


Clinical Outcomes of Patients Hospitalized with Coronavirus Disease 2019 (COVID-19) in Boston



Areej El-Jawahri, MD^{1,2} , Hacho B. Bohossian, MD^{3,4},
Michael K. Paasche-Orlow, MD, MA^{5,6}, Joshua R. Lakin, MD^{2,7},
P. Connor Johnson, MD^{1,2}, Zara Cooper, MD^{2,8}, Annemarie D. Jagiello, BA¹,
Elise N. Brannen, BA^{2,8}, Matthew J. Reynolds, BA², Kathleen Coogan, BS⁸,
Dagny Vaughn, BA¹, and Angelo Volandes, MD, MPH^{1,2,3,9}

¹Department of Hematology Oncology, Massachusetts General Hospital, Boston, MA, USA; ²Harvard Medical School, Boston, MA, USA; ³Newton-Wellesley Hospital, Newton, MA, USA; ⁴Tufts University School of Medicine, Boston, MA, USA; ⁵Boston Medical Center, Boston, MA, USA; ⁶Boston University School of Medicine, Boston, MA, USA; ⁷Dana Farber Cancer Institute, Boston, MA, USA; ⁸Brigham and Women's Hospital, Boston, MA, USA; ⁹Advance Care Planning (ACP) Decisions, Newton, MA, USA.

BACKGROUND: Outcomes of hospitalized patients with COVID-19 have been described in health systems overwhelmed with a surge of cases. However, studies examining outcomes of patients admitted to hospitals not in crisis are lacking.

OBJECTIVE: To describe clinical characteristic and outcomes of all patients with COVID-19 who are admitted to hospitals not in crisis, and factors associated with mortality in this population.

DESIGN: A retrospective analysis

PARTICIPANTS: In total, 470 consecutive patients with COVID-19 requiring hospitalization in one health system in Boston from January 1, 2020 to April 15, 2020.

MAIN MEASURES: We collected clinical outcomes during hospitalization including intensive care unit (ICU) admission, receipt of mechanical ventilation, and vasopressors. We utilized multivariable logistic regression models to examine factors associated with mortality.

KEY RESULTS: A total of 470 patients (median age 66 [range 23–98], 54.0% male) were included. The most common comorbidities were diabetes (38.5%, 181/470) and obesity (41.3%, 194/470). On admission, 41.9% (197/470) of patients were febrile and 60.6% (285/470) required supplemental oxygen. During hospitalization, 37.9% (178/470) were admitted to the ICU, 33.6% (158/470) received mechanical ventilation, 29.4% (138/470) received vasopressors, 16.4% (77/470) reported limitations on their desire for life-sustaining therapies such as intubation and cardiopulmonary resuscitation, and 25.1% (118/470) died. Among those admitted to the ICU ($N=178$), the median number of days on the ventilator was 10 days (IQR 1–29), and 58.4% (104/178) were discharged alive. Older age (OR=1.04, $P<0.001$), male sex (OR=2.14, $P=0.007$), higher comorbidities (OR=1.20, $P=0.001$), higher lactate dehydrogenase on admission (2nd tertile: OR=4.07, $P<0.001$; 3rd tertile: OR=8.04, $P<0.001$), and the need for supplemental oxygen on admission (OR=2.17, $P=0.014$) were all associated with higher mortality.

CONCLUSIONS: The majority of hospitalized patients with COVID-19 and those who received mechanical ventilation survived. These data highlight the need to examine public health and system factors that contribute to improved outcomes for this population.

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INTRODUCTION

The novel coronavirus disease 2019 (COVID-19) pandemic has infected millions of people worldwide, leading to a surge in hospital utilization.^{1–3} Although most patients with COVID-19 have a favorable prognosis, COVID-19 may result in critical illness requiring intensive interventions such as ventilatory support, especially in older patients and those with underlying serious comorbid conditions.^{3, 4} To meet these needs, health systems and hospitals have had to rapidly reorganize in-patient services and expand ICU capacity. An accurate representation of clinical outcomes for people hospitalized with COVID-19 can improve planning for health systems, hospitals, clinicians, and patients.

