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Heterogeneity in COVID-19 patient volume, characteristics and outcomes across US Department of Veterans Affairs facilities: an observational cohort study

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ABSTRACT

Objective Studies describe COVID-19 patient characteristics and outcomes across populations, but reports of variation across healthcare facilities are lacking. The objectives were to examine differences in COVID-19 patient volume and mortality across facilities, and understand whether facility variation in mortality was due primarily to differences in patient versus facility characteristics.

Design Observational cohort study with multilevel mixed effects logistic regression modelling.

Setting The Veterans Health Administration (VA) is the largest healthcare system in the USA.

Participants Patients with COVID-19.

Main outcome All-cause mortality within 45 days after COVID-19 testing (March–May, follow-up through 16 July 2020).

Results Among 13 510 patients with COVID-19, 3942 (29.2%) were admitted (2266/3942 (57.5%) ward; 1676/3942 (42.5%) intensive care unit (ICU)) and 679/3942 (17.2%) received mechanical ventilation. Marked heterogeneity was observed across facilities in median age (range: 34.3–83.9 years; facility mean: 64.7, SD 7.2 years); patient volume (range: 1–737 at 160 facilities; facility median: 48.5, IQR 14–105.5); hospital admissions (range: 1–286 at 133 facilities; facility median: 11, IQR 1–26.5); ICU caseload (range: 1–85 at 115 facilities; facility median: 4, IQR 0–12); and mechanical ventilation (range: 1–53 at 90 facilities; facility median: 1, IQR 0–5). Heterogeneity was also observed in facility mortality for all patients with COVID-19 (range: 0%–29.7%; facility median: 8.9%, IQR 2.4%–13.7%); inpatients (range: 0%–100%; facility median: 18.0%, IQR 5.6%–28.6%); ICU patients (range: 0%–100%; facility median: 28.6%, IQR 14.3%–50.0%); and mechanical ventilator patients (range: 0%–100%; facility median: 52.7%, IQR 33.3%–80.6%). The majority of variation in facility mortality was attributable to differences in patient characteristics (eg, age).

Conclusions Marked heterogeneity in COVID-19 patient volume, characteristics and mortality were observed

Strengths and limitations of this study

► Observational cohort study from the largest healthcare system in the USA.
► Focus on the facility level.
► Evaluated care of COVID-19 positive Veteran patients at US Department of Veterans Affairs (VA) facilities; findings should not be generalised to patients cared for in non-VA facilities.
► Described the proportion of patients who were treated in an intensive care unit or received mechanical ventilation, we cannot comment on the appropriateness of such care.

across VA facilities nationwide. Differences in patient characteristics accounted for the majority of explained variation in mortality across sites. Variation in unadjusted COVID-19 mortality across facilities or nations should be considered with caution.

BACKGROUND

Although studies have described the clinical characteristics of patients with COVID-19, outcome rates, and predictors of adverse outcomes across diverse populations in various countries, these reports have generally focused only on the population level—not the facility level.[1–4] Reports have described variation in outcomes of patients with COVID-19 across geographic regions and over time, generally reporting higher mortality early in the pandemic.[5] Studies have also examined the association between patient characteristics and outcomes, for example, consistently identifying an association between older age and increased mortality for patients with COVID-19.[6] Although a few studies have examined facility characteristics that are associated with

COVID-19 outbreaks within nursing homes,[7 8] evaluations of the relative contribution of facility-level characteristics and patient characteristics to patient outcomes have been lacking.

The US Veterans Health Administration (VA) is the largest integrated healthcare system in the USA, providing care for approximately 6.1 million Veteran patients within 170 diverse medical centres.[9 10] VA medical centres are dispersed across the USA and vary in terms of size and services provided. Given that the burden of COVID-19 disease has varied across US communities, we sought to describe the variety in experiences of the 160 VA medical centres that have provided care for patients with COVID-19. We had two objectives: (1) to describe observed variation between facilities in terms of overall COVID-19 patient volume, hospital admissions, intensive care unit (ICU) admissions and mechanical ventilation; and (2) to examine the degree to which variance in mortality could be explained by patient-level versus facility-level characteristics by constructing models estimating mortality among patients with COVID-19 based on patient characteristics, care setting (eg, outpatient, inpatient admission and ICU) and facility characteristics.

METHODS
Cohort construction
This observational cohort included all Veteran patients (outpatients and inpatients) with a positive COVID-19 test date during the period 1 March 2020–31 May 2020 and followed them for 45 days after the positive test (follow-up period through 16 July 2020). We included Veterans tested in a VA laboratory with COVID-19 positive tests (PCR or antigen testing) and Veterans tested outside of the VA using data from the VA National Surveillance Tool (VA-NST). The VA-NST is a registry that extracts COVID-19 cases in near real time using a combination of laboratory results and natural language processing (NLP) on clinical notes and other documents in the medical record.

In addition, we excluded: patients with a positive antibody test prior to a positive PCR test and non-Veteran patients tested or receiving care at a VA facility (ie, humanitarian cases). We assigned patients to the facility where they obtained their COVID-19 positive test for the description of overall caseload and to the facility where they were admitted for the analyses that included care setting (note: VA facilities span the spectrum from providing primarily outpatient or domiciliary care whereas others provide tertiary care including critical care).

