Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Major Article

Clinical characteristics, outcomes and prognosticators in adult patients hospitalized with COVID-19

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A B S T R A C T

Background: COVID-19 is a novel disease caused by SARS-CoV-2.
Methods: We conducted a retrospective evaluation of patients admitted with COVID-19 to one site in March 2020. Patients were stratified into 3 groups: survivors who did not receive mechanical ventilation (MV), survivors who received MV, and those who received MV and died during hospitalization.
Results: There were 140 hospitalizations; 22 deaths (mortality rate 15.7%), 83 (59%) survived and did not receive MV, 35 (25%) received MV and survived; 18 (12.9%) received MV and died. Thee mean age of each group was 57.8, 55.8 and 72.7 years, respectively ($P = .0001$). Of those who received MV and died, 61% were male ($P = .01$). More than half the patients (n = 90, 64%) were African American. First measured d-dimer >575.5 ng/mL, procalcitonin > 0.24 ng/mL, lactate dehydrogenase >445.6 units/L, and brain natriuretic peptide (BNP) >104.75 pg/mL had odds ratios of 10.5, 5, 4.5 and 2.9, respectively for MV ($P < .05$ for all). Peak BNP >167.5 pg/mL had an odds ratio of 6.7 for inpatient mortality when mechanically ventilated ($P = .02$).
Conclusions: Age and gender may impact outcomes in COVID-19. D-dimer, procalcitonin, lactate dehydrogenase and BNP may serve as early indicators of disease trajectory.

BACKGROUND

A cluster of cases of pneumonia of unknown etiology in Wuhan, China were reported to the World Health Organization on December 31, 2019. Subsequently, the causative agent was identified as the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and the associated disease was named COVID-19. By June 19, 2020, 117,472 deaths in the United States were attributed to COVID-19.[1]

Clinical characteristics of the disease and predictors of mortality have been described in patients from China, Italy and from cohorts in the Seattle and New York City region.[2-5] In order to further our understanding of the disease, it is important to describe its course in multiple settings to determine the consistency of previously described features and to validate any emerging patterns.

We describe all consecutively admitted patients with COVID-19 to our institution between March 1 and March 31, 2020 to both characterize the population that requires hospitalization and to explore prognostic indicators.

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METHODS

The protocol was reviewed by the local Institutional Review Board and deemed exempt.

The study was conducted at a large, academic, Midwestern institution which serves as a referral center for the State of Indiana. Surge planning allowed our institution to accommodate up to 278 patients with COVID-19 who may require intensive care and up to 400 patients who may require medical-surgical or progressive levels of care. The first patient with testing confirmed COVID-19 was admitted to our hospital on March 11, 2020.

Initially, polymerase chain reaction based testing was available through coordination with the State Department of Health for all patients. Polymerase chain reaction testing became available within the institution on March 18, 2020. A list of all patients who present to the hospital and have testing performed is maintained by our Infection Preventionist (K.K.). We used this list to identify all patients admitted to the hospital between March 1 and March 31, 2020 whose test results indicated infection by the novel coronavirus.

A data collection form was created in REDCap, a secure web-based tool to facilitate research (data collection form available as supplementary material).[6] Items included demographics, comorbid conditions, clinical presentations, time stamped laboratory values, and hospital course. Data collection was discussed and operationalized between 3 authors who reviewed the electronic medical record of each patient (W.G., E.C., A.K.). The form was pilot tested and edited to enhance ease of use and consistency. Each patient's admission history and physical was reviewed and corroborating diagnostic information was retrieved when relevant (eg. hemoglobin A1c for patients with diabetes mellitus). Presenting symptoms were categorized as (1) respiratory complaints (cough, shortness of breath, and chest pain), (2) gastrointestinal (GI) complaints (nausea, vomiting, diarrhea, and abdominal pain), (3) fever, (4) syncope and altered mental status and, (5) constitutional symptoms (myalgias, anosmia, dysgeusia, anorexia, night sweats, fatigue, and weakness). The first recorded set of vital signs, imaging and laboratory data was captured. Vital signs and respiratory care notes were reviewed to assess the timing and magnitude of increasing oxygen needs. Laboratory data was reviewed for the entire hospital stay. The timing and values of first drawn possible prognosticators were recorded and peak values and timing were captured when these laboratories were checked more than once. Medications prior to admission were determined by reviewing the pharmacist's admission medication history. The medication administration record was accessed to confirm the receipt of COVID-19 specific therapies, steroids and vasopressors. The discharge summary was reviewed for complications. All patients admitted for confirmed or suspected COVID-19 during the study period at our institution had a complete blood count (CBC) and basic chemistries drawn on admission. Timing of prognostic laboratories and clinical trajectories were reported relative to the timing of this admission CBC. Data were collected for all patients until June 5, 2020.

