Original article

Hospitalization, mechanical ventilation, and case-fatality outcomes in US veterans with COVID-19 disease between years 2020–2021

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A B S T R A C T

Purpose: Although veterans represent a significant proportion (7%) of the USA population, the COVID-19 disease impact within this group has been underreported. To bridge this gap, this study was undertaken.
Method: A total of 419,559 veterans, who tested positive for COVID-19 disease in the Veterans Affairs hospital system from March 1st, 2020 to December 31st, 2021 with 60-days follow-up, was included in this retrospective review. Primary outcome measures included age-adjusted incidences and relative incidences of COVID-19 hospitalization, mechanical ventilation, and case-fatality outcomes.
Results: Of this veteran cohort with COVID-19 disease, predominately 85.7% were male, 59.1% were White veterans, 27.5% were ages 50–64, and 40.5% were obese. Although Black veterans were at 63% higher relative risk (RR) for hospitalization incidences, they had a similar risk RR for in-hospital deaths compared to the White-veteran referent. Asian, American Indian/Alaska Native races, advanced age ≥65, and the underweight were at high RR for mechanical ventilator and/or in-hospital deaths compared to respective referent groups. Veterans who are ≥85 years old had a nearly 5-fold higher incidence of death compared respective referent group. The monthly outcomes for hospitalization, ventilation, and case-fatality data showed decreasing trends with time.
Conclusion: An increased incidence of death was associated with age ≥65 years and underweight veterans compared to the referent group. Age-adjusted data, however, did not show any increased incidence of death in Black veterans compared to White veterans.
Ratings of the quality of the evidence: 3 (Case-control studies; retrospective cohort study).

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Introduction

Earlier coronavirus disease 2019 (COVID-19) pandemic reports found the association of severe disease with advanced age, race, male sex, and preexisting comorbidities [1,2]. The United States (US) veterans, with many of the aforementioned risk factors, are a vulnerable population and also susceptible to service-related physical, mental, and social issues that places them at a higher risk of experiencing poorer outcomes during this pandemic [3–7]. Today, only a few studies reported the veterans' COVID-19 symptom severity outcomes [8–12].

The United States Department of Veterans Affairs (VA) patient population is unique, because they are eligible to receive healthcare services within the nationwide network of VA hospitals. As such, the socioeconomic disparity that affects healthcare access within this cohort is somewhat uniform. Due to the unique VA system separate from the general public, veterans have been largely excluded from the national epidemiological COVID-19 studies. The limited earlier studies assessing COVID-19 impact on veterans were restricted to short periods and regional VA facilities [8–15]. This study reports demographics and outcomes (hospitalization, mechanical ventilation (MV), and case-fatality) of COVID-19 infected

veterans in VA facilities for the years 2020 and 2021. Furthermore, we assessed monthly hospitalization, MV, and case-fatality rates for each age group to understand whether any improvement in clinical care might have occurred during the onset of this pandemic.

Methods

Data source & Databases

Using local (VA) Institutional Review Board approval (#00133238), the VA COVID-19 Shared Data Resource was accessed for collecting patient data for this retrospective study. For this study, the VA COVID-19 Shared Data Resources were used, which is a part of VA Informatics and Computing Infrastructure (VINCI). This shared data resource domain specifically tracks all COVID-19 infected veteran patients within the national VA hospital system with veteran's COVID positivity data traced from the National Surveillance Tool that gathers data from publicly available databases to track COVID-19 cases across the country in real-time. The VA COVID-19 Shared Data Resource domain also collects other pertinent veteran data from the VA Corporate Data Warehouse (CDW) to provide full patient-level data to VA investigators. This shared data is only accessible through the VINCI server. For this reported study, the VA COVID-19 Shared Data Resource was accessed on March 22nd, 2022.

Study Population

Veterans, who tested positive for COVID-19 disease and received care, both inpatient and outpatient, at the VA healthcare hospital system with an index date (ID) between March 1st, 2020 to December 31st, 2021, with 60-days follow-up (i.e., up to February 28th, 2022) outcomes were studied. The ID was defined as the date of the first positive COVID-19 test. If the patient was hospitalized 15 days prior to a positive COVID-19 test, then the hospitalization date serves as the ID. During an early pandemic, there were a number of hospitalizations without a laboratory-confirmed positivity for COVID-19. Post-hospitalization, the COVID-19 test was conducted. Thus, within the COVID-19 Shared Data Resources, the index date was defined as the date of the first positive SARS-CoV-2 test or the hospitalization admission date if veterans were receiving care within 15 days before the positive test date. Severity was defined as hospitalization, mechanical ventilator use, or death within 60-days of hospitalization/index date.