Data sources
Electronic health record data
Corporate Data Warehouse (CDW) data include information from the Veterans Information Systems and Technology Architecture (VistA). VistA is the electronic medical record system used across the VA system.[11] CDW data included: inpatient and outpatient data files (eg,

clinical encounters with diagnostic and procedure codes) in the 2 years prior to the COVID-19 positive test date to identify past medical history,[12] healthcare utilisation and procedures; vital signs; laboratory data; orders; and medications. The date of death was obtained from multiple sources, including: CDW data; the VA Vital Status File, which uses VA and non-VA sources to identify dates of death for VA beneficiaries; inpatient records that indicated a death disposition; note titles; and chart review.[13] Facility complexity data were obtained from the VA Office of Productivity, Efficiency and Staffing: facilities are classified into five levels (1a, 1b, 1c, 2 or 3) where level 1a is the most complex and level 3 is the least complex.[14] Complexity level is based on multiple domains including ICU level, operative complexity, teaching status, research, clinical programme offerings (eg, interventional cardiac catheterisation, transplant, interventional radiology and polytrauma), multicampus status, rurality, community care and mental health services. ICU level is scored from 1 (no ICU) to 5 (a level 1 ICU).

Hospital admission
VA hospital admission status was identified either after the COVID-19 test date or prior to the COVID-19 test, if the patient was already hospitalised at the time of the testing.

Outcome: 45-day mortality
Zero-time was the date of the positive COVID-19 test. The primary outcome was all-cause mortality within 45 days of the positive COVID-19 test. We chose the 45-day time frame because our chart review indicated that some patients who died from COVID-19 disease would have been omitted by using a 30-day time horizon.

Chart review validation of electronic health record data
We conducted chart reviews on samples of patients with COVID-19 to validate the electronic health record data. The chart reviews were conducted iteratively. For example, we validated the COVID-19 positive laboratory test status for 31 patients to ensure that our approach to identifying patients with COVID-19 excluded patients who had non-COVID-19 coronavirus laboratory testing (eg, human coronavirus types 229E, NL63, OC43 and HKU1).

Chart reviews were also conducted to confirm positive test status for non-VA laboratory tests that were included in the VA-NST data. We conducted chart reviews on a sample of 217 charts of patients included in the VA-NST who were not included in VA laboratory data. Chart reviews confirmed that the positive test result in the VA-NST was accurate (ie, a true COVID-19 case). However, the date of positive test was not consistently accurate (because the VA-NST uses NLP and other approaches to identify case status, the first note in the VA medical record about COVID-19 may actually reference testing that was conducted in the non-VA setting days or weeks prior to the date recorded in the VA-NST).

To ensure that we had complete mortality data, we developed an algorithm validated through chart review. To validate inpatient mortality, we conducted chart reviews on all patients admitted at two large VA hospitals in diverse geographic regions and confirmed that the death information from the various CDW files included mortality status for all inpatients who had died during their hospital stay. To validate mortality in the postdischarge period, we conducted chart review on all patients who were discharged alive from a VA facility but who had neither new laboratory tests nor were not readmitted (both indicators that the patient was alive). To validate mortality in the outpatient setting, we examined 200 charts and 55 facilities searching for mortality status evidence. The mortality algorithm we developed identified 103 of the 111 (92.8%) deaths, which were identified by chart review.

Statistical analysis

Our analyses were conducted over two main phases. First, we examined unadjusted, observed heterogeneity in patient volume (ie, the number of patients with COVID-19) across VA facilities. Specifically, we evaluated total COVID-19 patient volume, number of patients admitted to the hospital, ICU patient volume and number of patients who were mechanically ventilated. Similarly, we examined unadjusted, observed heterogeneity in 45-day mortality across VA facilities.

Second, we sought to examine differences in mortality across facilities after risk adjustment. We began by examining patient-level differences in baseline characteristics among patients with COVID-19 who were admitted versus not admitted to the hospital, and among patients who died versus those who survived 45 days from the COVID-19 positive test date. χ^2 tests and Wilcoxon rank-sum tests were used to compare differences in categorical variables. We calculated the Spearman correlation coefficient for the association between baseline characteristics (eg, age) and mortality. Next, we used mixed effects logistic regression modelling to estimate 45-day patient-level mortality across VA facilities with a random effect for facility. We tested four models. Model 1 adjusted only for baseline patient characteristics (eg, age). Model 2 included patient and facility characteristics (to examine relative contribution of the facility characteristics). Model 3 added where the setting where the patient received care (eg, inpatient ward vs ICU) to model 1. Model 4 added facility characteristics to model 3. Finally, we examined the variance in facility mortality across models to explore the degree to which differences in mortality across facilities was associated with patient-level versus facility-level characteristics.

We conducted sensitivity analyses by restricting the cohort only to Veteran patients with a positive COVID-19 test at a VA laboratory (excluding patients who were only identified in the VA-NST because of our inability to confirm the dates of the COVID-19 tests) and also excluded patients residing in VA Community Living Centers (CLC) at the time of the COVID-19 positive test (because some COVID-19 CLC patients were transferred to a different VA for admission, and other patients were retained within the same facility but moved from the CLC unit to the acute care part of the hospital). We also used proportional hazard modelling mortality across the same 45-day time frame as in the main analysis as a confirmatory analysis. All analyses were performed using SAS Enterprise Guide V.7.11.

Data availability

These data must remain on VA servers. No data are available. In the interest of data transparency, investigators interested in working with the data are encouraged to contact the corresponding author.

Ethics approval

A waiver of informed consent and Health Insurance Portability and Accountability Act (HIPAA) authorisation were granted for the collection of medical record data.