Data were then downloaded from REDCap and described using descriptive statistics. We stratified the sample into three distinct groups of worsening severity based on outcomes: patients who did not receive mechanical ventilation (MV) and survived, those who received MV and survived, and those who received MV and died during the hospitalization.

Laboratory values that may serve as markers of disease severity were compared among these three groups. Based on prior research, laboratory values that were tracked included alanine transaminase, brain natriuretic peptide (BNP), creatine kinase (CK), c-reactive protein (CRP), d-dimer, ferritin, lactate dehydrogenase (LDH), procalcitonin and troponin. First and peak recorded values were retrieved and compared using analysis of variance testing. If testing revealed statistically significant differences in values between groups at $P < .05$, odds ratios were then calculated. At the time of presentation, concerns about the trajectory of patients with COVID-19 often revolve around whether the patient will require MV; and shift towards survival once MV is necessary. To parallel these clinical questions, the first measured values were used to calculate the odds of receiving MV, while peak values were used to calculate the odds of inpatient mortality in those who received MV. The 75th percentile value in the group that did not receive MV and survived was used as the cut-off to calculate the odds for receiving MV, while the 75th percentile value in those who received MV and survived was used as the cut-off to calculate the odds of mortality in those who received MV. The timing of both the first and peak prognostic laboratory values relative to the admission CBC time were also compared between the three groups.

Data was analyzed using the *pandas* package for Python, with Fisher exact testing used for categorical variables and contingency tables. Analysis of variance testing was performed for continuous variables, using the SciPy STATS package.[7] Characteristics of the sample were compared between the 3 outcome groups.

RESULTS

Between March 1 and March 31, 2020, there were 140 admissions to the hospital with testing confirmed COVID-19. More than half (59.3%) of the sample did not receive MV.

There were a total of 22 deaths (15.7% mortality rate) however, 4 patients had goals of care that were focused on comfort and did not receive MV. Of those who received MV, 35 (66%) survived.

Demographics and comorbidities

Overall the sample had roughly equal numbers of males and females; however, 68% of those who received MV were male. The mean age of those who received MV and died was 73 years while the mean age of those who received MV and survived was 55.8 years. More than half the sample (64%) was African American and 67% of those who did not survive MV were African American. Gender and age distribution were statistically significantly different between the three outcome groups (Table 1).

Hypertension and diabetes mellitus were the most frequently noted comorbidities with the overall sample having a mean of 2.9 comorbidities per patient. The mean number of outpatient medications at the time of admission per patient was 7.6. Patients had few inpatient stays in our hospital system before the current encounter with a mean of 0.4 hospitalizations per patient over the prior 12 months.

The group that received MV and survived had the highest mean body mass index (BMI) (36) and the lowest proportion of individuals with normal BMIs. The mean BMI for those who received MV and did not survive was 27.2 which was lower than the mean BMI for the group who did not receive MV (32.3) ($P < .05$ for all pair-wise comparisons of BMI).

Presenting symptoms and initial evaluation

Most patients presented with multiple symptoms, however patients who received MV and died reported fewer symptoms on presentation. Symptoms related to the respiratory system were the most frequent (93.6%) followed by reports of fever (65%) and GI complaints (51%). Fewer patients who received MV and died reported fever on admission and reported shorter duration of symptoms at the time of presentation (Table 2).

While fever was a common complaint, the first mean recorded temperature for all groups was <38°C. More than half the sample (52%) met systemic inflammatory response (SIRS) criteria on

Table 1
Demographics and medical comorbidities: adult admissions for COVID-19 between March 1-March 31, 2020 at an academic health center