Statistical analysis

Modified Poisson regression models [16] were utilized to calculate the age-adjusted incidence for hospitalization, MV, and case fatality. Relative incidences (RRs) for hospitalization were calculated for the entire cohort. RRs for ventilation and case-fatality were calculated only for the hospitalized cohort. For each demographic, RR for each outcome compared to a referent group was presented with 2-sided 95% confidence intervals (CI).

Line graphs were used to visualize the change in hospitalization, ventilation, and case-fatality rates over time by age. 60-day outcome rates for each index month were calculated as the number of veterans with an ID within that month who experienced the outcome within 60-days of their ID divided by the total number of veterans with an ID in that month. The P values for linear trend over time for each demographic group were obtained by subsetting the data by demographic group and performing modified Poisson regression with hospitalization, ventilation, or case-fatality as the outcome variable and month as a continuous predictor variable. Two-sided significance for all tests was assessed at the $P <$

.05 level. All analyses were completed with R version 4.2.0. A detailed description of the analysis is given in the eMethods section.

Results

Patient Demographics

The demographic characteristics and symptom severity outcomes of 419,559 veterans who were tested positive for COVID-19 between March 1st, 2020 to December 31st, 2021, are given in Table 1. Of these veterans, 85.7% were male, 59.1% were White, 19.8% were Black, and 8.9% were Hispanic/Latino. The age distributions were 31.0% ≤49 years old, 27.5% 50–64 years old, and 41.4% ≥65 years old. The majority of the veterans who tested positive were obese (40.5%) or overweight (31.1%).

Hospitalization

A total of 58,728 (14%) veterans who tested positive for COVID-19 were hospitalized (Table 1). Of those, the majority were male (94.2%), White race (58.6%), 65–74 years old (35.1%), and obese (36.0 %). The age-adjusted hospitalization rates for the race category were highest among Black (17%) and Hispanic (13.7%) veterans. Overall, ≥85 years of age (29.1%) and normal weight (25.9%) veterans were highest amongst the age-adjusted hospitalization outcomes within their respective groups. The RRs for hospitalization, MV, and case-fatalities are given in Table 2. Compared to White veterans, Black veterans had a relatively 63% higher incidence of hospitalization (RR = 1.63, 95%CI 1.60–1.65), followed by 31% for Hispanics (RR = 1.31, 95%CI 1.28–1.35) and 30% for AIAN (RR = 1.30, 95%CI 1.20–1.42). Compared to the normal weight veterans, the underweight (RR = 1.70, 95%CI 1.64–1.77) showed increased relative incidences of hospitalization. Compared to the 50–64 age group referent, while younger veterans had a lower incidence ($P< .001$), older veterans had a higher incidence of hospitalization ($P< .001$). Interestingly, monthly hospitalization data trended down over the study period (-34%; Fig. 1) with statistical significance ($P < .001$) for all age groups.

Mechanical Ventilation

Of those who were hospitalized, 6,789 (11.6%) veterans were placed on MV within the VA facilities. The majority of them were male (96.1%), White race (57.1%), 65–74 years old (43.1%), and obese (39.9%). The age-adjusted MV rates for the race category were highest in NHPI (15.2%) and Asian (14.4%) veterans (Table 1). Within the age category, the MV rate appeared to increase with advancing age, except for ≥85 years of age veterans. Increased age-adjusted relative incidences for MV were seen in the AIAN veterans (RR = 1.36, 95%CI 1.10–1.69), followed by Asian (RR = 1.30, 95%CI 1.02–2.66) when compared to the White veteran referent. Hispanic/Latino and Black (RR = 1.20, CI 1.11–1.30 and RR = 1.07, 95%CI 1.01–1.12, respectively) veterans also showed statistically significant and increased incidences of MV. Compared to the normal weight cohort, those in a higher weight category had higher incidences of MV (overweight: RR = 1.26, 95%CI 1.18–1.35; obese: RR = 1.50, 95%CI 1.41–1.61; morbidly obese: RR = 1.86, 95%CI 1.70–2.04). Compared to the 50–64 age group referent, those who are younger had a lower incidence for MV, while those 65–74 years old showed a relative 28% higher incidence (RR = 1.28, 95%CI 1.21–1.36), followed by those 75–84 years old (RR = 1.12, 95%CI 1.05–1.20). Contrarily, those >84 years old had a lower incidence of MV (RR = 0.61, 95%CI 0.55–0.68) (Table 2). Monthly MV rates of the age groups 65–74 (-23.4%), 50–64 (-18.7%), 75–84 (-13.1%), 40–49 (-7.8%), and ≥85 (-10.2%) showed statistically significant reduction ($P< .001$) over consecutive months. The age groups 18–29,

Table 1
Baseline characteristics and 60-day outcomes of veterans who tested positive (+) for COVID-2019 in 2020 and 2021.