Among patients admitted to hospitals, key parameters include the portion that will need ICU level care and ventilatory support, the length of time people would need such services, and the mortality rate. To date, much of the data for such factors has come from health systems in China, Italy, and New York that endured critical shortages of services.^{3–7} Accordingly, in prior reports, it can be hard to differentiate the impact of COVID-19 from the influence of overwhelmed capacity.

A clear understanding of outcomes is also extremely important for advance care planning (ACP). ACP is a shared decision-making process in which patients and clinicians weigh the risks and benefits of such interventions in the context of the patient's values and preferences.^{8, 9} The intent of ACP remains unchanged during times of a

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pandemic—aligning medical care delivery with patient preferences.^{8–10} However, extrapolating data from health systems in crisis, where the demand for care far outpaced the supply, is problematic for clinicians who are working to make individual patient decisions.

We sought to report the clinical characteristics and factors associated with ventilatory support, survival, and discharge disposition for all COVID-19 patients admitted to hospitals that are not in crisis, but where COVID-19 disease burden was high and in a surge state, a critically important situation that is unique from prior studies and reports of COVID-19 outcomes. We present a retrospective analysis from a large health care system in the Boston metropolitan region. Although considered an early hotspot for COVID-19, Boston did not surpass capacity or initiate crisis standards.

METHODS

Study Design

This study was approved by the Partners Institutional Review Board. We conducted a retrospective analysis of all patients hospitalized with confirmed diagnoses of COVID-19 treated at Partners hospitals between January 1, 2020 and April 15, 2020. We used the Partners HealthCare Research Patient Data Registry (RPDR) which stores clinical data for 6.5 million individuals who receive their care from Partners HealthCare providers in Massachusetts. Partners HealthCare provides care in academic, community hospitals, and rehabilitation networks across New England. Partners HealthCare has emergency services integrated across most of its member institutions and includes over 200 ICU beds. We included patients admitted to 5 academic and community hospitals within Partners HealthCare in this study. We used COVID-19 diagnoses codes to identify patients hospitalized with COVID-19, which we confirmed by manual chart review. Partners hospitals did not utilize strict criteria for hospital admission. Instead, the decision regarding the need for hospital admission was left at the discretion of the treating physician. All patients with a positive nasopharyngeal polymerase chain reaction test were included. Clinical outcomes were monitored until May 11, 2020. Patients who were still hospitalized by May 11, 2020, were excluded from analyses. Transfers from one hospital to another were merged and considered a single visit. For patients with a readmission during the study period, data from multiple admissions were merged and considered a single visit.

Demographic and Clinical Characteristics

We conducted a comprehensive chart review to obtain information regarding patients' demographics, comorbidities, home medications, and laboratory findings. We collected race and ethnicity using the electronic health record (EHR) pre-specified fixed categories. We obtained data on home

medications based on the admission medication reconciliation record. We used the Charlson Comorbidity Index (CCI) to examine comorbid conditions as documented in the EHR.¹¹ We also collected data on the use of certain therapies during hospitalization including corticosteroids, hydroxychloroquine, remdesivir, and tocilizumab.

Clinical Outcomes

We obtained information regarding hospital length of stay (LOS), ICU admission, and the need for mechanical ventilation, vasopressors, renal replacement therapy, and extracorporeal membrane oxygenation (ECMO) from the electronic medical record. We also collected data on palliative care consultation, code status at the time of admission to the hospital and any changes to code status throughout the hospitalization using EHR order entry. We also collected vital status (discharged alive or dead) as well as discharge disposition. To ensure data fidelity, two coders independently reviewed 10% of all hospitalization outcome data and achieved excellent reliability (97% agreement).

Statistical Analysis

We used descriptive statistics including frequencies and percentage for categorical variables and means \pm standard deviations (SD) for continuous variables to summarize participant characteristics and clinical outcomes. All reported *P* values were two-sided, with *P* < 0.05 considered statistically significant.