Patient and public involvement

No patients or members of the public were involved in the design or conduct of this study. Results will be distributed to VA leadership at the national and regional levels.
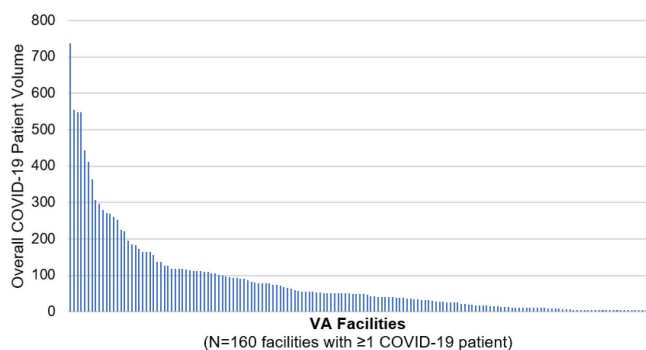
RESULTS

Among 13 510 COVID-19 positive Veterans: 3942 (29.2%) were admitted to a VA hospital, either to an inpatient ward (2266/3942 (57.5%)) or to ICU (1676/3942 (42.5%)); and 679/3942 (17.2%) received mechanical ventilation. A total of 493/13 510 (3.6%) patients were hospitalised at the time of their COVID-19 testing. The median time from COVID-19 test to admission (among patients for whom the test was performed before or on the day of admission) was 0 days (IQR 0–1). A total of 276/13 510 (2.0%) patients (at 30 VA facilities) obtained their COVID-19 positive test at one VA facility but were admitted to a different hospital.
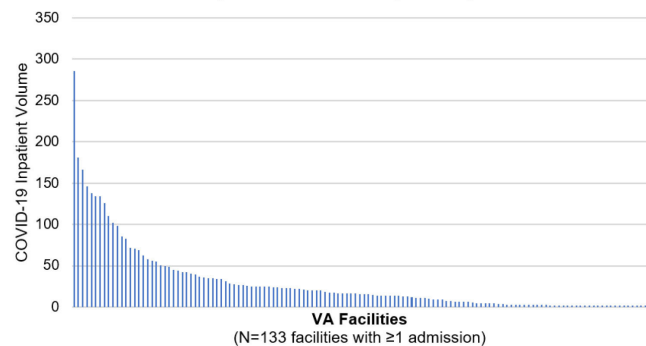
Heterogeneity in caseload across VA facilities

Substantial heterogeneity in COVID-19 caseload was observed (figure 1). COVID-19 patient volume ranged from 1 to 737 across 160 VA facilities (facility median: 48.5, IQR 14–105.5). Hospital admissions ranged from 1 to 286 (facility median: 11, IQR 1–26.5) with at least one patient being admitted at 133 facilities. ICU caseload ranged from 0 to 85 across facilities (facility median: 4, IQR 0–12) with at least one patient being admitted to the ICU at 115 facilities. Among the 133 facilities with at least one COVID-19 hospital admission, the proportion of patients within a facility who were cared for in the ICU ranged from 0% to 77.8%. The number of patients requiring mechanical ventilation ranged from 0 to 53 across facilities (facility median: 1, IQR 0–5) with patients receiving mechanical ventilation at 90 facilities. Among the 115 facilities with at least one COVID-19 ICU admission, the proportion of patients within a facility who received mechanical ventilation ranged from 0% to 55.6%.
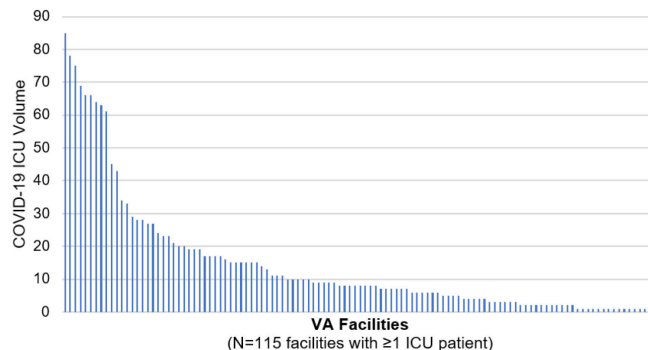
Panel A. Total COVID-19 Patient Volume by Facility

Panel C. COVID-19 Intensive Care Unit Patients by Facility

Panel B. COVID-19 Hospital Admissions by Facility

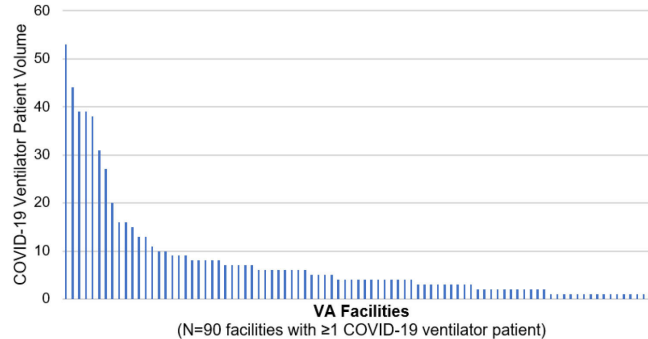Panel D. COVID-19 Mechanical Ventilator Patients by Facility

Figure 1 The figure displays the total number of COVID-19 Veteran patients across US Veterans Health Administration facilities (panel A; n=160 facilities had at least one COVID-19 positive patient), the number of hospital admissions (panel B; n=133 facilities had at least one COVID-19 hospital admission), the number of patients cared for in an intensive care unit (ICU) per facility (panel C; n=115 facilities had at least one ICU admission); and the number of patients with mechanical ventilation (panel D; n=90 facilities had at least one patient on a mechanical ventilator).

Heterogeneity in case-mix across VA facilities

Heterogeneity across facilities in factors that have been associated with poor COVID-19 outcomes was also observed (online supplemental figure A). For example, the median age of patients with COVID-19 by facility varied from 34.3 to 83.9 years (mean across facilities: 64.7±SD, 7.2 years). The facility median age was <50 years at 5/160 (3.1%) facilities, ≥50 but <60 years at 24/160 (15.0%) facilities, ≥60 but <70 years at 94/160 (58.8%) facilities and ≥70 years for 37/160 (23.1%) facilities. In unadjusted analyses, older patients were more likely to be admitted than younger patients (table 1). For example, only 14.7% (520/3549) of patients with COVID-19 who were <55 years old were admitted to the hospital, but 35.4% (504/1422) of patients ≥85 years old were admitted (p<0.001). In unadjusted analyses, older patients were also more like to die than younger patients (table 1): 1.0% (34/3549) of patients with COVID-19 <55 years old died within 45 days of the COVID-19 positive laboratory test compared with 33.8% (481/1422) mortality among patients ≥85 years old (p<0.001; online supplemental figure B). Several patient characteristics were more common among patients with COVID-19 who were admitted to the hospital including: black race; male gender; history of hypertension, diabetes, chronic obstructive pulmonary disease (COPD), chronic kidney disease (CKD), congestive heart failure (CHF), atrial fibrillation, cancer and myocardial infarction (MI);

current smoking; low body mass index ($<25\,\text{kg/m}^2$); and residence in a long-term care facility (table 1).