	Total	Did not receive Mechanical Ventilation - survived	Received Mechanical Ventilation - survived	Received Mechanical Ventilation - died	*P*-value*
Total number	140	83 (59.3%)	35 (25.0%)	18 (12.9%)	
Gender					.01
Female	68 (48.6%)	48 (57.8%) 1 pregnant	10 (28.6%)	7 (38.9%)	
Male	72 (51.4%)	35 (42.2%)	25 (71.4%)	11 (61.1%)	
Mean age (years)	60	57.8	55.8	72.7	.0001
IQR	48-72	45-69	42-65	67-81	
Race and ethnicity					
African American	90 (64.3%)	60 (72.3%)	17 (48.6%)	12 (66.7%)	.07
White	37 (26.4%)	16 (19.3%)	13 (37.1%)	5 (27.8%)	
Asian	5 (3.6%)	2 (2.4%)	2 (5.7%)	1 (5.6%)	
Hispanic	7 (5.0%)	5 (6.0%)	2 (5.7%)	0 (0.0%)	
Not recorded	1 (0.7%)	0 (0.0%)	1 (2.9%)	0 (0.0%)	
Health care worker	11 (7.9%)	10 (12.0%)	1 (2.9%)	0 (0.0%)	.1
Presented from Group living	5 (3.6%)	5 (6.0%)	0 (0.0%)	0 (0.0%)	.3
Mean number of comorbid conditions per patient	2.9	2.7	2.9	3.2	.4
IQR	2-4	2-4	2-4	2-4	
Hypertension	96 (68.6%)	53 (63.9%)	25 (71.4%)	14 (77.8%)	.4
Diabetes mellitus	51 (36.4%)	24 (28.9%)	17 (48.6%)	7 (38.9%)	.1
Mean Hemoglobin A1c in the last 6 months	8.3 n=47	8.5 n=22	8.7 n=16	7 n=5	.5
Chronic lung disease†	28 (20.0%)	15 (18.1%)	5 (14.3%)	6 (33.3%)	.2
Ischemic heart disease	27 (19.3%)	15 (18.1%)	6 (17.1%)	5 (27.8%)	.5
Congestive heart failure	22 (15.7%)	9 (10.8%)	6 (17.1%)	4 (22.2%)	.3
Mean ejection fraction if echo in last 24 months	48.4 n = 20	46.2 n = 8	50.5 n = 6	38.2 n = 4	.1
Immune-suppressed‡	12 (8.6%)	6 (7.2%)	3 (8.6%)	3 (16.7%)	.5
Adult asthma	15 (10.7%)	10 (12.0%)	4 (11.4%)	1 (5.6%)	.8
Dialysis dependent	11 (7.9%)	8 (9.6%)	1 (2.9%)	1 (5.6%)	.5
History of malignancy§	11 (7.9%)	7 (8.4%)	1 (2.9%)	2 (11.1%)	.3
Recent cancer treatment	4 (2.9%)	2 (2.4%)	1 (2.9%)	1 (5.6%)	.7
Transplant recipient¶	4 (2.9%)	3 (3.6%)	1 (2.9%)	0 (0.0%)	1.0
Stroke/TIA	8 (5.7%)	4 (4.8%)	1 (2.9%)	2 (11.1%)	.3
HIV positive	3 (2.1%)	1 (1.2%)	1 (2.9%)	1 (5.6%)	.3
CD4 counts		418	169	198	
Chronic hepatitis	2 (1.4%)	2 (2.4%)	0 (0.0%)	0 (0.0%)	1.0
Smoking status					
Current smoker	10 (7.1%)	5 (6.0%)	4 (11.4%)	1 (5.6%)	.6
Never smoker	82 (58.6%)	48 (57.8%)	24 (68.6%)	7 (38.9%)	.1
Mean number of medications	7.6	7	7.7	9	.4
IQR	3-12	2-10	5-11	6-12	
Angiotensin-converting enzyme inhibitor use	26 (18.6%)	14 (16.9%)	5 (14.3%)	5 (27.8%)	.4
Angiotensin receptor blocker use	29 (20.7%)	17 (20.5%)	9 (25.7%)	3 (16.7%)	.7
Mean BMI	32.4	32.3	36	27.2	.01
IQR	25-38	25-39	30-38	22-30	
BMI Categories					
Underweight (BMI <18.5)	7 (5.0%)	5 (6.3%)	0 (0.0%)	2 (11.1%)	.1
Normal (BMI 18.5-24.9)	25 (17.9%)	15 (19.0%)	1 (2.9%)	7 (38.9%)	.002
Overweight (BMI 25-29.9)	29 (20.7%)	14 (17.7%)	10 (28.6%)	4 (22.2%)	.3
Class I Obesity (BMI 30-34.9)	28 (20.0%)	15 (19.0%)	9 (25.7%)	3 (16.7%)	.6
Class 2 Obesity (BMI 35-39.9)	23 (16.4%)	14 (17.7%)	8 (22.9%)	1 (5.6%)	.3
Class 3 Obesity (BMI ≥40)	24 (17.1%)	16 (20.3%)	7 (20.0%)	1 (5.6%)	.4
Mean number of hospitalizations in the last 12 months	0.4	0.4	0.3	0.8	.1
IQR	0-0	0-0	0-0	0-1	

BMI, body mass index; HIV, human immunodeficiency virus; IQR, interquartile range; SD, standard deviation; TIA, transient ischemic attack.
**P* values comparing the three outcome groups. Total column includes 4 patients whose goals of care focused on comfort.
†Chronic lung disease = COPD, sarcoidosis, interstitial lung disease, pulmonary hypertension, cystic fibrosis, restrictive lung disease.
‡Immune suppressed = chronic steroid use, biologic agents for rheumatologic disorders or inflammatory bowel disease, recent chemotherapy, hematologic malignancy, history of bone marrow or solid organ transplant.
§Site of malignancy = lung (1), breast (2), colon (1), head and neck (1), renal (1), melanoma (1), prostate (4), hematologic (1) one patient had both prostate and colon cancer.
¶2 lung transplant, 2 kidney transplant recipients.

admission; however, the distribution of the mean quick sequential organ failure assessment (Q SOFA) score differed between the three groups with the highest mean score noted in those who received MV and died.[8]

Initial chest X-ray imaging was normal in 13.6% of presentations and bilateral infiltrates were the most commonly noted abnormality (69%). Bilateral infiltrates were less frequently observed in those who did not receive MV and survived.

