original reports

COVID-19 Severity and Outcomes in Patients With Cancer: A Matched Cohort Study

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abstract

PURPOSE SARS-CoV-2 (COVID-19) is a systemic infection. Patients with cancer are immunocompromised and may be vulnerable to COVID-related morbidity and mortality. The objectives of this study were to determine if patients with cancer have worse outcomes compared with patients without cancer and to identify demographic and clinical predictors of morbidity and mortality among patients with cancer.

METHODS We used data from adult patients who tested positive for COVID-19 and were admitted to two New York–Presbyterian hospitals between March 3 and May 15, 2020. Patients with cancer were matched 1:4 to controls without cancer in terms of age, sex, and number of comorbidities. Using Kaplan-Meier curves and the log-rank test, we compared morbidity (intensive care unit admission and intubation) and mortality outcomes between patients with cancer and controls. Among those with cancer, we identified demographic and clinical predictors of worse outcomes using Cox proportional hazard models.

RESULTS We included 585 patients who were COVID-19 positive, of whom 117 had active malignancy, defined as those receiving cancer-directed therapy or under active surveillance within 6 months of admission. Presenting symptoms and in-hospital complications were similar between the cancer and noncancer groups. Nearly one half of patients with cancer were receiving therapy, and 45% of patients received cytotoxic or immunosuppressive treatment within 90 days of admission. There were no statistically significant differences in morbidity or mortality ($P = .894$) between patients with and without cancer.

CONCLUSION We observed that patients with COVID-19 and cancer had similar outcomes compared with matched patients without cancer. This finding suggests that a diagnosis of active cancer alone and recent anticancer therapy do not predict worse COVID-19 outcomes and therefore, recommendations to limit cancer-directed therapy must be considered carefully in relation to cancer-specific outcomes and death.

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INTRODUCTION

New York City (NYC) has been at the epicenter of the public health epidemic caused by the SARS-CoV-2 (COVID-19) pandemic. As of July 2020, there have been more than 200,000 confirmed cases in NYC. Initial reports have described the characteristics of patients with COVID-19,[1,2] and although COVID-19 manifests primarily as a respiratory tract infection, emerging data indicate a more systemic infection with a variety of multisystem manifestations.[3,4] As such, patients with cancer may be particularly vulnerable to COVID-19 because of immunocompromise from underlying disease and the sequalae of cancer-directed treatment.

Early reports from China regarding COVID-19 stated that patients with cancer were more susceptible to infection by COVID-19 and that they experienced higher rates of severe complications.[5-9] In these studies, cancer-directed therapy within 14 days of admission resulted in increased rates of intensive care unit (ICU) admission, invasive ventilation, and death.[7] Two additional cohort studies reported that patients with cancer had a higher risk of critical illness and fatalities compared with patients without cancer.[10,11] However, these studies did not control for confounding factors including age, sex, and comorbidities, which are known contribute to worse patient outcomes.[12]

Some institutions in the United States have recently reported similar trends, including higher rates of COVID-related complications and death among patients with cancer compared with patients without cancer.[12-15] However, interpretation of these studies is also limited because of heterogeneous cancer populations, small sample sizes, and limited comparisons to cohorts without cancer.[16] On the basis of these sparse data, the care of patients with cancer has been altered or delayed significantly and perhaps compromised.[17-18] Guidelines have further recommended caution when treating patients with cancer.[19-21]

ASSOCIATED CONTENT

Appendix

Author affiliations and support information (if applicable) appear at the end of this article.

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CONTEXT

Key Objective

Patients with cancer, and particularly those receiving active treatment, are suggested to be at increased risk of poor outcomes when contracting the novel coronavirus, SARS-CoV-2 (COVID-19). However, it is unclear if this increased risk is a result of malignancy, its treatment, or other factors. This study evaluated the morbidity and mortality of hospitalized COVID-19–infected patients with cancer compared with a matched cohort of patients without cancer.

Knowledge Generated

We observed no differences in the rate of intensive care unit (ICU) admission, ventilation, or death between patients with and without cancer who were hospitalized with COVID-19. Patients with cancer undergoing anticancer therapy also had no differences in outcomes including ICU admission, ventilation, or death compared with patients who were not receiving anticancer therapy.

Relevance

Our results suggest that patients with cancer with limited comorbidities may continue their cancer care with caution.

However, we must accept the realization that cancer treatment can be lifesaving and often improves patients' outcomes, making the decision of how to manage cancer in the context of COVID-19 all the more acute.[17] As oncology practices cautiously decrease cancer-directed therapies because of COVID-19, we must consider the consequences that limited care for patients with cancer have on cancer-specific outcomes and mortality. Given the outstanding question of the impact of COVID-19 in patients with cancer, and those receiving anticancer therapy, the objective of this study was to determine whether patients with cancer developed higher rates of morbidity and mortality compared with a matched noncancer population.