	COVID-19 positive VA cohorts Total n (%) (n = 419,559)	Hospitalization outcome (H) (n = 58,728)		Mechanical ventilation outcome (MV) of hospitalized cohort (n = 6789)		Fatality outcome (F) hospitalized cohort (n = 8642)	
		Total # (%)	Age-adjusted hospitalization rate % of n (95% CI)	Total # (%)	Age-adjusted Ventilation rate % (95% CI)	Total # (%)	Age-adjusted Fatality rate % (95% CI)
*Sex or Gender							
Female	59965 (14.3%)	3412 (5.8%)	8.14 (7.21,9.19)	267 (3.9%)	8.14 (7.21,9.19)	201 (2.3%)	8.06 (7.01,9.25)
Male	359591 (85.7%)	55316 (94.2%)	11.75 (11.46,12.04)	6522 (96.1%)	11.75 (11.46,12.04)	8441 (97.7%)	12.10 (11.78,12.42)
Race or Ethnicity							
White	247950 (59.1%)	34439 (58.6%)	10.44 (10.31,10.57)	3877 (57.1%)	11.11 (10.76,11.47)	5473 (63.3%)	11.85 (11.48,12.23)
Black or African American	83173 (19.8%)	15221 (25.9%)	16.97 (16.69,17.24)	1782 (26.2%)	11.84 (11.30,12.40)	1868 (21.6%)	11.39 (10.88,11.94)
Hispanic or Latino	37293 (8.9%)	4811 (8.2%)	13.72 (13.34,14.11)	627 (9.2%)	13.33 (12.33,14.42)	657 (7.6%)	12.94 (11.98,13.98)
Asian	3789 (0.9%)	411 (0.7%)	12.98 (11.78,14.29)	57 (0.8%)	14.42 (11.12,18.69)	47 (0.5%)	12.00 (9.01,15.97)
NHPI	3096 (0.7%)	474 (0.8%)	13.61 (12.44,14.90)	71 (1.0%)	15.15 (12,19.12)	77 (0.9%)	14.77 (11.81,18.48)
AIAN	3030 (0.7%)	407 (0.7%)	11.82 (10.73,13.03)	52 (0.8%)	12.97 (9.88,17.02)	61 (0.7%)	13.68 (10.64,17.59)
Unknown	41228 (9.8%)	2965 (5.0%)	7.76 (7.48,8.04)	323 (4.8%)	10.90 (9.77,12.16)	459 (5.3%)	12.45(11.35,13.66)
Age							
18 – 29	18904 (4.5%)	542 (0.9%)	2.87 (2.87,2.87)	20 (0.3%)	3.69 (3.67,3.71)	2 (0.0%)	0.37 (0.36,0.38)
30 – 39	56831 (13.5%)	2494 (4.2%)	4.39 (4.39,4.39)	142 (2.1%)	5.69 (5.68,5.70)	49 (0.6%)	1.96 (1.95,1.97)
40 – 49	54726 (13.0%)	3519 (6.0%)	6.43 (6.43,6.43)	306 (4.5%)	8.70 (8.69,8.71)	114 (1.3%)	3.24 (3.23,3.25)
50 – 64	115470 (27.5%)	14242 (24.3%)	12.33 (12.33,12.33)	1576 (23.2%)	11.07 (11.06,11.08)	1004 (11.6%)	7.05 (7.05,7.05)
65 – 74	104301 (24.9%)	20596 (35.1%)	19.75 (19.75,19.75)	2924 (43.1%)	14.20 (14.20,14.20)	3055 (35.4%)	14.83 (14.83,14.83)
75 – 84	49101 (11.7%)	11454 (19.5%)	23.33 (23.33,23.33)	1425 (21.0%)	12.44 (12.43,12.45)	2424 (28.0%)	21.16 (21.15,21.17)
≥ 85	20226 (4.8%)	5881 (10.0%)	29.08 (29.07,29.09)	396 (5.8%)	6.73 (6.72,6.74)	1994 (23.1%)	33.91 (33.90,33.92)
BMI (kg/m^2)							
Underweight (< 18.5)	3996 (1.0%)	1669 (2.8%)	15.20 (14.91,15.49)	146 (2.2%)	8.71 (8.22,9.22)	429 (5.0%)	12.22 (11.68,12.80)
Normal weight (18.5 – 24.9)	63210 (15.1%)	13201 (22.5%)	25.86 (24.62,27.16)	1213 (17.9%)	8.18 (6.95,9.63)	2530 (29.3%)	15.38 (13.94,16.97)
Overweight (25 – 29.9)	130447 (31.1%)	17824 (30.4%)	11.26 (11.08,11.43)	1992 (29.3%)	10.97 (10.50,11.47)	2552 (29.5%)	11.04 (10.58,11.52)
Obese (30 – 39.9)	169948 (40.5%)	21167 (36.0%)	11.50 (11.34,11.66)	2711 (39.9%)	13.10 (12.61,13.60)	2531 (29.3%)	11.62 (11.17,12.09)
Morbidly Obese (≥ 40)	32275 (7.7%)	4646 (7.9%)	14.55 (14.14,14.98)	710 (10.5%)	16.21 (15.05,17.46)	535 (6.2%)	13.92 (12.79,15.16)
Unknown	19683 (4.7%)	221 (0.4%)	1.56 (1.37,1.78)	17 (0.3%)	7.60 (4.73,12.23)	65 (0.8%)	19.56 (15.39,25.11)