Table 2
Details of initial clinical presentation for adult admissions for COVID-19 between March 1-March 31, 2020 at an academic health center

	Total	Did not receive Mechanical Ventilation - survived	Received Mechanical Ventilation-survived	Received Mechanical Ventilation – died	*P*-value*
Total number	140	83	35	18	
Mean number of symptoms	4.1	4.5	3.9	2.9	.001
IQR	3-5	3-6	3-5	2-4	
Symptom categories					
Respiratory	131 (93.6%)	79 (95.2%)	31 (88.6%)	17 (94.4%)	.3
Gastrointestinal	72 (51.4%)	49 (59.0%)	15 (42.9%)	6 (33.3%)	.07
Fever	91 (65.0%)	59 (71.1%)	23 (65.7%)	7 (38.9%)	.03
Syncope, altered mental status	18 (12.9%)	14 (16.9%)	2 (5.7%)	2 (11.1%)	.2
Constitutional	70 (50.0%)	45 (54.2%)	18 (51.4%)	5 (27.8%)	.1
Mean duration of symptoms (days)	7.7	7.2	9.5	5.4	.009
IQR	4-10	4-9	5-14	4-7	
Mean first Temperature (°C)	37.6	37.6	37.6	37.4	.6
IQR	37-38	37-38	37-38	36-39	
Mean first systolic BP (mm Hg)	133.8	133.3	138	126.7	.2
IQR	118-148	118-147	120-156	114-142	
Mean first heart rate (beats/min)	98.6	99	99.4	99.9	.9
IQR	86-110	86-112	85-108	86-111	
Mean first respiratory rate (breaths/min)	22.2	21.5	22.9	23.9	.1
IQR	18-25	18-24	18-26	19-28	
Met SIRS criteria†	73 (52.1%)	40 (48.2%)	21 (60.0%)	12 (66.7%)	.2
Mean QSOFA score**	0.7	0.5	0.9	1.1	.003
IQR	0-1	0-1	0-1	0-2	
Chest X ray findings					
Normal	19 (13.6%)	15 (18.5%)	2 (5.7%)	1 (5.9%)	.1
Bilateral infiltrates	97 (69.3%)	51 (63.0%)	29 (82.9%)	15 (88.2%)	.03
Unilateral infiltrates	21 (15.0%)	15 (18.5%)	4 (11.4%)	1 (5.9%)	.3
Mean white count (k/mm^3)	7.4	6.7	8.2	9.7	.001
IQR	5-9	5-8	5-10	6-12	
Mean hemoglobin (gm/dL)	13.2	13.2	13.6	12.8	.37
IQR	12-14	12-14	12-14	10-15	
Mean platelet count (k/mm^3)	216.1	228.2	204.7	195.4	.2
IQR	146-266	151-277	148-254	140-239	
Mean absolute neutrophil count (k/mm^3)	5.4	4.8	6.3	7.2	.002
IQR	3-7	3-6	3-7	5-9	
Mean absolute lymphocyte count (k/mm^3)	1.1	1.1	0.9	1.4	.3
IQR	0.6-1.2	0.7-1.4	0.6-1.0	0.6-1.0	
Mean sodium (mmol/L)	136.5	136.6	135.8	137.4	.3
IQR	134-139	134-138	134-138	134-140	
Mean blood urea nitrogen (mg/dL)	24.2	20.3	24.1	37.7	.0009
IQR	12-29	11-23	13-29	22-51	
Mean creatinine (mg/dL)	1.8	1.8	1.6	2	.8
IQR	1-2	1-1	1-1	1-2	
Mean glucose (mg/dL)	142.1	132.4	163.1	145.6	.1
IQR	103-146	102-129	108-166	113-158	
Co-infection by Respiratory viral panel	3/97 3%	Rhinovirus (1) Bordatella *parapertussis* (1)	0	Human metapneumovirus (1)	

BP, blood pressure; IQR, interquartile range.
**P* values comparing the three outcome groups. Total column includes 4 patients whose goals of care focused on comfort.
†SIRS= systemic inflammatory response syndrome (met ≥ 2 of the following criteria: Temp > 38°C, HR> 90, RR> 20, white count > 12k or < 4k).
**q SOFA =quick sequential organ failure assessment (1 point each for Glasgow coma scale < 15, respiratory rate >= 22, systolic BP < = 100).