We conducted unadjusted analyses examining the association between demographic and clinical factors of interest with mortality. The following factors were considered in the unadjusted analyses: demographics (age, sex, race (White vs. all other racial categories), and ethnicity), home medications (statins, non-steroidal anti-inflammatory drugs, corticosteroids, angiotensin-converting enzyme inhibitors, or angiotensin II receptor blockers), history of smoking, obesity, comorbidities (CCI), the need for supplemental oxygen on admission, inflammatory markers (lactate dehydrogenase, C-reactive protein, ferritin, and D-dimer), and treatments (remdesivir, corticosteroids, or hydroxychloroquine). Factors that were associated with mortality with a *P* value < 0.10 were then included in the multivariate logistic regression model, as recommended by literature on logistic regression model building.^{12–14} Given collinearity between inflammatory markers, only lactate dehydrogenase was included in the final multivariable logistic regression model.

RESULTS

Patient Characteristics

Table 1 depicts the clinical characteristics of all patients (*N* = 470) included in this analysis. The median age of the cohort was 66.0 (range 23–98). Overall, 254 patients

were male (54.0%) and 286 were non-Hispanic (60.9%) and the plurality were White (200/470, 42.6%). Most patients were living at home prior to admission (73.4%, 345/470), and 86 (18.3%) were admitted from a skilled nursing facility. The most common comorbidities were obesity (41.3%, 194/470), diabetes (38.5%, 181/470), cancer (18.1%, 85/470), congestive heart failure (14.5%, 68/470), and dementia (14.0%, 66/470). The median CCI score was 4 (range 0–14).

Two hundred eighty-five patients required supplemental oxygen at the time of admission (60.6%) and 197 (41.9%) were febrile on admission. Inflammatory markers at the time of admission are presented in Table 2. Most patients were “full code” with no restrictions on life-sustaining treatments at the time of admission (83.6%, 393/470).

Overall, 91 patients remained hospitalized by May 11, 2020, and were excluded from the analyses. Among those who remained hospitalized, 50.6% (46/91) were admitted to the ICU, but only 16.5% (15/91) remained in the ICU at the time of last follow-up.

Table 1 Baseline Characteristics of Patients Hospitalized with COVID-19. ACE-I, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; BMI, body mass index

Baseline characteristics	Total cohort (N = 470)
Age, median (range)	66.0 (23–98)
Sex, N (%)	
Male	254 (54.0%)
Female	216 (46.0%)
Race, N (%)	
White	200 (42.6%)
Black	110 (23.4%)
Asian	13 (2.8%)
American Indian	1 (0.2%)
Other	137 (29.1%)
Missing	9 (1.9%)
Ethnicity, N (%)	
Hispanic	174 (37.0%)
Non-Hispanic	286 (60.9%)
Missing	10 (2.1%)
Living situation, N (%)	
Home	345 (73.4%)
Skilled nursing facility	86 (18.3%)
Other	29 (6.2%)
Missing	10 (2.1%)
History of statin use, N (%)	230 (48.9%)
History of ACE-I/ARB use, N (%)	149 (31.7%)
Comorbidities, N (%)	
Diabetes	181 (38.5%)
Prior smoking history	186 (39.6%)
Myocardial infarction	36 (7.7%)
Congestive heart failure	68 (14.5%)
Dementia	66 (14.0%)
Chronic obstructive lung disease	49 (10.4%)
Liver cirrhosis	17 (3.6%)
Chronic kidney disease (creatinine > 2)	64 (13.6%)
Hemodialysis use	22 (4.7%)
Cancer	85 (18.1%)
Obesity (BMI ≥ 30)	194 (41.3%)
Morbid obesity (BMI ≥ 35)	72 (15.3%)
Charlson Comorbidity Index, median (range)	4 (0–14)

Table 2 Clinical Measures at the Time of Admission for COVID-19. SD, standard deviation