Abbreviations: AIAN = American Indian or Alaska Native; BMI = body mass index; NHPI = Native Hawaiian or Other Pacific Islander.

Table 2
The age-adjusted relative risks of veteran patients hospitalized with COVID-2019 in 2020 and 2021.

	Hospitalizations outcome of total COVID-19 positive VA cohorts		Mechanical ventilation outcome of hospitalized cohort		Fatality outcome hospitalized cohort	
	Age-adjusted RR (95% CI)	P value	Age-adjusted RR (95% CI)	P value	Age-adjusted RR (95% CI)	P value
Sex or Gender						
Female	1		1		1	
Male	1.64 (1.59–1.7)	<.001	1.44 (1.28–1.63)	<.001	1.50 (1.31–1.72)	<.001
Race or Ethnicity						
White	1		1		1	
Black or African American	1.63 (1.60–1.65)	<.001	1.07 (1.01–1.12)	.03	0.96 (0.92–1.01)	.15
Hispanic or Latino	1.31 (1.28–1.35)	<.001	1.20 (1.11–1.30)	<.001	1.09 (1.02–1.17)	.03
Asian	1.24 (1.14–1.36)	<.001	1.30 (1.02–1.66)	.05	1.01 (0.79–1.31)	.93
NHPI	1.13 (1.04–1.24)	.01	1.17 (0.90–1.51)	.27	1.16 (0.93–1.44)	.26
AIAN	1.30 (1.20–1.42)	<.001	1.36(1.10–1.69)	.01	1.25 (1.02–1.53)	.05
Unknown	0.74 (0.72–0.77)	<.001	0.98 (0.88–1.09)	.75	1.05 (0.97–1.14)	.31
Age group						
18–29	0.23 (0.21–0.25)	<.001	0.33 (0.22–0.51)	<.001	0.05 (0.01–0.21)	<.001
30–39	0.36 (0.34–0.37)	<.001	0.51 (0.44–0.61)	<.001	0.28 (0.21–0.37)	<.001
40–49	0.52 (0.50–0.54)	<.001	0.79 (0.70–0.88)	<.001	0.46 (0.38–0.56)	<.001
50–64	1		1		1	
65–74	1.60 (1.57–1.63)	<.001	1.28 (1.21–1.36)	<.001	2.10 (1.97–2.25)	<.001
75–84	1.89 (1.85–1.93)	<.001	1.12 (1.05–1.20)	<.001	3.00 (2.80–3.22)	<.001
≥ 85	2.36 (2.30–2.42)	<.001	0.61 (0.55–0.68)	<.001	4.81 (4.49–5.16)	<.001
BMI (kg/m²)						
Underweight (< 18.5)	1.70 (1.64–1.77)	<.001	0.94 (0.80–1.11)	.48	1.26 (1.15–1.37)	<.001
Normal weight (18.5–24.9)	1		1		1	
Overweight (25–29.9)	0.74 (0.73–0.76)	<.001	1.26 (1.18–1.35)	<.001	0.90 (0.86–0.95)	<.001
Obese (30–39.9)	0.76 (0.74–0.77)	<.001	1.50 (1.41–1.61)	<.001	0.95 (0.90–1.00)	.09
Morbidly Obese (≥ 40)	0.96 (0.93–0.99)	.01	1.86 (1.70–2.04)	<.001	1.14 (1.04–1.24)	.01
Unknown	0.10 (0.09–0.12)	<.001	0.87 (0.55–1.38)	.58	1.61 (1.33–1.94)	<.001