Mean presenting white counts, absolute neutrophil counts and blood urea nitrogen values were noted to be highest amongst those who received MV and died.

Only 3% of patients had a coinfection detected by respiratory viral panel testing.

Clinical trajectory

Upon initial presentation, 79 patients (56%) did not receive supplemental oxygen while 26 (18.6%) did not receive any supplemental oxygen throughout the stay.

In patients who did not receive MV support and survived, the mean peak oxygen requirement by nasal cannula was 5.1 L. If needs were not met by nasal cannula, the mean peak FiO2 was 42.5%. These peak needs were reached in a mean of 32.4 hours following admission.

Patients who received MV and survived had a mean peak preintubation requirement of 12.1 liters by nasal cannula or mean FiO2 80% when nasal cannula did not suffice, reaching this peak in a mean of 35.9 hours following admission. In those who received MV and died, mean peak preintubation requirements by nasal cannula were 10.25 liters or FiO2 72.5%. These peak needs were reached in a mean of 36.1 hours following admission (Supplementary Table 1).

The mean time to MV from admission in those who survived was 30 hours and for those who died was 52.5 hours ($P = .1$).

Laboratory values and prognostication

Laboratory values that showed differences in distribution between groups with *P*-value <.05 in the first reported values included BNP, d-dimer, LDH, and procalcitonin. Odds ratio using the specified cut-offs for receiving MV were statistically significant for each of these laboratory values with the highest odds ratio (10.5) for

receiving MV noted for d-dimer values elevated above 575.5 ng/mL (Tables 3 and 4).

Alanine transaminase, BNP, CK, CRP, d- dimer IL-6, and LDH values were statistically different between the groups at peak and were used to calculate the odds for mortality in patients receiving MV. At the thresholds used, only peak BNP achieved statistical significance with levels elevated above 167.5 pg/mL associated with a 6.8-fold increased risk for mortality in patients receiving MV (Tables 3 and 4).

Ferritin and troponin did not achieve statistically significant differences between groups at either first or peak measured values.

The timing of first reported laboratory values relative to admission CBC were similar between the 3 groups, however there were statistically significant differences in when peak values of CK,CRP, ferritin, procalcitonin, and troponin were achieved between the groups (Table 3).

Treatment

Most (n = 109, 78%) patients received at least one dose of hydroxychloroquine during the course of the hospitalization. At least one dose of azithromycin was given in 68% (n = 95) of cases. Six (4%) patients received tociluzimab and 1 (0.7%) received remdesivir. Systemic steroids were administered in 44 (31%) patients.

Outcomes and complications

The mean length of stay was 6.5 days for patients who did not receive MV and 21.3 days for those who received MV and survived ($P < .00001$).

Shock requiring vasopressors was noted in 54.3% of those who survived MV and in 77.8% of those who received MV and died. Secondary bacterial infection which included pneumonia and bacteremia was common amongst those who received MV (noted in 42.9% of survivors who received MV and in 44.4% of those who received MV and died). Venous thromboembolism occurred in 3.6% of patients who did not receive MV and survived, in 20% of those who received MV and survived and in 27.8% of those who received MV and died. The 14-day readmission rate was 8.4% for those who did not receive MV and 11.4% for those who did. Renal failure necessitating the initiation of renal replacement therapy was noted in a third of those who received MV and died (Table 5).

DISCUSSION

We present in rich detail the clinical characteristics, laboratory evaluation, trajectories, and outcomes of all patients admitted with COVID-19 to our institution in March 2020 and explore prognostic implications of certain clinical and laboratory markers.

Our data corroborates the increased risk of severe disease and mortality in COVID-19 conferred by increasing age and male gender noted in previous studies. An early US report found a mortality rate of 67% in patients admitted to the intensive care unit where the mean age of the population was 70 years, and more serious illnesses in the US have been noted in older adults.[9,10] In our sample, while more males received ventilatory support than females, these differences were less marked than the initial data from China where 85% of those who required ICU care were male.[4] Data from hospitalized patients in the New York City area also noted worse outcomes in older and male patients.[11] Strategies to protect vulnerable, older adults should continue to be prioritized and further data adjusted for potential confounders will be needed to explore gender related disparities in COVID-19 outcomes.

We also note racial differences in the epidemiology of COVID-19. African Americans represented 64% of all hospitalized COVID-19 patients in our sample. To place this in perspective, in the five months preceding March 2020, the proportion of patients admitted to our facility who were African American was 21%. Our work does not allow us to explain the root causes of these differences however urgent attention is needed to understand and mitigate this trend.