Heterogeneity in observed mortality across VA facilities

The unadjusted, observed facility 45-day all-cause mortality rate for all patients with COVID-19 ranged from 0% to 29.7% (facility median: 8.9%, IQR 2.4%–13.7%). Among facilities with at least 10 patients with COVID-19, the mean facility mortality rate was 10.1% (SD of 6.3%). The facility mortality rate for patients with COVID-19 who were admitted to the hospital ranged from 0% to 100% (facility median: 18.0%, IQR 5.6%–28.6%). Among facilities with at least 10 patients with COVID-19 who were admitted to the hospital, the mean facility mortality rate among admitted patients was 20.7% (SD of 10.7%). In contrast, the facility mortality for patients with COVID-19 who were not admitted ranged from 0% to 32.1% (facility median: 3.6%, IQR 0%–8.3%). The facility mortality for COVID-19 ICU patients ranged from 0% to 100% (facility median: 28.6%, IQR 14.3%–50.0%). Among facilities with at least 10 patients with COVID-19 in the ICU, the mean facility mortality rate for ICU patients was 32.7% (SD of 14.3%). The facility mortality for patients with COVID-19 requiring mechanical ventilation ranged from 0% to 100% (facility median: 52.7%, IQR 33.3%–80.6%). Figure 2 displays the unadjusted mortality rates with patient volume for each facility. In general, facilities

Table 1 Patient characteristics among COVID-19 positive Veteran patients

Baseline characteristics	Overall (n=13510) Column N (%)	Not admitted (n=9568) Row N (%)	Admitted (n=3942) Row N (%)	P value	Alive (n=12043) Row N (%)	Died within 45 days (n=1467) Row N (%)	P value
Age (years)				<0.001			<0.001
<55	3549 (26.3)	3029 (85.4)	520 (14.6)		3515 (99.0)	34 (1.0)	
55–64	2872 (21.3)	2076 (72.3)	796 (27.7)		2750 (95.8)	122 (4.2)	
65–74	3814 (28.2)	2414 (63.3)	1400 (36.7)		3338 (87.5)	476 (12.5)	
75–84	1853 (13.7)	1131 (61.0)	722 (39.0)		1499 (80.9)	354 (19.1)	
≥85	1422 (10.5)	918 (64.6)	504 (35.4)		941 (66.2)	481 (33.8)	
Race				<0.001			<0.001
White	6906 (51.1)	5128 (74.3)	1778 (25.7)		6065 (87.8)	841 (12.2)	
Black	5571 (41.2)	3633 (65.2)	1938 (34.8)		5034 (90.4)	537 (9.6)	
Unknown	700 (5.2)	544 (77.7)	156 (22.3)		644 (92.0)	56 (8.0)	
Asian	130 (1.0)	102 (78.5)	28 (21.5)		119 (91.5)	11 (8.5)	
American Indian or Alaskan Native	104 (0.8)	80 (76.9)	24 (23.1)		91 (87.5)	13 (12.5)	
Native Hawaiian or other Pacific Islander	99 (0.7)	81 (81.8)	18 (18.2)		90 (90.9)	9 (9.1)	
Ethnicity				0.089			<0.001
Not Hispanic	12262 (90.8)	8658 (70.6)	3604 (29.4)		10889 (88.8)	1373 (11.2)	
Hispanic	1248 (9.2)	910 (72.9)	338 (27.1)		1154 (92.5)	94 (7.5)	
Gender				<0.001			<0.001
Female	1239 (9.2)	1046 (84.4)	193 (15.6)		1205 (97.3)	34 (2.7)	
Male	12270 (90.8)	8529 (69.4)	3749 (30.6)		10837 (88.3)	1433 (11.7)	
Medical history							
Hypertension				<0.001			<0.001
No	4815 (35.6)	3955 (82.1)	860 (17.9)		4486 (93.2)	329 (6.8)	
Yes	8695 (64.4)	5613 (64.6)	3082 (35.4)		7557 (86.9)	1138 (13.1)	
Diabetes				<0.001			<0.001
No	8334 (61.7)	6362 (76.3)	1972 (23.7)		7590 (91.1)	744 (8.9)	
Yes	5176 (38.3)	3206 (61.9)	1970 (38.1)		4453 (86.0)	723 (14.0)	
Chronic obstructive pulmonary disease				<0.001			<0.001
No	10322 (76.4)	7589 (73.5)	2733 (26.5)		9301 (90.1)	1021 (9.9)	
Yes	3188 (23.6)	1979 (62.1)	1209 (37.9)		2742 (86.0)	446 (14.0)	
Chronic kidney disease				<0.001			<0.001
No	11047 (81.8)	8289 (75.0)	2758 (25.0)		10081 (91.3)	966 (8.7)	
Yes	2463 (18.2)	1279 (51.9)	1184 (48.1)		1962 (79.7)	501 (20.3)	
Congestive heart failure				<0.001			<0.001
No	11518 (85.3)	8516 (73.9)	3002 (26.1)		10458 (90.8)	1060 (9.2)	
Yes	1992 (14.7)	1052 (52.8)	940 (47.2)		1585 (79.6)	407 (20.4)	
Atrial fibrillation				<0.001			<0.001
No	11877 (87.9)	8651 (72.8)	3226 (27.2)		10739 (90.4)	1138 (9.6)	
Yes	1633 (12.1)	917 (56.2)	716 (43.8)		1304 (79.8)	329 (20.2)	
Cancer				<0.001			<0.001
No	12484 (92.4)	8996 (72.1)	3488 (27.9)		11194 (89.7)	1290 (10.3)	
Yes	1026 (7.6)	572 (55.8)	454 (44.2)		849 (82.8)	177 (17.2)	
Myocardial infarction				<0.001			<0.001