Clinical characteristics	Total cohort (N = 470)
Febrile (temperature > 38.0 °C), n (%)	197 (41.9%)
Requiring supplemental oxygen, n (%)	285 (60.6%)
Normal C-reactive protein, n (%)	
≤ 10 mg/L	38 (8.1%)
C-reactive protein, mean mg/L (SD)	
1st tertile	23.6 (15.7)
2nd tertile	85.4 (21.4)
3rd tertile	197 (54.7)
Missing, n (%)	38 (8.1%)
Normal ferritin, n (%)	
≤ 150 µg/L	68 (14.5%)
Ferritin, mean µg/L (SD)	
1st tertile	164.8 (94.7)
2nd tertile	553.2 (144.4)
3rd tertile	2753.0 (5588.7)
Missing, n (%)	50 (10.6%)
Normal lactate dehydrogenase, n (%)	
≤ 250	136 (28.9%)
Lactate dehydrogenase, mean U/L (SD)	
1st tertile	206.5 (36.6)
2nd tertile	320.4 (36.7)
3rd tertile	562.0 (254.60)
Missing	20 (4.3%)
Normal D-dimer, n (%)	
≤ 500 ng/mL	55 (11.7%)
D-dimer, mean ng/mL (SD)	
1st tertile	558.5 (217.6)
2nd tertile	1260.3 (220.3)
3rd tertile	3579.1 (2190.4)
Missing	33 (7.0%)
Absolute lymphocyte count, mean (SD)	1.3 (5.8)
Code status on admission	
Full code	393 (83.6%)
Do not resuscitate	14 (3.0%)
Do not intubate	4 (0.9%)
Do not resuscitate and do not intubate	59 (12.5%)

Clinical Measures and Outcomes for Hospitalized Patients with COVID-19

Table 3 depicts the clinical measures and outcomes for patients hospitalized with COVID-19 by survival status (alive vs. deceased). Overall, 194 (41.3%) of patients received hydroxychloroquine, 106 (22.6%) received remdesivir, 52 (11.1%) received corticosteroids, and 21 (4.5%) received tocilizumab. Deceased patients had higher inflammatory markers during admission and lower absolute lymphocyte count compared to those discharged alive (Table 3).

The median hospital LOS for the entire cohort was 8 days (IQR 1–37). Overall, 178 (37.9%) patients were admitted to the ICU, 158 (33.6%) received mechanical ventilation, 138 (29.4%) received vasopressors, and 118 (25.1%) died during hospitalization. When excluding patients who had documented limitation of life-sustaining therapies on admission, 21.1% (83/393) patients died during hospitalization. The mortality rate was higher for men and for higher age groups, as depicted in Figure 1. Overall, 22.3% (105/470) had a palliative care consultation. Among those who died during admission (n = 118), 65 (55.1%) received a palliative care consultation with a median time from palliative care consultation to death of 4 days (IQR 1–20). Additionally, 143 (30.4%) patients had orders to limit life-sustaining treatments such as resuscitation

Table 3 Clinical Measures and Outcomes of Patients Alive and Deceased. *SD*, standard deviation; *CRP*, C-reactive protein; *LDH*, lactate dehydrogenase; *ICU*, intensive care unit

	Patients alive (<i>N</i> = 352)	Patients deceased (<i>N</i> = 118)	Total cohort (<i>N</i> = 470)
Clinical measures			
Highest temperature, mean (SD)	38.5 (0.9)	38.8 (1.0)	38.6 (0.9)
Lowest ALC, mean (SD)	0.79 (0.66)	0.57 (0.89)	0.74 (0.73)
Inflammatory markers, mean (SD)			
Highest CRP (mg/L)	138.9 (94.9)	221.7 (95.5)	158.6 (101.6)
Highest Ferritin (μg/L)	1593 (4247.3)	2865 (7746.1)	1919.9 (5395.2)
Highest LDH (U/L)	436.6 (511.7)	659.2 (1440.2)	490.9 (842.4)
Highest D-dimer (ng/mL)	2469.7 (2156.7)	3826.5 (2628.8)	2809.7 (2355.8)
Treatments used, <i>n</i> (%)			
Corticosteroids	35 (9.9%)	17 (14.4%)	52 (11.1%)
Tocilizumab	13 (3.7%)	8 (6.8%)	21 (4.5%)
Remdesivir	86 (24.4%)	20 (16.9%)	106 (22.6%)
Hydroxychloroquine	144 (40.9%)	50 (42.4%)	194 (41.3%)
Palliative care consultation, <i>n</i> (%)	40 (11.4%)	65 (55.1%)	105 (22.3%)
Outcome measures, <i>n</i> (%)			
Orders to limit life-sustaining treatments	34 (9.7%)	109 (92.4%)	143 (30.4%)
ICU admission	104 (29.6%)	74 (62.7%)	178 (37.9%)
Mechanical ventilation	85 (24.1%)	73 (61.9%)	158 (33.6%)
Hospital LOS, median (IQR)	8.0 (1–37)	8.0 (1–29)	8.0 (1–37)

