1, there was a statistically significant decline in CFR by 80% in wave 2 (CFR ratio, 0.2; 95% CI, .2–.3) and by 40% in wave 3 (CFR ratio, 0.6; 95% CI, .5–.7).

In the unadjusted analyses, the CFR per 100 000 person-days for non-Hispanic black persons was higher compared to non-Hispanic white persons across all waves: 43.7 non-Hispanic black vs 27.2 non-Hispanic white in wave 1; 9.7 vs 7.6 in wave 2; and 28.3 vs 22.8 in wave 3, respectively (Table 1). In addition, the CFR ratio (rate ratio) for non-Hispanic black compared to non-Hispanic white persons was higher in each wave: 1.6 (95% CI, 1.3–2.1) in wave 1, 1.3 (95% CI, 1.0–1.6) in wave 2, and 1.2 (95% CI, 1.1–1.5) in wave 3 (Table 1).

In the adjusted analyses, compared with females, males were more likely to die in wave 1 (aHR, 1.5; 95% CI, 1.2–1.8), wave 2 (aHR, 1.5; 95% CI, 1.2–1.8), and wave 3 (aHR, 1.7; 95% CI, 1.5–2.0). Compared with non-Hispanic white persons, non-Hispanic black persons were more likely to die in wave 1 (aHR, 1.4; 95% CI, 1.1–1.8), wave 2 (aHR, 1.5; 95% CI, 1.2–1.9), and wave 3 (aHR, 1.7; 95% CI, 1.4–2.0). Cases with any disability, chronic renal disease, and cardiovascular disease were more likely to die across all waves compared with those without these comorbidities. Furthermore, cases with (1) immunocompromised status in wave 1 and (2) those with chronic lung diseases in wave 3 were more likely to die than cases without these comorbidities in the respective waves (Figure 2). Kaplan-Meier analysis showed that mortality was strongly associated with having more than 1 comorbidity at COVID-19 diagnosis in wave 1 ($P < .0001$), wave 2 ($P < .0001$), and wave 3 ($P < .0001$) (Figure 3).

Outcomes Among Hospitalized Cases

Of 4582 cases that were hospitalized during the study period, 990 (22%) were in wave 1, 1667 (36%) in wave 2, and 1925 (42%) in wave 3. The proportion of hospitalized non-Hispanic black cases that died decreased in the subsequent waves compared to wave 1: in wave 1, 197 (27%) died of 719 non-Hispanic black persons that were hospitalized; in wave 2, 114 (11%) died of 1024 non-Hispanic black persons that were hospitalized; and in wave 3, 156 (14%) died of 1132 non-Hispanic black persons that were hospitalized in wave 3.

The proportion of non-Hispanic black cases that were admitted to ICU decreased in the subsequent waves compared to

wave 1: in wave 1, 195 (27%) died of 719 non-Hispanic black persons that were hospitalized; in wave 2, 194 (19%) died of 1024 non-Hispanic black persons that were hospitalized; and in wave 3, 204 (18%) died of 1132 non-Hispanic black persons that were hospitalized.

Compared to wave 1, the proportion of hospitalized cases that died in the subsequent waves were significantly lower (25% in wave 1 vs 12% in wave 2 vs 16% in wave 3; $P < .001$). Compared to wave 1, the proportion of cases admitted to ICU decreased significantly in the subsequent waves (26% vs 18% vs 16%, respectively; $P < .001$). There were no statistically significant differences in length of hospital stay among the waves (Table 2).

DISCUSSION

We examined characteristics associated with death by COVID-19 pandemic waves in Fulton County, Georgia, a densely populated, diverse urban center that includes most of the city of Atlanta and its suburbs. These data provide valuable insights from one of the largest cohorts of COVID-19 cases in the Southeast United States, a region that showed rapidly rising numbers of COVID-19 in each pandemic wave. Despite improvements in overall epidemiological and clinical outcomes during this period, we found several groups with persistently greater risks of mortality, namely, males, non-Hispanic black individuals, and persons with medical comorbidities. Even with the widespread availability of vaccines that occurred after the time of this study, there have been persistent disparities in vaccine uptake (and boosting) that are likely to further exacerbate the clinical outcomes observed in our study. Given that these groups comprise large proportions of the US population, it is critical that COVID-19 interventions are designed to specifically address their health needs to turn the tide of this epidemic.