Continued

Table 1 Continued

| Baseline characteristics	Overall (n=13510) Column N (%)	Not admitted (n=9568) Row N (%)	Admitted (n=3942) Row N (%)	P value	Alive (n=12043) Row N (%)	Died within 45 days (n=1467) Row N (%)	P value
No	12 701 (94.0)	9171 (72.2)	3530 (27.8)		11 403 (89.8)	1298 (10.2)	
Yes	809 (6.0)	397 (49.1)	412 (50.9)		640 (79.1)	169 (20.9)	
Current smoker				<0.001			<0.001
No	11 231 (83.1)	8070 (71.8)	3161 (28.2)		9931 (88.4)	1300 (11.6)	
Yes	2279 (16.9)	1498 (65.7)	781 (34.3)		2112 (92.7)	167 (7.3)	
Body mass index (kg/m²)				<0.001			<0.001
<25	2645 (19.6)	1564 (59.1)	1081 (40.9)		2187 (82.7)	458 (17.3)	
25–29	4036 (29.9)	2871 (71.1)	1165 (28.9)		3623 (89.8)	413 (10.2)	
30–34	3339 (24.7)	2458 (73.6)	881 (26.4)		3086 (92.4)	253 (7.6)	
≥35	2601 (19.2)	1864 (71.7)	737 (28.3)		2384 (91.7)	217 (8.3)	
Missing	889 (6.6)	811 (91.2)	78 (8.8)		763 (85.8)	126 (14.2)	
Long-term care facility (prior 30 days)				<0.001			<0.001
No	12 865 (95.2)	9194 (71.5)	3671 (28.5)		11 550 (89.8)	1315 (10.2)	
Yes	645 (4.8)	374 (58.0)	271 (42.0)		493 (76.4)	152 (23.6)	
Primary care visit (prior 2 years)				0.172			<0.001
No	1012 (7.5)	736 (72.7)	276 (27.3)		845 (83.5)	167 (16.5)	
Yes	12 498 (92.5)	8832 (70.7)	3666 (29.3)		11 198 (89.6)	1300 (10.4)	
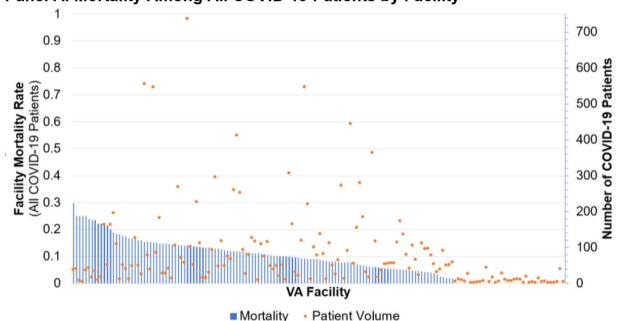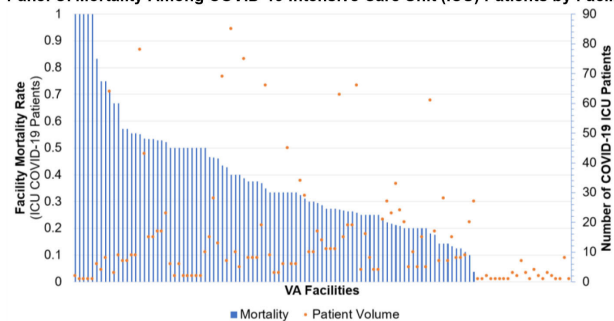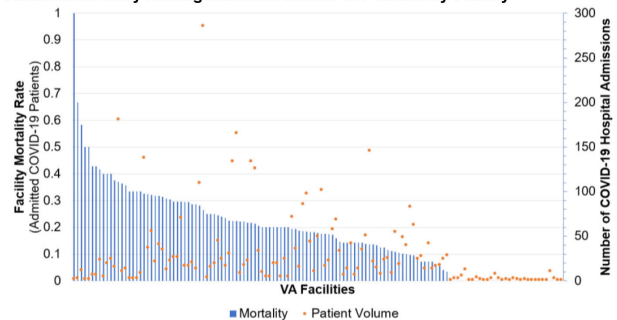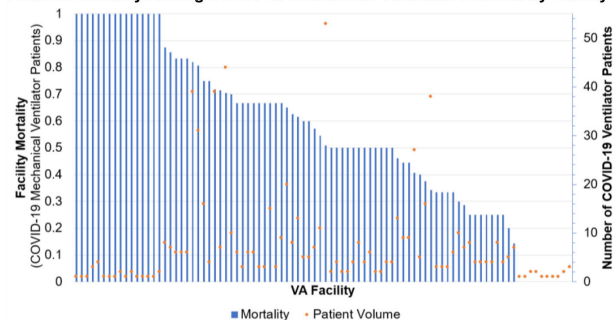
Figure 2 The figure displays the differences in the facility all-cause, 45-day mortality rates for COVID-19 patients: panel A includes 160 facilities with at least one patient with COVID-19; panel B includes 133 facilities with at least one COVID-19 inpatient cared for on a general ward or critical care unit; panel C includes 115 facilities with at least one COVID-10 ICU patient; and panel D includes 90 facilities with at least one patient with COVID-19 who received mechanical ventilation.

with extreme mortality rates (eg, 0% or 100% mechanical ventilator mortality; figure 2, panel D) had very few patients.