Abbreviations: AIAN = American Indian or Alaska Native; BMI = body mass index; NHPI = Native Hawaiian or Other Pacific Islander.
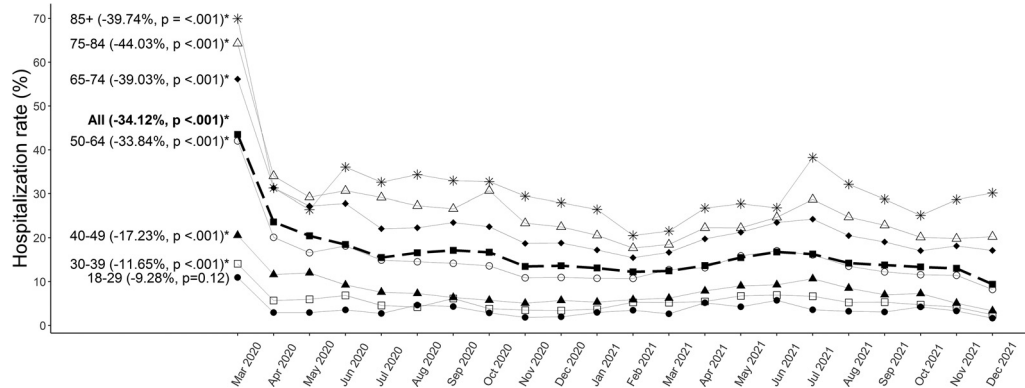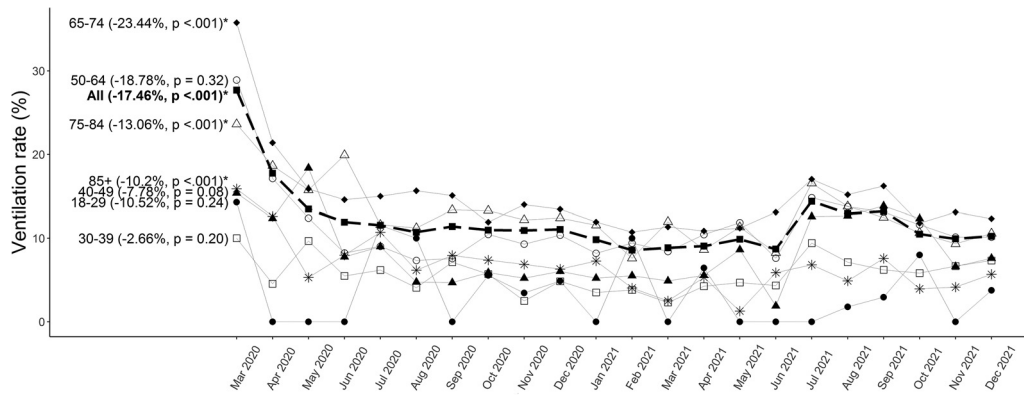

Fig. 1. Hospitalization rates by index month and age group. This graph illustrates the trend over time for veteran hospitalization rates by respective age group. The symbols for each age group are as follows: 18–29 – black circle, 30–39 – open square, 40–49 – black triangle, 50–64 – open circle, 65–74 - black diamond, 75 – 84 – open triangle, 85+ - star. For each age group, hospitalization rates are expressed as a percentage for each index month; rates were calculated by dividing the number of hospitalized veterans who had an index date in that month by the total number of veterans who had an index date in that month, then multiplying by 100. Linear trend tests for the time were performed for each age group by subsetting the data by age group and fitting a univariable modified Poisson regression with hospitalization as outcome and month as the predictor. Absolute percentage decrease in rate from March 2020 to December 2021 and P values for trend tests are shown in parentheses. Age groups showing a significant change in hospitalization over time at the P < .05 level are denoted with an asterisk. For all age groups, there were generally decreasing trends for hospitalization rates from March 2020 to December 2021, except for the 85+ group.

40–49, 75–84, and ≥85 had spikes of increased MV rates during the summer months (Fig. 2).

Case-Fatality

Of the veterans who were hospitalized, 8642 (14.7%) had died during this observation period. This group comprised predominantly male (97.7%), White veterans (63.3%), aged 65–74 (35.4%), normal weight, overweight as well as obese (∼29%) in their respective groups. The age-adjusted case-fatality rates were highest in NHPI (14.8%), AIAN (13.7%), and Asian (12.0%) veterans, ages ≥65 years, and the normal weight (15.4%) (Table 1).