We found that the CFR was high in the first wave of the pandemic but decreased over subsequent waves, coinciding with greater availability of COVID-19 testing and improvements in COVID-19 prevention and treatment. Despite this overall trend, non-Hispanic black persons had a disproportionately higher CFR and a persistently high-rate ratio across all waves, adding to the findings from studies conducted during the early part of the COVID-19 pandemic in California and Louisiana [11, 19]. In addition, although non-Hispanic black persons comprise 44% of the population in Fulton County [20], 55% of all confirmed COVID-19 cases and 76% of those that died in the first wave were non-Hispanic black. It is notable that the increased risk of death in this group was independent of age, gender, and medical comorbidities in the adjusted analyses. These data support known inequities in access to and utilization of healthcare and testing services among non-Hispanic blacks, in part caused by long-standing medical mistrust and experiences of racism [21]. In addition, non-Hispanic black persons comprise a higher proportion of frontline and essential workers in the United States,

placing them at greater risk for SARS-CoV-2 exposure and infection [22, 23]. Our findings raise important concerns that, despite awareness of racial and ethnic disparities in COVID-19 disease burden and outcomes since early in the pandemic, these gaps have persisted throughout subsequent waves. With data on similar disparities in COVID-19 vaccine uptake, our study supports the continued need to intensify diagnosis, treatment, and prevention efforts to close gaps in morbidity and mortality.

Consistent with early trends of the COVID-19 pandemic across the United States [24], we found an increased risk of mortality among COVID-19 cases with comorbid medical conditions across all pandemic waves. Furthermore, there was an increased risk of mortality for each increase in the number of comorbidities an individual had. This suggests that having additional comorbidities further complicates the management of COVID-19, which in turn results in increased mortality. Our findings underscore the need to ensure optimized treatment of comorbid conditions—particularly because health services have been disrupted for approximately 2 years—outreach for COVID-19 vaccine administration, and ongoing transmission prevention measures among individuals with these risk factors. It is important to note that our study period was during a time when the Alpha and Beta variants predominated and before vaccines were widely available [25]. However, the subsequent Delta variant (July–November 2021, “fourth wave”) was more transmissible, coupled with the general public’s COVID fatigue in rigorously maintaining precautions. This resulted in more hospitalizations, despite vaccine availability, further underscoring the need for targeted outreach to high-risk groups. Indeed, as subsequent variants (eg, Omicron) have demonstrated immune evasion leading to many vaccinated individuals becoming infected, the findings from our study remain highly relevant for monitoring groups who are likely to bear a disproportionate burden of disease.

Finally, we found that among hospitalized cases, the proportion that died in the hospital decreased in waves 2 and 3, compared to wave 1. Several factors likely contributed to the observed improvements. First, limited access to testing in the early parts of the pandemic likely resulted in delays in diagnosis until individuals developed more severe, persistent COVID-19 symptoms or became extremely ill. As testing for COVID-19 became more widely available and policies expanded to allow testing of all age groups, regardless of symptoms, there was an increase in number of cases being diagnosed earlier in the disease course, including persons with mild or asymptomatic infection [26]. Second, improved understanding of the pathophysiology of the COVID-19 disease, expansion of hospital capacity and inpatient supportive treatment, and use of more effective biomedical treatments have resulted in improvements in disease outcomes despite higher caseload in subsequent waves. These improvements in outcomes among hospitalized cases could be jeopardized with the recent Omicron wave (December