and intubation. Moreover, 104 patients (22.1%) transitioned to Comfort Measures Only during their hospitalization. Among the deceased cohort, the median time from code status change to death was 1 day (IQR 1–9). Among those discharged alive, the majority (59.1%) were discharged home, 23.3% were discharged to a rehab facility, and 15.5% were discharged to a

skilled nursing facility. Overall, 8.1% (38/470) of our cohort experienced a hospital readmission.

Clinical Measures and Outcomes of Patients Admitted to the ICU Due to COVID-19

Among patients admitted to the ICU (*N* = 178), 150 (84.3%) received mechanical ventilation, 138 (77.5%) received vasopressors, 17 (9.5%) received renal replacement therapy, and 4 (2.3%) received ECMO (Table 4). The median time on the ventilator was 10 days (IQR 1–29). The mean PaO₂/F ratio was 171.9 (SD = 73.5). Overall, 178 patients (58.4%) were discharged from the hospital alive (58.4%, 104/178). Of note, 11 patients (6.2%) received cardiopulmonary resuscitation (CPR) with one patient surviving to hospital discharge. Palliative care was consulted for 59 ICU patients (33.1%) and 81 ICU patients (45.5%) had orders to limit life-sustaining treatments such as resuscitation and intubation. Moreover, 64 patients (35.9%) transitioned to Comfort Measures Only during their ICU stay.

Factors Associated with Mortality During Hospitalization for COVID-19

In unadjusted analyses, older age, White race, history of statin use, history of angiotensin-converting enzyme inhibitors or angiotensin II receptor blockers use, higher comorbidity score, the use of supplemental oxygen on admission, and higher inflammatory markers on admission were all associated with higher odds of mortality (Table 5).

In the multivariate logistic regression analyses (*n* = 420) (Table 5), older age (OR = 1.04, [95% CI 1.02, 1.07], *P* < 0.001), male sex (OR = 2.14, [95% CI 1.23, 3.75], *P* = 0.007), higher comorbidity score (OR = 1.20, [95% CI 1.07, 1.34], *P* = 0.001), the use of supplemental oxygen on admission (OR = 1.20, [95% CI 1.07, 1.34], *P* = 0.001), and elevated lactate dehydrogenase