Risk-adjusted mortality across VA facilities

The patient characteristics that were independently associated with increased mortality included: increasing age, Asian race, diabetes, CKD, MI, CHF and residence in a long-term care facility (table 2, model 1). Patients who were admitted to the hospital, cared for in an ICU and those who received mechanical ventilation all had an higher odds of mortality compared with patients who were cared for entirely in the outpatient setting (table 2). The patient characteristics that were independently associated with decreased mortality included: female gender, higher body mass index ($\geq 25\,kg/m^2$), being seen by a primary care provider within prior 2 years and current smoking status (table 2).

The patient admission category (models 3 and 4) demonstrated a robust and statistically significant association with mortality: no admission (reference category), hospital admission without ICU or mechanical ventilation (OR1.25 (95% CI 1.04 to 1.500)), ICU without mechanical ventilation (OR 3.23 (95% CI 2.64 to 3.96)) and mechanical ventilation (OR 27.33 (95% CI 22.11 to 33.77)). When patient admission category was included, two comorbidities (diabetes and CHF) from model 1 were no longer significantly associated with mortality (table 2).

The facility characteristics that were associated with mortality in bivariate analyses included: mean age at the facility, proportion of patients admitted to the ICU, proportion receiving mechanical ventilation, overall caseload and facility complexity (online supplemental figures B and C). When facility characteristics were included in the multivariable models (models 2 and 4), the patient level estimates were similar to those obtained in models 1 and 3. The only facility characteristics that was independently associated with COVID-19 mortality after risk adjustment for patient characteristics was an increasing proportion of patients with mechanical ventilation (table 2, model 2). The total number of patients with COVID-19 was not associated with mortality (table 2, models 2 and 4). Similarly, facility complexity and rural location were also not independently associated with mortality (table 2, models 2 and 4). In sensitivity analyses, the mixed effects logistic regression results were similar when excluding CLC patients and registry-only patients (online supplemental table A). The proportional hazard model results were also similar to the primary analysis. The C-statistic was 0.796 for model 1, 0.866 for model 2, 0.868 for model 3 and 0.799 for model 4 (table 3).

Variation in mortality across VA facilities

Of the four multivariable models, model 2 with patient characteristics (excluding patient admission status) and facility characteristics reduced the variation most across facilities from 0.177 to 0.061 (table 3). However, the majority of the variance in mortality was accounted

for by patient factors only (model 1): 0.177 to 0.074 is a 58.2% reduction in variance. In contrast, the addition of facility characteristics to the multivariable modelling only reduced the variance in mortality from 0.074 (model 1) to 0.061 (model 2), which is a 7.3% reduction in variance. Including the patient-level variable for admission status to the model (model 3) increased the C-statistic from 0.799 to 0.868; however, the variation across facilities also increased from 0.061 to 0.136.[15]

DISCUSSION

Although studies have examined differences in COVID-19 prevalence[16] or outcomes[17] across geographic regions, few reports explicitly describe variation across facilities.[1] Substantial heterogeneity in caseload was observed across facilities within the VA system. We found that although observed mortality varied dramatically across facilities, heterogeneity in facility mortality rates was likely primarily due to differences in patient characteristics (eg, age, comorbidities and clinical disease severity) rather than differences in facility characteristics (eg, ICU level). This finding is reassuring from a public health perspective because it indicates that outcomes for patients with COVID-19 were similar across the full spectrum of hospitals from small, rural facilities without teaching services or research enterprises to large, academic centres.

The results are in alignment with the literature that has described the association between COVID-19 outcomes and patient factors (age in particular).[18 19] Across all four of the multivariable models, the association between age and mortality among patients with COVID-19 was monotonic and robust. Compared with younger patients (<55 years old), patients ≥85 years old had a ≥38-fold increased odds of death within 45 days of the positive COVID-19 laboratory test. These results support public health initiatives that seek to protect the elderly from exposure to COVID-19 given their very high risk of mortality.

The population that was the focus of this study, US Veterans, with a median age of 64.7 years was older than cohorts reported from China especially those evaluated early in the pandemic (median age was 46.2 years among 43 studies included in a meta-analysis).[20] However, when focusing on populations of patients with COVID-19 who were admitted to a hospital, this US Veteran population with COVID-19 was similar to a hospitalised population from England where the median age was 72 years and 36.1% were ≥80 years of age.[21] A study from Italy of patients hospitalised with COVID-19 reported a mean age of 67 years. Differences in age across populations may be a consequence of variation in testing practices. If hospitalised patients are more likely to be tested, and if older patients are more likely to be hospitalised, then regions with lower outpatient testing rates are expected to have overall older aged COVID-19 patient cohorts.

Our findings of variation of caseload across facilities is analogous to reports of geographic heterogeneity in disease prevalence.[22] For example, a serological survey

Table 2 Mixed effects logistic regression modelling 45-day mortality among patients with COVID-19