Diabetes mellitus was the most frequently reported comorbid condition in patients hospitalized with COVID-19 in China.[2,4] However, both our sample and a large series from New York City found hypertension to be the most frequent comorbidity noted in patients hospitalized with COVID-19.[2,11] Interestingly, patients admitted for COVID-19 in our sample did not appear to be high utilizers of health care with few prior hospitalizations within our system.

There is data emerging linking obesity and increased disease severity in COVID-19.[12]

We found similar higher mean BMIs in patients who received MV compared to those who did not. However, in those who received MV but died, mean BMIs fell in the overweight category with more than a third of those who died having normal BMIs. The interaction between weight, need for MV and outcomes when ventilated requires further exploration.

In terms of presenting symptoms, half the patients in our sample had GI complaints, higher than reports from China where GI symptoms were recorded for only 13% of patients.[13]

Fewer patients who received MV and died reported fever as a presenting complaint and presented with a shorter duration of symptoms. These findings may offer clues to the differences in presentation that may signal different trajectories.

Presenting vital signs between patients in the 3 outcome groups appeared comparable and the high prevalence of meeting SIRS criteria on admission limits its utility as a predictor of clinical trajectory. However, q SOFA scoring on admission may prove to be a useful prognosticator on admission. Imaging and laboratory evaluations may also be helpful in guiding initial clinical concern as the presence of bilateral infiltrates, higher white counts, higher absolute neutrophil and blood urea nitrogen values on admission were noted more frequently in those who received MV and died.

Patients appear to “declare” themselves in the first 48 hours of admission with the mean time to reaching maximum oxygen requirements ranging from 32 to 36 hours following admission. Statistically nonsignificant differences were noted in the times to receiving MV. While the time from admission to MV in those who subsequently survived appears to be shorter than the time from admission to MV in those who died, we cannot determine whether this observation represents a difference in the rate of decline (with slower rates of decline portending worse prognosis), an impact on outcomes by early versus late MV or whether the decision to intubate was impacted by the team’s awareness of prognosis.

Several laboratory values are being investigated as prognostic markers for severe disease. We analyzed the predictive ability of laboratory evaluations in two critical clinical periods posing two different decisions. We used the first measured values to predict the need for mechanical ventilation and the peak values to predict inpatient mortality in those who were mechanically ventilated. Multiple studies and our own data have demonstrated the marked derangements seen in patients with COVID-19.[14] Accordingly, we used cutoff values derived from the distribution of our own data set rather than reference ranges as thresholds to calculate odds ratios to present more meaningful and discriminatory interpretations for clinicians. D-dimer values have been reported to be abnormal in more than a third of patients presenting in China and with values >1,000 ng/mL associated with mortality.[13] Our findings indicate that initial d-dimer values may also be used to predict the need for mechanical ventilation with values >575.5 ng/mL conferring a 10.5-fold increase in risk. Increasing procalcitonin and LDH values have also been associated with increased odds of mortality in COVID-19.[4,15] Our findings indicate that their first reported values may also predict the need for