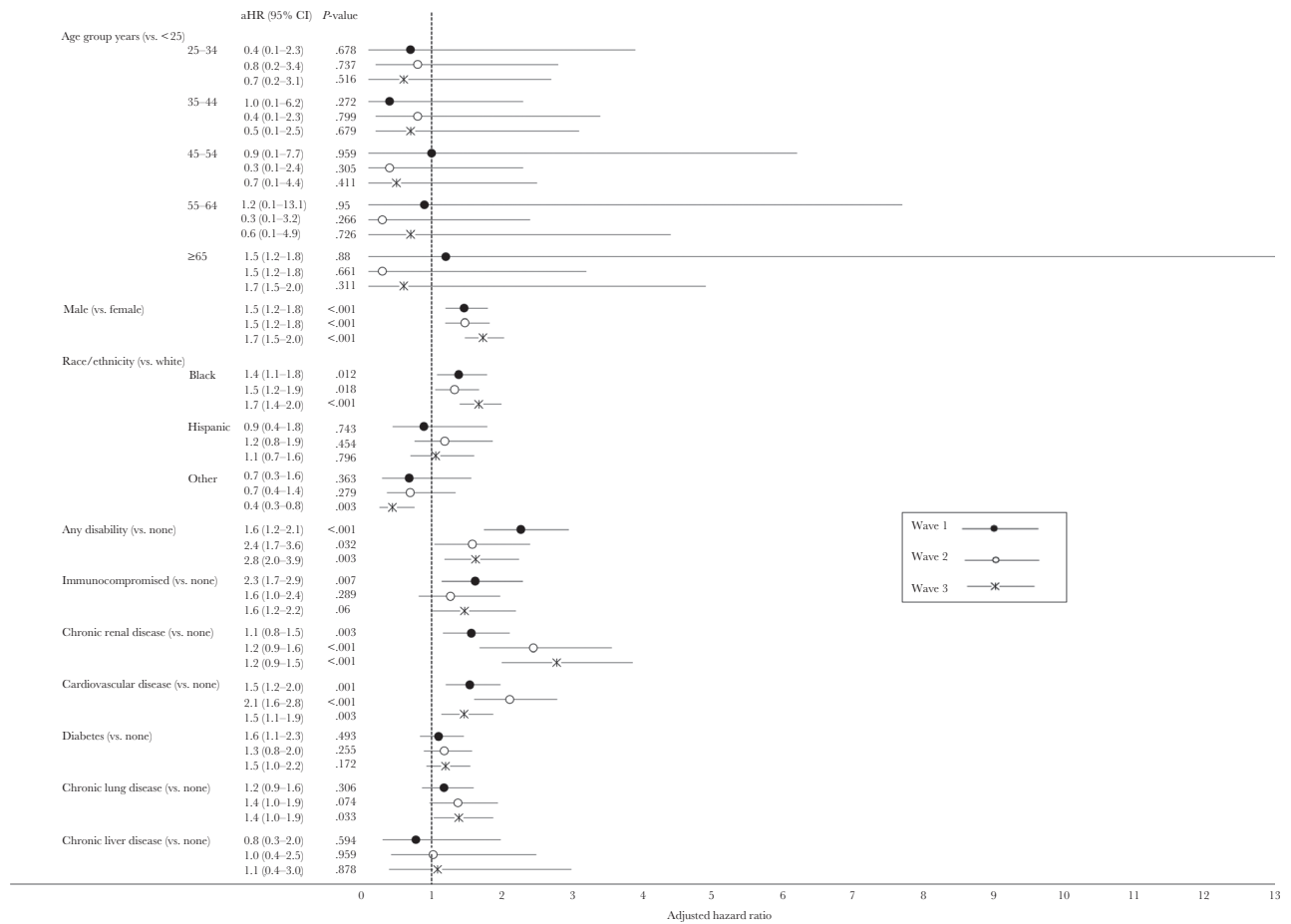


Figure 2. Factors associated with death, among coronavirus disease 2019 cases in Fulton County, Georgia (March 2020–February 2021).

2021 onwards) that has resulted in profound staffing shortages, hospitals operating under crisis conditions, and ongoing supply chain issues despite being a milder variant.