	Patients with COVID-19 (n=13510 patients at n=160 facilities)							
	Patient characteristics only		Patient and facility characteristics		Patient characteristics and admission category		Patient and facility characteristics, and admission category	
	Model 1		Model 2		Model 3		Model 4	
Characteristics	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Patient-level characteristics								
Age (years)		<0.001		<0.001		<0.001		<0.001
<55	1		1		1		1	
55–64	3.98 (2.69 to 5.88)		3.95 (2.67 to 5.84)		3.33 (2.21 to 5.00)		3.29 (2.19 to 4.95)	
65–74	11.13 (7.71 to 16.07)		11.03 (7.63 to 15.94)		9.38 (6.41 to 13.73)		9.25 (6.32 to 13.55)	
75–84	17.80 (12.20 to 25.97)		17.56 (12.02 to 25.65)		17.12 (11.55 to 25.39)		16.86 (11.36 to 25.03)	
≥85	38.73 (26.46 to 56.68)		38.23 (26.08 to 56.04)		43.89 (29.50 to 65.32)		43.06 (28.91 to 64.15)	
Race		0.017		0.02		0.099		0.092
American Indian or Alaskan Native	1.68 (0.88 to 3.22)		1.66 (0.86 to 3.19)		1.43 (0.68 to 3.01)		1.43 (0.67 to 3.01)	
Asian	2.46 (1.22 to 4.97)		2.43 (1.19 to 4.95)		2.22 (1.00 to 4.92)		2.29 (1.03 to 5.11)	
Black	1.14 (0.99 to 1.31)		1.14 (0.99 to 1.31)		0.91 (0.78 to 1.07)		0.93 (0.79 to 1.09)	
Native Hawaiian or other Pacific Islander	1.50 (0.71 to 3.15)		1.58 (0.75 to 3.32)		1.45 (0.63 to 3.32)		1.52 (0.66 to 3.48)	
Unknown	0.84 (0.62 to 1.15)		0.84 (0.62 to 1.15)		0.79 (0.57 to 1.10)		0.78 (0.56 to 1.08)	
White	1				1		1	
Hispanic	1.05 (0.82 to 1.35)	0.676	1.05 (0.82 to 1.35)	0.691	0.96 (0.73 to 1.26)	0.767	0.97 (0.73 to 1.27)	0.802
Female	0.57 (0.39 to 0.82)	0.002	0.57 (0.40 to 0.83)	0.004	0.67 (0.46 to 0.99)	0.045	0.67 (0.46 to 0.99)	0.044
Medical history								
Hypertension	0.99 (0.84 to 1.17)	0.932	0.99 (0.84 to 1.17)	0.903	0.93 (0.77 to 1.11)	0.422	0.93 (0.78 to 1.12)	0.443
Diabetes	1.22 (1.07 to 1.38)	0.003	1.21 (1.06 to 1.38)	0.004	1.13 (0.98 to 1.30)	0.102	1.12 (0.97 to 1.29)	0.112
Chronic obstructive pulmonary disease	1.06 (0.92 to 1.21)	0.411	1.05 (0.92 to 1.21)	0.456	0.97 (0.84 to 1.13)	0.718	0.97 (0.84 to 1.13)	0.738
Chronic kidney disease	1.39 (1.21 to 1.60)	<0.001	1.39 (1.21 to 1.60)	<0.001	1.34 (1.15 to 1.56)	0	1.35 (1.16 to 1.58)	0
Atrial fibrillation	0.99 (0.84 to 1.16)	0.88	0.99 (0.85 to 1.16)	0.917	0.95 (0.80 to 1.13)	0.538	0.95 (0.80 to 1.13)	0.548
Myocardial infarction	1.24 (1.01 to 1.52)	0.038	1.22 (1.00 to 1.50)	0.055	1.25 (1.00 to 1.56)	0.048	1.25 (1.00 to 1.56)	0.049
Cancer	1.16 (0.96 to 1.39)	0.129	1.16 (0.96 to 1.40)	0.122	1.16 (0.95 to 1.42)	0.149	1.16 (0.95 to 1.42)	0.145
Congestive heart failure	1.24 (1.06 to 1.46)	0.007	1.23 (1.05 to 1.45)	0.009	1.18 (0.99 to 1.40)	0.063	1.17 (0.98 to 1.39)	0.074
Body mass index (kg/m^2)		<0.001		<0.001		0.001		0.001
<25	1		1		1		1	
25–29	0.82 (0.70 to 0.95)		0.82 (0.70 to 0.96)		0.80 (0.67 to 0.95)		0.80 (0.68 to 0.95)	
30–34	0.77 (0.64 to 0.92)		0.78 (0.65 to 0.93)		0.75 (0.62 to 0.92)		0.75 (0.62 to 0.92)	
≥35	1.15 (0.94 to 1.40)		1.16 (0.95 to 1.41)		1.04 (0.84 to 1.30)		1.04 (0.84 to 1.30)	
Missing	0.94 (0.72 to 1.24)		0.96 (0.72 to 1.26)		1.18 (0.88 to 1.58)		1.17 (0.88 to 1.57)	
Primary care within prior 2 years	0.67 (0.53 to 0.85)	0.001	0.68 (0.54 to 0.86)	0.001	0.77 (0.60 to 0.99)	0.043	0.77 (0.60 to 0.99)	0.045
Community Living Centre: prior 30 days	1.41 (1.12 to 1.76)	0.003	1.41 (1.03 to 1.95)	0.035	1.77 (1.39 to 2.25)	<0.001	1.74 (1.37 to 2.23)	<0.001
Current smoker	0.81 (0.67 to 0.97)	0.025	1.61 (1.16 to 2.22)	0.005	0.75 (0.62 to 0.93)	0.007	0.76 (0.62 to 0.93)	0.007
Patient admission category						<0.001		<0.001
No admission (reference)					1		1	
Hospital admission (not ICU, not mechanical ventilation)					1.25 (1.04 to 1.50)		1.29 (1.07 to 1.56)	
ICU (not mechanical ventilation)					3.24 (2.65 to 3.96)		3.40 (2.77 to 4.18)	
Mechanical ventilation					27.37 (22.14 to 33.83)		29.12 (23.42 to 36.21)	
Facility-level characteristics								