Table 3
Initial and peak laboratory values in all patients

Laboratory	Total	Did not receive mechanical ventilation - survived	Received Mechanical Ventilation - survived	Received Mechanical Ventilation – died	*P*-value*
First measured ALT					
Mean value (units/L)	32.9	32.1	35.7	33.9	0.8
IQR	16-37	14-34	21-41	18-47	
Mean time to first measured value (hours)	8.8	6.9	7.8	19.8	.05
Peak measured ALT					
Mean value (units/L)	140	45.2	135.9	445.1	.00001
IQR	25-111	16-60	66-160	57-748	
Mean time to peak value (hours)	152.7	101.7	182.9	152.4	.1
First measured BNP					
Mean value (pg/mL)	259.6	167.1	144.1	587.4	.04
IQR	35-120	39-105	26-101	80-342	
Mean time to first measured value (hours)	1158.5	2450.2	58.2	46	.5
Peak measured BNP					
Mean value (pg/mL)	434.8	154	116.4	1276.3	.001
IQR	66-423	42-221	56-168	514-1636	
Mean time to peak value (hours)	103.9	78	124.3	103.8	.3
First measured CK					
Mean value (units/L)	742.1	463.6	859.9	1820	.1
IQR	76-325	78-230	47-273	248-2279	
Mean time to first measured value (hours)	42.1	32	66.5	46.7	.3
Peak measured CK					
Mean value (units/L)	1174.1	594.6	1634.9	3130.7	.03
IQR	106-1126	100-340	126-1762	1474-2905	
Mean time to peak value (hours)	149.1	84.7	257	153.3	<.00001
First measured CRP					
Mean value (mg/dL)	13.3	11	18.7	12.3	.1
IQR	5-15	3-12	10-27	8-14	
Mean time to first measured value (hours)	730.3	1239	32.1	15.2	.7
Peak measured CRP					
Mean value (mg/dL)	19.9	12.3	27.6	28.7	<.00001
IQR	10-28	7-16	23-33	18-41	
Mean time to peak value (hours)	116.2	70.1	147.6	162.9	.01
First measured D-dimer					
Mean value (ng/mL)	1874.9	550.1	846.9	6743.2	.001
IQR	291-984	234-576	379-886	886-4478	
Mean time to first measured value (hours)	1112.3	33.7	47.4	5534.6	.1
Peak measured D-dimer					
Mean value (ng/mL)	5857.5	1605.6	4598.7	13354.7	.008
IQR	683-4206	383-1039	930-4056	2528-12396	
Mean time to peak value (hours)	5.6	2.4	14	1.4	.2
First measured ferritin					
Mean value (ng/mL)	1211.4	1356.9	1165.2	723.8	.6
IQR	275-1044	191-969	379-1324	240-838	
Mean time to first measured value	855.8	1555.1	44.6	46.4	.6
Peak measured ferritin					
Mean value (ng/mL)	2740.1	2519.1	1677.7	5477.7	.1
IQR	348-2157	289-1325	788-2187	271-3074	
Mean time to peak value (hours)	16.2	0	21.8	7.3	<.00001
First measured IL-6					
Mean value (pg/mL)	33.5	12	42.5	35.8	.08
IQR	5-38	2-12	8-54	10-30	
Mean time to first measured value (hours)	1398.2	4640.5	59	60.4	.3
Peak measured IL-6					
Mean value (pg/mL)	130.4	0	119.9	144.8	<.00001
IQR	41-170	0-0	34-170	46-100	
Mean time to peak value (hours)	953.7	1803.4	110.3	164.6	.6
First measured LDH					
Mean value (units/L)	432.2	360.9	489.4	562.9	.0002
IQR	305-519	260-446	358-579	342-736	
Mean time to first measured value (hours)	24.4	20.7	28.6	30.9	.5
Peak measured LDH					
Mean value (units/L)	772.9	448	631.7	1716.2	.001
IQR	368-719	316-519	504-696	524-1224	
Mean time to peak value (hours)	63.1	44.6	99.2	86.4	.2
First measured procalcitonin					
Mean value (ng/mL)	1.4	0.3	1.8	4.7	.007
IQR	0-1	0-0	0-1	0-3	
Mean time to first measured value (hours)	733.9	11.8	2622.8	14.6	.2
Peak measured procalcitonin					
Mean value (ng/mL)	3.2	1.8	2.7	5.6	.2
IQR	0-2	0-1	0-2	1-4	

(*continued*)

Table 3 (*Continued*)

Laboratory	Total	Did not receive mechanical ventilation - survived	Received Mechanical Ventilation - survived	Received Mechanical Ventilation – died	*P*-value*
Mean time to peak value (hours)	166.1	0	160.8	173.5	<.00001
First measured troponin					
Mean value (ng/mL)	0.3	0	0.8	0.2	.3
IQR	0-0	0-0	0-0	0-0	
Mean time to first measured value (hours)	0.6	0	1.8	0.8	.1
Peak measured troponin					
Mean value	0.6	0	1.8	0.8	0.1
IQR	0-0	0-0	0-0	0-1	
Mean time to peak value (hours)	111.6	37.9	133.4	146.2	.04

IQR, interquartile range; ALT,alanine transaminase; BNP, B type natriuretic peptide; CK, creatine kinase; CRP, C-reactive protein; LDH, lactate dehydrogenase.
Reference ranges: ALT = 7-52, BNP = 0-100, CK = 30-223,CRP = <1, D-dimer <=292, ferritin = 15-400, LDH-140-271, procalcitonin = <0.5 low risk for sepsis,>2 high risk for sepsis, troponin <=0.03.
**P* values comparing the three outcome groups. Total column includes 4 patients whose goals of care focused on comfort.

Table 4
Unadjusted odds ratios for receiving mechanical ventilation and mortality if mechanically ventilated based on laboratory evaluation