Mortality by Age Group and Sex

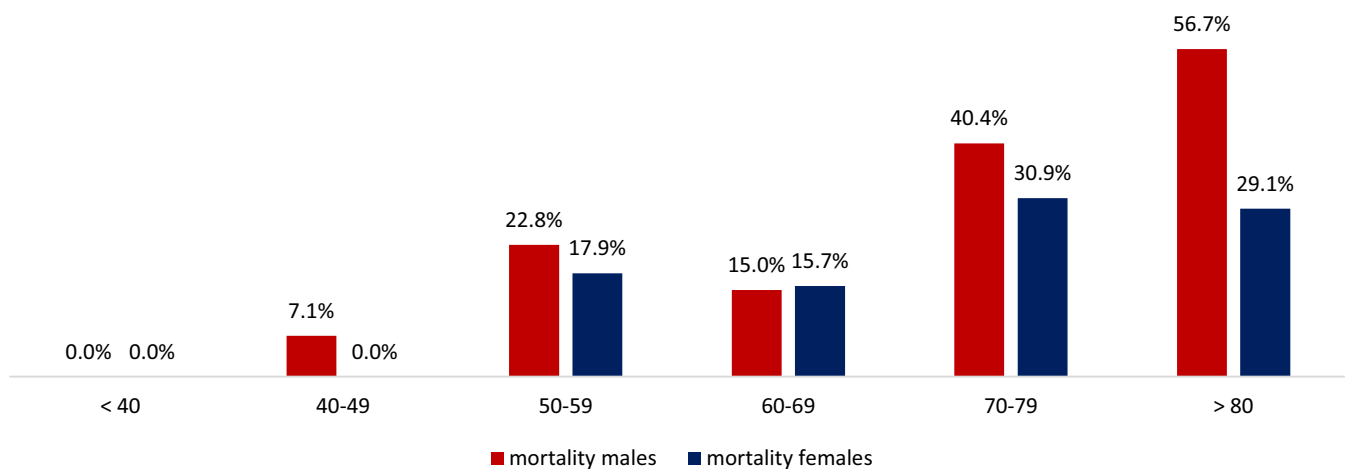


Figure 1 Mortality rates by age group and sex.

Table 4 Clinical Measures and Outcomes of Patients Admitted to the Intensive Care Unit Due to COVID-19. *SD*, standard deviation; *ICU*, intensive care unit; *CVVH*, continuous veno-venous hemofiltration; *ECMO*, extracorporeal membrane oxygenation; *FIO₂*, fraction of inspired oxygen; *CPR*, cardiopulmonary resuscitation

Clinical measures and outcomes	Patients admitted to ICU (N = 178)
Mechanical ventilation, n (%)	150 (84.3%)
Days on the ventilator, median (IQR)	10.0 (1–29)
ICU length of stay, median (IQR)	10.0 (1–34)
PaO ₂ /FIO ₂ ratio, mean (SD)	171.8 (73.5)
Receipt of vasopressors, n (%)	138 (77.5%)
CVVH, n (%)	17 (9.6%)
ECMO, n (%)	4 (2.3%)
CPR, n (%)	11 (6.2%)
Palliative care consultation, n (%)	59 (33.1%)
Orders to limit life-sustaining treatments, n (%)	81 (45.5%)
Discharged alive, n (%)	104 (58.4%)

(compared to 1st tertile, 2nd tertile OR = 4.07, [95% CI 1.91, 8.69], *P*<0.001; 3rd tertile: OR = 8.04, [95% CI 3.59], 18.0, *P*<0.001) were all associated with higher mortality among patients hospitalized for COVID-19. We conducted sensitivity analyses incorporating the other inflammatory markers (C-reactive protein, ferritin, and D-dimer) in separate multivariate regression models and obtained similar results. We also conducted a sensitivity analysis excluding patients who had limitations on life-sustaining therapies on admission to the hospital and obtained similar results in our multivariate regression model (Supplemental Table 1).

DISCUSSION

In this study, we demonstrate that the majority of hospitalized patients with COVID-19 and even the majority of those who received mechanical ventilation survived to hospital discharge. Mortality rates were 25%, markedly lower than those previously reported. Hospital LOS and days on ventilator were approximately 5–6 longer than prior reports. Age, male sex, Charlson Comorbidity Index score, inflammatory markers, and supplemental oxygen use on admission were all associated with mortality.

The surge in hospital utilization due to COVID-19 is unprecedented in the modern era.¹⁵ Health systems have had to rapidly re-organize in-patient services and expand ICU capacity. Initial studies from cities overwhelmed by COVID-19 patients described exceptionally high mortality rates.^{4, 7} The more favorable outcomes we report likely reflect COVID-19 outcomes in a health system that was not tested to the point of critical resource scarcity.