Continued

Table 2 Continued

	Patients with COVID-19 (n=13510 patients at n=160 facilities)							
	Patient characteristics only		Patient and facility characteristics		Patient characteristics and admission category		Patient and facility characteristics, and admission category	
	Model 1		Model 2		Model 3		Model 4	
Characteristics	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Number of patients with COVID-19				0.131				0.174
<20			1.14 (0.69 to 1.87)				0.74 (0.42 to 1.31)	
20–49			1.40 (1.06 to 1.84)				1.27 (0.91 to 1.77)	
50–99			1.06 (0.84 to 1.34)				0.98 (0.74 to 1.30)	
≥100 (reference)			1				1	
Mean patient age			1.02 (1.00 to 1.04)	0.066			1.02 (0.99 to 1.04)	0.138
Percentage of patients admitted (no ICU, no vent)				0.95				0.779
0 (reference)			1				1	
0.01–19.99			0.95 (0.68 to 1.33)				0.88 (0.59 to 1.32)	
20.0+			0.95 (0.66 to 1.36)				0.86 (0.56 to 1.32)	
Percentage of patients in ICU with mechanical ventilation				0.706				0.117
0 (reference)			1				1	
0.01–9.99			1.10 (0.75 to 1.60)				1.07 (0.69 to 1.66)	
≥10.0			1.02 (0.69 to 1.48)				0.82 (0.53 to 1.29)	
Percent patients with mechanical ventilation				0.017				0.156
0 (reference)			1				1	
0.01–4.99			1.41 (1.03 to 1.95)				1.03 (0.70 to 1.49)	
≥5.0			1.61 (1.16 to 2.22)				0.80 (0.55 to 1.18)	
Complexity 1a, 1b, 1c versus 2 and 3			1.09 (0.81 to 1.47)	0.548			1.09 (0.76 to 1.56)	0.626
Rural facility			1.13 (0.77 to 1.66)	0.532			1.12 (0.72 to 1.76)	0.609

ICU, intensive care unit.

from Spain reported substantial geographical variation, with higher prevalence near Madrid (>10%) and lower prevalence in coastal areas (<3%).[23] A study from the USA reported higher COVID-19 mortality in rural versus urban communities; however, that study was limited to county-level (not patient level) data.[24] In contrast, our results indicated that facility rurality was not independently associated with COVID-19 patient mortality. The current study

Table 3 Random variation across facility 45-day mortality rates

| Model | All patients (n=13510 patients at n=160 facilities) | | VA laboratory patients* (excluded registry and CLC patients) (n=7535 patients at n=149 facilities) |
	C-statistic	Variance (SE)	Variance (SE)
Null model	–	0.177 (0.043)	0.236 (0.067)
Model 1: patient characteristics only	0.796	0.074 (0.028)	0.081 (0.037)
Model 2: patient characteristics+facility characteristics	0.799	0.061 (0.026)	0.047 (0.031)
Model 3: patient characteristics+admission category†	0.866	0.160 (0.046)	0.190 (0.067)
Model 4: patient characteristics+admission category†+facility characteristics	0.868	0.136 (0.044)	0.170 (0.070)

*This sensitivity analysis included Veterans identified in the VA laboratory data only; Veterans identified only in the VA-NST registry and those who were Community Living Centre (CLC) residents in the 30 days prior to the COVID-19 positive test were excluded.
†Admission category refers to the setting where patients with COVID-19 received care: outpatient, admission to an inpatient ward, intensive care unit and mechanical ventilator.
VA-NST, VA National Surveillance Tool.

adds to the existing literature by describing heterogeneity at the facility level within a national healthcare system.

Our finding that current smokers with COVID-19 were more likely to be admitted than non-smokers but that in multivariable modelling current smoking was associated with a lower risk of mortality is consistent with reports from cohorts in England,[18] China[25] and Italy,[26] as well as an ecological study of 38 European countries.[27] Although studies have suggested that nicotine exposure is related to ACE2 expression,[28] and diseases associated with smoking such as COPD increase the risk of severe COVID-19 infection,[29] the role of nicotine and smoking in COVID-19 disease remains a topic of active investigation.

The results suggest that reported variation in unadjusted mortality rates should be considered with caution and must be evaluated within the context of sample size and patient characteristics.[1] For example, the overall in-hospital mortality rate of 18.2% among VA hospitals is somewhat higher than reports from the Kaiser Permanente Northern California system of 15.6%, a healthcare system that cares for a younger cohort (mean age 61.0 years compared with 63.5 years in the VA).[30] Future studies of COVID-19 outcomes should include risk adjustment for relevant patient characteristics and should report C-statistics or other measures of model performance.

Limitations

Several potential limitations of this national cohort study merit description. First, we evaluated care of COVID-19 positive Veteran patients at VA facilities; findings cannot be generalised to Veterans cared for in community (non-VA) facilities.[31] Second, this study did not evaluate outcomes for non-COVID-19 patients at VA hospitals; therefore, we did not evaluate the potential effects of COVID-19 on non-COVID-19 hospital operations.[32] Third, although a methodological strength of the study was the chart review validation of the administrative data, the outpatient mortality rates may still be underestimates because of delays in updating national VA death indices. Fourth, we do not have non-VA healthcare utilisation; therefore, patients may have received COVID-19 testing within the VA but were subsequently hospitalised at a non-VA community hospital. Fifth, we described the proportion of patients who were treated in an ICU or received mechanical ventilation; we cannot comment on the appropriateness of such care. Sixth, we examined all-cause mortality in the 45-day period after COVID-19 testing. Although it is likely that death among patients with COVID-19 was attributable to COVID-19 disease, some patients may have died from other causes (eg, preexisting illness). Seventh, US Veterans are predominantly male, which may limit generalisability of findings to non-Veteran populations. Finally, although many key patients and facility characteristics were included in the analyses, there are many potential factors that may contribute to mortality among patients with COVID-19 including patient characteristics (eg, occupation) and facility characteristics (eg, environmental factors) that were not included in the multivariable modelling.

Conclusions

In this national cohort of 13 510 US Veterans with a positive COVID-19 test during the period March–31 May 2020 across 160 VA facilities, marked heterogeneity in patient volume, admissions to the hospital and to the ICU, mechanical ventilation and 45-day, all-cause mortality were observed across VA facilities. However, after adjustment for differences in patient characteristics, mortality was similar across VA facilities nationwide.

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