Laboratory type	Laboratory value	Cut-off threshold	Outcome	Odds Ratio	*P*-value
First measured value					
	D-Dimer (ng/mL)	575.5	Receive mechanical ventilation	10.5	<.00001
	Procalcitonin (ng/mL)	0.24	Receive mechanical ventilation	5.06	.00004
	LDH (units/L)	445.5	Receive mechanical ventilation	4.46	.0003
	BNP (pg/mL)	104.75	Receive mechanical ventilation	2.95	.03
Peak value					
	BNP (pg/mL)	167.5	Inpatient mortality if mechanically ventilated	6.79	.02
	D-Dimer(ng/mL)	4055.5	Inpatient mortality if mechanically ventilated	2.15	.3
	LDH (units/L)	695.75	Inpatient mortality if mechanically ventilated	2.15	.3
	CRP (mg/dL)	33.47	Inpatient mortality if mechanically ventilated	1.69	.5
	ALT (units/L)	159.75	Inpatient mortality if mechanically ventilated	1.3	.7
	CK (units/L)	1762	Inpatient mortality if mechanically ventilated	3.05	.2
	IL-6 (pg/mL)	170	Inpatient mortality if mechanically ventilated	2.06	.6

ALT, alanine transaminase; BNP, brain natriuretic peptide; CK, creatine kinase; CRP, c-reactive protein; IL-6, interleukin 6; LDH, lactate dehydrogenase.

mechanical ventilation. We additionally identified the potential of first and peak BNP values to predict the need for mechanical ventilation and mortality respectively. Previous reports have found ferritin and troponin values to be predictive of mortality.[5,16] In our sample, however, these values were not statistically significantly different between groups at either first or peak measurement. Our findings may form the basis of future work to create scoring systems to improve our ability to predict the trajectory of patients presenting with COVID-19, stratify risk and guide subsequent management. The differences in the timing of peak values noted for certain laboratory

Table 5
Outcomes and complications for adult patients admitted with COVID-19 between March 1- March 31, 2020 at an academic health center

	Total	Did not receive Mechanical Ventilation- survived	Received Mechanical Ventilation - survived	Received Mechanical Ventilation- died	*P*-value*
Total	140	83	35	18	
Mean length of stay (days)	10.7	6.5	21.3	12.8	.00001
IQR	4-15	3-8	12-25	8-16	
Mean days on ventilator	10.9	NA	11.1	10.6	.03
IQR	6-14		6-14	6-13	
Readmitted within 14 days	11 (7.9%)	7 (8.4%)	4 (11.4%)	NA	.7
Shock requiring vasopressors	33 (23.6%)	0 (0.0%)	19 (54.3%)	14 (77.8%)	1.0
Secondary infection	27 (19.3%)	3 (3.6%)	15 (42.9%)	8 (44.4%)	2.0
Adult respiratory distress syndrome	19 (13.6%)	0 (0.0%)	13 (37.1%)	6 (33.3%)	2.0
Acute kidney injury	41 (29.3%)	14 (16.9%)	12 (34.3%)	12 (66.7%)	.00006
Venous thromboembolism	15 (10.7%)	3 (3.6%)	7 (20.0%)	5 (27.8%)	.0007
New need for renal replacement therapy	10 (7.9%)	0 (0.0%)	4 (11.4%)	6 (33.3%)	.000004
Arrythmias	21 (15.0%)	8 (9.6%)	8 (22.9%)	5 (27.8%)	.04
Other complications***	37 (26.4%)	13 (15.7%)	14 (40.0%)	9 (50.0%)	.001
New O2 requirement upon discharge	3 (2.1%)	2 (2.4%)	1 (2.9%)	NA	.9
Discharge disposition not home	16 (11.4%)	6 (7.2%)	10 (28.6%)	NA	.005

Notes:
***'Other' complications included diabetic ketoacidosis (2), prolonged encephalopathy/ delirium (6) thrombocytopenia (2) stridor following extubation (3).
IQR, interquartile range; NA, not applicable; O2, oxygen.
**P* values comparing the three outcome groups. Total column includes 4 patients whose goals of care focused on comfort.

values (CK, CRP, ferritin, procalcitonin, and troponin) raise additional areas for future research.

The medical management of these patients appears to be complex and resource intensive with multiple complications, long lengths of stay and need for placement upon discharge. In addition to shock, venous thromboembolism and secondary bacterial infections, we also noted patients with prolonged encephalopathy and sequelae of prolonged intubation. Long-term monitoring is needed to identify delayed or prolonged deficits arising from the initial illness.

Our study has limitations. It is a single center's experience with a novel illness over the first month of its appearance at our institution. We relied on discharge summary documentation of complications with targeted review of corroborating diagnostics and may therefore be under reporting adverse outcomes. While our health system shares an electronic medical record platform across all 18 hospitals, we did not access city wide data to confirm readmissions or prior hospitalizations. Importantly, we present unadjusted odds ratios and analysis of differences between the three outcome groups. The differences found should be considered exploratory and hypothesis generating requiring confirmation in larger, multivariate analysis.

As the burden of this novel disease grows, sharing clinical information about patients will help us generate hypotheses and adapt our management and prevention strategies. Continued research on presentations, outcomes and complications in different settings and over longer periods will help improve the care we provide our patients.

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SUPPLEMENTARY MATERIALS

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