When health systems are not overwhelmed and patients can remain hospitalized or on ventilators for prolonged periods, outcomes are not as poor. It is important to note that a substantial number of patients in prior reports were still hospitalized and this may have inflated mortality rates for patients receiving ICU care. Nonetheless, 25% of the patients hospitalized with COVID-19 and over 40% of those admitted to the ICU died during their hospitalization, underscoring the gravity of this illness. These

Table 5 Unadjusted and Multivariate Logistic Regression Examining Factors Associated with Mortality in Hospitalized Patients with COVID-19. *CI*, confidence interval; *ACE-I*, angiotensin-converting enzyme inhibitor; *ARB*, angiotensin receptor blocker; *BMI*, body mass index; *NSAID*, non-steroidal anti-inflammatory drugs; *LDH*, lactate dehydrogenase; *CRP*, C-reactive protein

Factors	Unadjusted analyses		Multivariate logistic model	
	Odds ratio (95% CI)	<i>P</i> value	Odds ratio (95% CI)	<i>P</i> value
Age (years)	1.05 (1.03, 1.07)	<0.001	1.04 (1.02, 1.07)	<0.001
Male sex	1.77 (1.15, 2.72)	0.009	2.14 (1.23, 3.75)	0.007
White race	1.57 (1.03, 2.39)	0.035	1.54 (0.84, 2.81)	0.160
Hispanic ethnicity	0.67 (0.43, 1.05)	0.082	1.03 (0.55, 1.93)	0.921
Obese BMI	1.06 (0.69, 1.62)	0.780		
Charlson Comorbidity Index score	1.28 (1.19, 1.37)	<0.001	1.20 (1.07, 1.34)	0.001
History of statin use	2.01 (1.31, 3.08)	0.001	0.96 (0.54, 1.70)	0.898
History of ACE-I/ARB use	1.70 (1.10, 2.62)	0.016	1.64 (0.94, 2.86)	0.080
History of NSAID use	1.11 (0.70, 1.76)	0.654		
History of corticosteroid use	1.68 (0.89, 3.15)	0.105		
History of smoking	1.51 (0.98, 2.32)	0.058	1.07 (0.61, 1.88)	0.814
Supplemental oxygen on admission	3.52 (2.13, 5.81)	<0.001	2.17 (1.17, 4.03)	0.014
LDH on admission				
1st tertile	Ref		Ref	
2nd tertile	2.02 (1.09, 3.73)	0.025	4.07 (1.91, 8.69)	<0.001
3rd tertile	3.99 (2.22, 7.16)	<0.001	8.04 (3.59, 18.0)	<0.001
CRP on admission				
1st tertile	Ref			
2nd tertile	1.95 (1.07, 3.54)	0.028		
3rd tertile	2.84 (1.59, 5.06)	<0.001		
Ferritin on admission				
1st tertile	Ref			
2nd tertile	1.21 (0.69, 2.09)	0.505		
3rd tertile	1.47 (0.85, 2.52)	0.162		
D-Dimer on admission				
1st tertile	Ref			
2nd tertile	3.60 (1.95, 6.65)	<0.001		
3rd tertile	3.63 (1.97, 6.72)	<0.001		
Treatment with remdesivir	0.63 (0.36, 1.08)	0.094	0.70 (0.35, 1.40)	0.315
Treatment with hydroxychloroquine	1.06 (0.69, 1.62)	0.780		

Bold indicate statistically significant findings

results have large macro-policy implications for emergency preparedness as the USA considers preparations for subsequent waves of COVID-19 and other pandemics. Even in areas experiencing a high volume of COVID-19 cases, ensuring that there are adequate resources to meet the potential demand for medical resources is of foremost importance to the national response to COVID-19.^{16, 17}

These mortality rates have significant implications for patient and family decision-making. ACP and decision-making for serious illness more broadly relies on accurate information about the risks and benefits of life-prolonging interventions and the likely disposition.^{9, 10, 18} Early reported mortality rates for COVID-19 were quite high, which may have led to ACP discussions and decisions that were not fully informed. The present study serves as a more accurate portrayal of survival with COVID-19 in a busy health system with a surge of patients and hopefully leads to more informed decision-making. It is important to note that most patients in our cohort did not have any limitations on life-sustaining therapies at the time of admission to the hospital, despite their older age and multiple comorbid conditions. Unfortunately, this likely reflects the lack of adequate ACP discussions and automatic “full code” status often employed in the USA compared to other countries.¹⁹ Nonetheless, ACP discussions are critical to ensure patients make informed decisions regarding their medical care.