The relative incidence of case-fatality was 25% higher in the AIAN race compared to White veterans (RR = 1.25, 95%CI 1.02–1.53). Compared to the 50–64 age referent, the relative incidence of death in veterans <50 years old was significantly reduced, while those >64 years of age were significantly increased (P< .001). Overall, ≥85 years old veterans showed a nearly 5-fold higher incidence of death compared to the 50–64 referent age group. Compared to the normal weight referent, the morbidly obese veterans only exhibited a relative 14% increase in the incidence of case-fatality (RR = 1.14, 95%CI 1.04–1.24) with a significant level (P= .01). Also, underweight veterans had a relative 26% higher incidence of case-fatality (RR = 1.26, 95%CI 1.15–1.37) (Table 2). Al-

Figure 2. Sixty-day ventilation rates for hospitalized veterans by index month and age group. This graph illustrates the trend over time for veteran ventilation rates by age group for the hospitalized cohort. The symbols for each age group are as follows: 18–29 – black circle, 30–39 – open square, 40–49 – black triangle, 50–64 – open circle, 65–74 - black diamond, 75 – 84 – open triangle, 85+ - star. For each age group, ventilation rates are expressed as a percent for each index month were calculated by dividing the number of hospitalized veterans who had an index date in that month by the total number of veterans who had an index date in that month, then multiplying by 100. Linear trend tests for the time were performed for each age group by subsetting the data by age group and fitting a univariable modified Poisson regression with hospitalization as outcome and month as the predictor. The absolute percentage decrease in rate from March 2020 to December 2021and P values for the trend tests are shown above in parentheses. Age groups showing a significant change in ventilation over time at the $P < .05$ level are denoted with an asterisk. The ventilation rates decreased from March 2020 to December 2021.
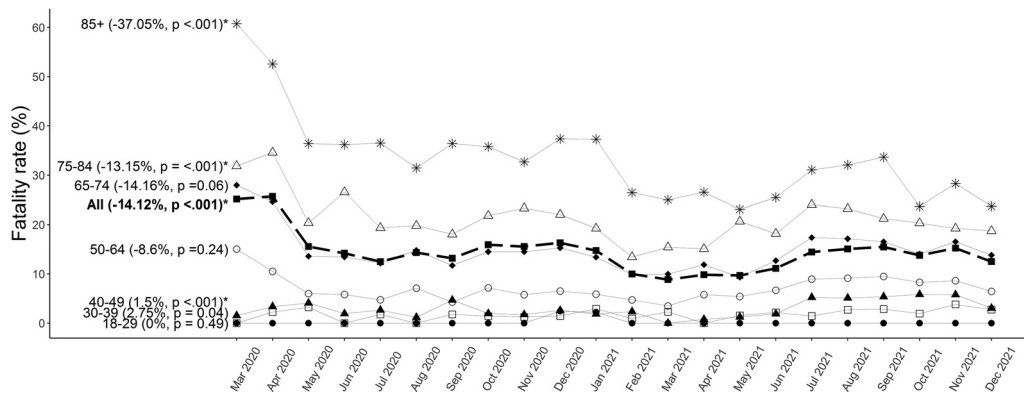
Figure 3. Sixty-day fatality rates for hospitalized veterans by index month and age group. This graph illustrates the trend over time for veteran fatality rates by age group for the hospitalized cohort. The symbols for each age group are as follows: 18–29 – black circle, 30–39 – open square, 40–49 – black triangle, 50–64 – open circle, 65–74 - black diamond, 75 – 84 – open triangle, 85+ - star. For each age group, fatality rates are expressed as a percentage for each index month were calculated by dividing the number of hospitalized veterans who had an index date in that month by the total number of veterans who had an index date in that month then multiplying by 100. Linear trend tests for the time were performed for each age group by subsetting the data by age group and fitting a univariable modified Poisson regression with hospitalization as outcome and month as the predictor. Absolute percentage decrease in rate from March 2020 to December 2021 and P values for trend tests are shown above in parentheses. Age groups showing a significant change in fatality over time at the $P < .05$ level are denoted with an asterisk. The overall case-fatality rate decreased from March 2020 to December 2021.

though monthly case-fatality rates for the age groups <40 remained constant, all other groups depicted exponentially decreasing trends, which appeared to plateau around July to August 2020 (Fig. 3).