Our study is subject to limitations that are inherent to the use of routinely collected public health surveillance data. This includes gaps in reporting of confirmed cases by providers and testing sites, in addition to reporting lag time of up to several weeks for severe outcomes (hospitalization and deaths). To minimize this, we limited case inclusion to cases reported as of February 28, 2021, to allow for sufficient time for reporting and completing case investigations up to March 31, 2021. In addition, we could not utilize hospitalization data fully because, as the COVID-19 pandemic progressed, data on hospitalization became less consistently available in the state electronic disease notification surveillance database. In addition, gaps in implementation of testing may have led to an under ascertainment of the true number of cases particularly in the early outbreak period of the COVID-19 pandemic and in the period after change in testing policy. Specifically, the testing policy in the early phase was restricted to symptomatic persons and specific demographics. After the policy was changed to be more inclusive, there were variations in the implementation of testing of all cases. As with other analyses of COVID-19

disparities [27], our surveillance data were incomplete for age, gender, race, and ethnicity. However, compared with other studies, in each wave, we had ≤11% of cases missing race and ethnicity, and ≤1% missing age and gender, strengthening the robustness of our findings. We did not include vaccination status as a covariate in our analysis due to delayed linkage between the disease and vaccination surveillance systems. Nonetheless, widespread availability of COVID-19 vaccine in Fulton County did not occur until March 2020 (the end of our study period); thus, the improving trend we observed was unlikely to be due to the protective effect of vaccination.

CONCLUSIONS

In conclusion, as the COVID-19 pandemic progressed in Fulton County, Georgia, there were notable improvements in CFR and rate ratios in subsequent waves. Nonetheless, important gaps persisted among males and non-Hispanic black persons, despite adjusting for age and comorbid medical conditions. Our study is among the largest to examine trends over time in mortality and confirms the early findings of factors associated with mortality, which include gender and race/ethnic disparities, and the presence of any disability, chronic renal disease, and cardiovascular