There was extensive use of palliative care services in the ICU. Given the critical role palliative care can play in helping patients and families make informed decisions about their care,^{8, 20, 21} the existing national shortage of palliative care clinicians is an urgent crisis and rivals other needs such as personal protective equipment and nasal swabs.^{22–26} Exploring goals of care, coordinating and effectuating patient preferences, and controlling pain and suffering are of paramount importance in the face of an uncertain illness such as COVID-19.^{27, 28} Significantly expanding the clinician workforce with these skills and rapidly disseminating tools to support ACP is vital. Earlier ACP may also help ease the burden of limited in-patient palliative care resources downstream.^{27–29}

This study has several notable limitations and numerous strengths. First, while the study population was diverse with more than half being non-White, the cohort is from a single metropolitan area, thereby limiting the generalizability of our findings. Second, 91 patients remained hospitalized and their outcome data were absent from our analyses. We excluded these patients since Boston hospitals experienced crisis of COVID-19 cases by the end of April and our goal was to report on patient outcomes in hospitals not experiencing crisis. Prior studies in the USA had largely incomplete data sets. Nonetheless, excluding patients who remained hospitalized may result in a selection bias as those who remained hospitalized may have different outcomes compared to the study cohort. Third, knowledge and practices regarding COVID-19 treatment are rapidly changing and this data set reflects the early period of COVID-19 in the USA. It is

possible that mortality rates change over time due to identification of effective treatments. Fourth, there was limited follow-up; longer term sequelae remain unclear. Fourth, data regarding race was obtained from the EHR, which includes an “other” category that is not fully explained, which limits our ability to interpret data on outcomes of patients based on race. Fifth, while our multivariate logistic regression model adjusted for factors such as comorbidities and severity of illness at presentation, it is possible that there are other unmeasured confounders that may affect the relationship between treatment received and risk of mortality. Additionally, we utilized a $P < 0.10$ as a cut-off in our multivariable analysis modeling approach, which may have also omitted potential confounders. Finally, this study included only hospitalized patients with confirmed COVID-19. Patients who did not present to the hospital and died at home, or were discharged to hospice from the emergency department are not included. Prior studies also had similar limitations.

Managing the COVID-19 global pandemic involves ensuring that health systems are not overwhelmed. This study was conducted in a region of the USA that did not experience crisis standards and exhibited a much lower rate of hospital mortality than in prior papers which reported data from areas enduring critical shortages. Protecting health systems so they will not be over-run and surpass the surge capacity for medical resources such as ICU beds, ventilators, and appropriately trained medical staff have a salutary effect on prognosis and survival.

Corresponding Author: Areej El-Jawahri, MD; Department of Hematology Oncology, Massachusetts General Hospital, Boston, MA, USA (e-mail: ael-jawahri@partners.org).

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Author Contributions Drs. El-Jawahri and Volandes had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: El-Jawahri, Bohossian, Paasche-Orlow, Lakin, Cooper, and Volandes

Acquisition of data: El-Jawahri, Bohossian, Lakin, Johnson, Jagielo, Brannen, Reynolds, Coogan, and Vaughn

Analysis and interpretation of data: El-Jawahri, Bohossian, Paasche-Orlow, Lakin, Johnson, Cooper, Jagielo, Brannen, Reynolds, Coogan, Vaughn, and Volandes

Drafting of the manuscript: El-Jawahri, Paasche-Orlow, and Volandes

Critical revision of the manuscript for important intellectual content: El-Jawahri, Bohossian, Paasche-Orlow, Lakin, Johnson, Cooper, Jagielo, Brannen, Reynolds, Coogan, Vaughn, and Volandes

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