Discussion

This study describes the demographic and severity outcomes for 419,559 COVID-19 positive veterans treated within the VA hospital system between March 1st, 2020, and December 31st, 2021. Among all COVID-19 positive veterans, the hospitalization rate was 14.0%. Within the hospitalized cohort of 58,728 veterans, 11.5% were MV, and 14.7% have succumbed to the disease. The MV data was comparable to national data, which showed 13.3% of the hospitalized placed on MV [17]. However, the case-fatality rate for hospitalized veterans (14.7%) was slightly higher than the national average of 11.5% [18]. This difference could be attributed to the makeup of the hospitalized veterans, which was a relatively older population than the national average.

During the onset of a pandemic, studies reported inequities in systemic health and socioeconomic factors that put racial and eth-

nic minority groups at increased risk of getting sicker and dying from COVID-19 [19–23]. Our findings showed higher hospitalization, but not death rates, in Black veterans and Hispanic/Latino than in White veterans. Some previous studies supported -similar findings [8–10,19,24]. High infection rates may be explained by the higher community spread of COVID-19 amongst these groups due to their living situations (densely populated communities, multigenerational homes, overrepresentation in jails/prisons/detention centers), work conditions (essential workers, lack of paid sick leave), health conditions (lack of health insurance, healthcare access or utilization, underlying comorbidities, limited health education, lower life expectancy), and transportation limitations (dependency on public transportation) [20,21,25–29]. However, it appears that adequate in-hospital care and management of illness provided within the VA hospital system may have played a role in reducing the case-fatality incidence within Black veterans, Hispanic/Latino, Asian, and NHPI groups. However, the AIAN group showed a significantly increased ($P = .05$) incidence of in-hospital death.

Although AIAN veterans only comprised 0.7% of those who tested positive and were hospitalized in our study, they have a relative 36% higher incidence of MV and a relative 25% higher

incidence of death than White veterans, supporting the current national CDC data [30,31]. Similarly, other studies reported, within the AIAN general population, the COVID-19 incidence (3.3x) [32] and mortality (1.8–2.2x) [26,33] rates were higher: especially in the younger population [26,32,34]. Interestingly, during the 2009 influenza A(H1A1), AIAN persons were reported to have suffered disproportional deaths when compared to White persons, [35,36] indicating possible social, lifestyle, healthcare, and financial disparities. Along with the aforementioned social inequalities, the AIAN groups are additionally more likely to live in rural or small-town areas, lack plumbing, and running water, and lack the infrastructure to receive quicker medical care [25–29,37]. Furthermore, compared to veterans of other races, AIAN veterans have higher unemployment rates, a geographical disadvantage in receiving VA healthcare services, comorbidities, and have more service-connected disabilities [38]. Regardless, it is important to acknowledge these disparities exist and identify those who are at risk early to prioritize resources and services, and to promote community awareness for limiting poor outcomes associated with this and future, highly contagious infectious disease. More importantly, there are still gaps that exist in public health data collection for the AIAN groups, [32] which could be overcome with a structured community awareness education in collaboration with respective tribal leaders.

It is now widely accepted that the risk of severe COVID-19 illness increases sharply with elevated BMI. However, the CDC data suggests a non-linear relationship between BMI and symptom severity [17]. Our age-adjusted data showed that while underweight and morbidly obese veterans have increased incidences of hospitalization, overweight and obese veterans have lower incidences, supporting the CDC data (Table 2). Perhaps, these differences may be related to the other confounding variables, such as comorbidities, which were not controlled in this study. Underweight veterans appeared to have a relative 70% higher incidence of hospitalization within our dataset and a relative 26% higher incidence of death than normal-weight referent. This finding was supported by an earlier veteran study [39]. In a New York study with similar findings, underweight patients had higher odds of death (OR = 1.44, 95%CI 1.08–1.92), but not with MV (OR = 0.85, 95%CI 0.57–1.27) [40]. The authors reasoned that the underweight groups might have deferred MV on the basis of goals of care discussion [40]. A Korean study also found higher mortality risks (crude hazard ratio = 2.56) in the underweight cohort [41]. A US study across 800 hospitals of COVID-19 outcomes in 2020 found higher hospitalization but not ICU admission, MV, or death risks in the underweight cohort [17]. It is reported that COVID-19 causes inflammation leading to cachexia after an acute illness, and malnourished patients, especially those lacking in protein, have impaired immune response and limited reserve for fending off infection [42]. Regardless of the reasons, underweight patients did not appear to tolerate the COVID-19 infection well, and they need to be closely monitored.