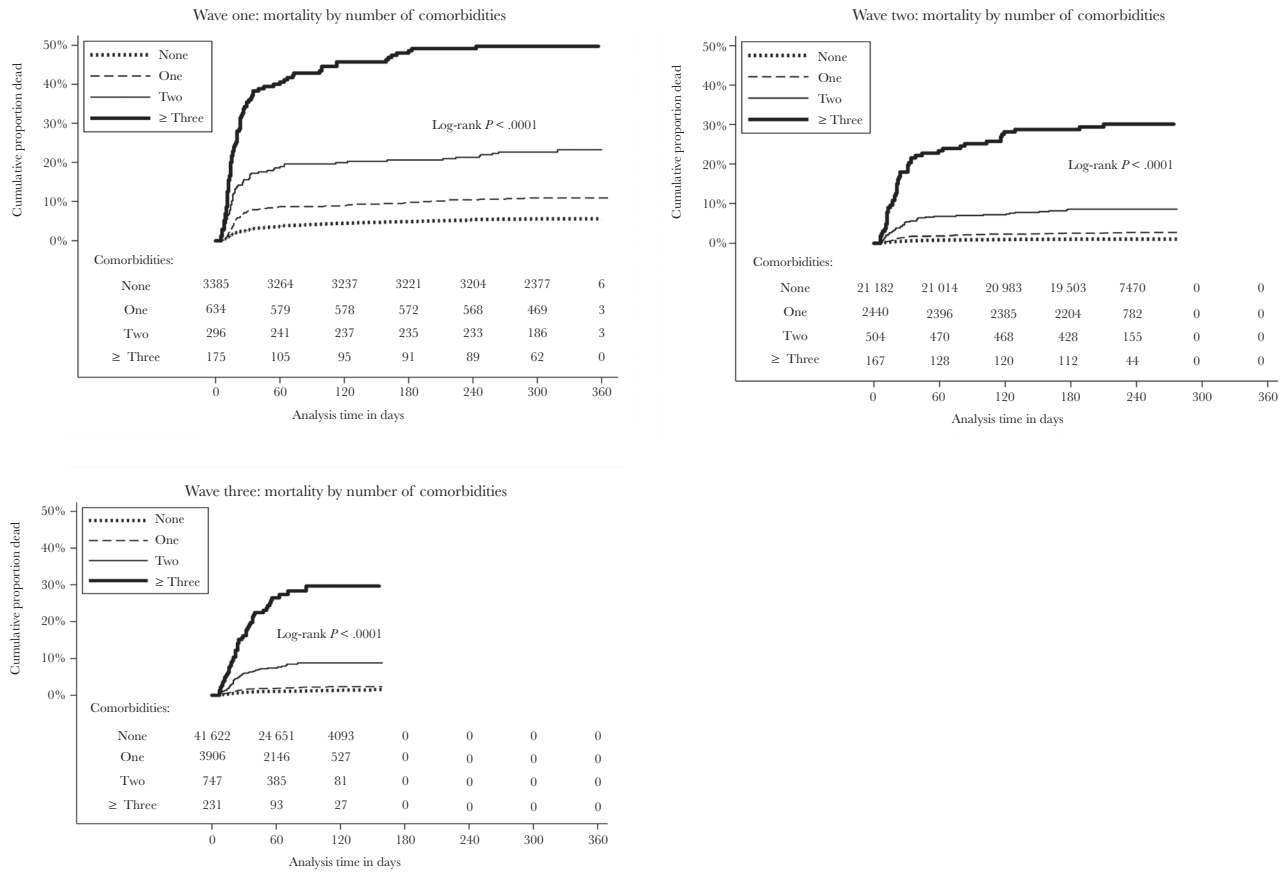


Figure 3. Mortality of coronavirus disease 2019 cases by number of comorbidities in each wave—Fulton County, Georgia, March 2020–February 2021. Kaplan-Meier curves were fit to examine survival functions by number of comorbidities in each wave, and the log-rank test was used to examine statistical difference among these groups.

disease that persisted across the 3 COVID-19 pandemic waves. As access to COVID-19 vaccines increase across the United States, similar gaps have been observed, raising concerns for further widening of disparities in morbidity and mortality for vulnerable groups. As the SARS-Cov-2 continues to evolve,

the time is now to redouble efforts by clinicians, public health providers, and policy makers to ensure timely prevention, diagnosis, treatment, increased vaccination, and outreach to turn the tide of this pandemic that has shown to surge in waves even among individuals that have been previously vaccinated.

Table 2. Outcomes Among Hospitalized COVID-19 Cases in Fulton County, Georgia (March 2020–February 2021)

	Wave 1	Wave 2	Wave 3	P Value ^a
Disposition and Time Variables	990 Hospitalized	1667 Hospitalized	1925 Hospitalized	
Discharge Disposition, n (Column%)				<.001
Died in hospital	247 (25)	196 (12)	314 (16)	
Discharged alive ^b	482 (49)	941 (56)	984 (51)	
Remained hospitalized/unknown as of February 28, 2021	261 (26)	530 (32)	627 (33)	
Admitted to intensive care unit	253 (26)	297 (18)	311 (16)	<.001
Median (IQR) time to death, days	12 (6–27)	16 (7–30)	13 (6–24)	.0614
Length of Hospital Stay, Median (IQR), Days				
Among those who died	12 (6–27)	16 (7–30)	13 (6–24)	.0614
Among those discharged alive	4 (3–8)	3 (1–6)	3 (2–6)	.0001
Among those still admitted as of end of each wave	49 (31–64)	66 (40–81)	70 (44–97)	.0001

Abbreviations: COVID-19, coronavirus disease 2019; IQR, interquartile range.

^aThe χ^2 test was used to calculate the *P* values for differences in proportions. The Wilcoxon rank-sum test was used to calculate the *P* values for differences in median times.

^bOf those that were discharged alive, the following died afterward: 45 in wave 1; 31 in wave 2; and 49 in wave 3.

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