Obesity is reported to be a risk factor for symptom severity with COVID-19 infections [43–48]. Our finding supports these national data for MV. Consistent with previous studies, the incidence of MV increased with increasing BMI, with morbidly obese veterans having a 2-fold increased incidence of MV than the referent group [17]. Importantly, morbidly obese patients had decreased incidences of hospitalization (P = .01), but, increased incidences of ventilator use ($P <$ .001), and hospital fatality (P = .01). In summary, the risk of MV appeared to increase as BMI increases over 25 kg/m^2, which demonstrated an increase in disease severity with weight, with the morbidly obese experiencing the worst outcomes MV. Contrary to published data, lower incidences were seen in case-fatality for overweight and obese veterans, potentially indicat-

ing the role and importance of healthcare access in limiting case-fatalities.

As expected, an advancing age increases the relative incidences of hospitalization, MV, and death. In our study, those who were ≥85 years old had over a 5-fold increase in the incidence of death, which supported the national trend. The CDC has reported 8 out of 10 US COVID-19 deaths have been in adults ages ≥65 [49], which is lower than the reported death in veterans, where 86.5% of the cases were within this age group. These numbers could be related to the average age of the VA cohort. A United Kingdom study found those ≥75 years old had 13-times a mortality risk compared to those <65 years old, and those ≥75 years old without additional risk factors had four times the risk of mortality compared to those <65 years old [50]. Although advanced age was an independent risk factor for COVID-19 mortality [50], the elderly are more likely to have underlying medical conditions, decreased immune functions, and live in nursing home communities where the virus can quickly spread [51]. Furthermore, they are more likely to present with atypical symptoms, such as falls, reduced mobility, generalized weakness, or delirium, that delay diagnosis and care [52].

In our study, the relative incidence of MV decreased as age increased, ≥65 years old, but not for veterans who are ≥85 years. This may be attributed to advanced directives since the mortality of patients in their 80s or 90s placed on ventilators has been very high, even in the best of circumstances [53]. A US epidemiological study found 50% of those aged ≥85 who were ventilated died in the hospital [53]. Thus, they may not have received MV unless they were severely ill, which is reflected in the number of cases (n = 396 [5.8%]).

Monthly rates of hospitalization (-34.1%; $P <$ .001), MV (-17.4%; $P <$ .001), and death (-14.1%; $P <$ .001) improved as 2021 progressed (Figs. 1–3). At first, it would seem that MV and death were decreasing simply because hospitalization was decreasing, where hospitalization was more related to the severity of illness and spread of disease than to medical care. However, when looking at MV and death, the cohort being followed was only hospitalized patients, where the outcomes are affected by medical care rather than outside influences such as a downward trend in infections within the community. Perhaps during the initial months, the more susceptible veterans contracted and succumbed to the disease faster, but as the disease spread through the less susceptible population, the trends plateaued. Another possible explanation is the improved management of disease through a better understanding of COVID-19 by the providers and the later availability of treatment modalities at the VA hospital system's disposal. It is worth noting that MV rates spiked for the age groups 40–49 during May and 75–84 during June, which echoed the increased incidence of cases during that period [54]. Furthermore, the spike coincided with the availability of more ventilators as part of the VA's COVID-19 response plan. The central Veterans Hospital Administration provided more ventilators, medical equipment and supplies, pharmaceuticals, and acquisition and logistical support to the local VA hospital through VA National Acquisition Center [55]. Moreover, in a study assessing ICU capacity during 2020 in VA hospitals, the April and May months exceeded capacity and experienced strain in ICU care that resulted in a nearly 2-fold increase in the relative incidence of mortality compared to low demand months [13], supporting our overall data. Spikes were seen in the 18–29 group, but the changes over time were insignificant ($P=$ .49). This may be attributed to the overall small number (n = 20 [0.3%]) of veterans ventilated in this age group. Also, there was an overall spike in hospitalization and MV use between April 2021 to June 2021, perhaps attributable to a more virulent delta variant.

Limitations

There are several limitations to the study. This is a retrospective study that utilized data from the VA hospital system, which is not generalizable since veterans are relatively older than the general population. Hospitalization, MV, and death of veterans data were taken only from the hospitalized within the nationwide VA hospital system. Therefore, those treated outside the VA hospital system were excluded from this study. Finally, besides age, the risks were not adjusted for other confounding variables such as race, socioeconomic factors, comorbidities, and medications.

Conclusion

The variables associated with COVID-19 disease severity in veterans are race, advanced age, obesity for MV, and underweight and advanced age for in-hospital death. The overall management and outcomes for COVID-19 patients within the VA hospital system improved and reached a plateau by the summer of 2020, with a baseline shift during the delta variant dominance.

Declaration of Competing Interest

Acknowledgments

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.annepidem.2022.04. 003.

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