METHODS

Study Design and Setting

We used data from a retrospective observational cohort of adult patients who presented to the emergency department (ED) at two New York–Presbyterian (NYP) hospitals (Weill Cornell Medicine and Lower Manhattan Hospital) between March 3 and May 15, 2020, and who tested positive for COVID-19, defined as a positive reverse transcription polyerase chain reaction (RT-PCR) assay. Both hospitals are academic institutions that deliver similar high-quality care. The development of this cohort has been described previously.[2] This study was approved by the Weill Cornell Medicine Institutional Review Board, which waived informed consent.

Cancer cohort. We included all consecutively hospitalized patients with an active hematologic or solid tumor malignancy who tested positive for COVID-19. Active malignancy was defined as cancer-directed therapy (eg, chemotherapy, targeted therapy, immunotherapy, radiotherapy, or surgery) or active surveillance within 6 months of COVID-19 diagnosis and ongoing management. Each record of active malignancy was independently reviewed and verified by two oncologists (G.B. and M.S.).

Noncancer controls. Every cancer case was matched to four COVID-19–positive noncancer controls. Matching was performed in terms of age, sex, and number of comorbid conditions (obesity, diabetes, hypertension, chronic obstructive pulmonary disease [COPD], asthma, end-stage renal disease, cirrhosis, coronary artery disease, heart failure, and HIV). Comorbidities were grouped into five categories: 0, 1, 2, 3, and ≥ 4. Age was categorized into six 10-year age groups from 30 to 99 years.

Primary Outcome

Our primary study outcome was a composite incident outcome of (1) ICU admission, (2) intubation, and (3) death. Only an individual's incident event was considered.

Covariables. From the electronic health record, we considered age, sex, ethnicity, pre-existing comorbidities (smoking status, obesity, hypertension, COPD, asthma, end-stage renal disease, coronary artery disease, heart failure, cirrhosis, and HIV), and medications taken at home. We also included each patient's highest level of supplemental oxygen within 3 hours of ED admission, and chest radiographic findings. First vital signs at ED presentation (body temperature, heart rate, blood pressure, and respiratory rate) and laboratory tests within 48 hours of ED admission (CBC, metabolic panel, coagulation factors, and inflammatory markers including troponin, D-dimer, ferritin, erythrocyte sedimentation rate, C-reactive protein, fibrinogen, lactase dehydrogenase (LDH), creatine kinase, and procalcitonin) were obtained from the electronic health record through an automated algorithm.[22]

Cancer-specific covariables. Cancer-specific covariables included cancer type, stage, diagnosis date, cancer treatment, and date of last cancer treatment, which were

TABLE 1. Characteristics of 585 Hospitalized Patients With COVID-19: Demographics, Clinical Variables, and ER Presentation, Overall and by Cancer Status

Characteristic	Total No. With Data Available	Total (N = 585), %	Noncancer (n = 468), No. (%)	Cancer (n = 117), No (%)
Demographics on admission				
Age, years	585 of 585	71.3 (62.2-79.7)[a]	71.2 (62.1-79.6)[a]	72.5 (64.2-79.9)[a]
Male	320 of 585	54.7	256 (54.7)	64 (54.7)
Ethnicity				
White	233 of 585	39.8	178 (38.0)	55 (47.0)
Black	78 of 585	13.3	57 (12.2)	21 (18.0)
Asian	117 of 585	20.0	104 (22.2)	13 (11.1)
Other	103 of 585	17.6	87 (18.6)	16 (13.7)
Not reported	54 of 585	9.2	42 (9.0)	12 (10.3)
Health care worker	25 of 585	4.3	25 (5.3)	0 (0.0)
Hospital location				
Weill Cornell Medical Center	466 of 585	79.7	364 (77.8)	102 (87.2)
Lower Manhattan Hospital	119 of 585	20.3	104 (22.2)	15 (12.8)
Admitted from				
Home	489 of 585	83.6	397 (84.8)	92 (78.6)
Rehabilitation/nursing home	62 of 585	10.6	45 (9.6)	17 (14.5)
Other hospital	7 of 585	1.2	6 (1.3)	1 (0.9)
Other/undomiciled	27 of 585	4.6	20 (4.3)	7 (6.0)
Smoking history				
Never smoked	416 of 585	71.2	338 (72.4)	78 (66.7)
Former smoker	147 of 585	25.2	111 (23.8)	36 (30.8)
Current smoker	21 of 585	3.6	18 (3.9)	3 (2.6)
Comorbidities				
Obesity (BMI $\geq$ 30 kg/m^2 [$\geq$ 28 kg/m^2 for Asians]	148 of 585	25.3	120 (25.6)	28 (23.9)
Diabetes	174 of 585	29.7	136 (29.1)	38 (32.5)
Hypertension	331 of 585	56.6	269 (57.5)	62 (53.0)
Chronic obstructive pulmonary disease	42 of 585	7.2	33 (7.1)	9 (7.7)
Asthma	35 of 585	6.0	29 (6.2)	6 (5.1)
End-stage renal disease	26 of 585	4.4	23 (4.9)	3 (2.6)
Cirrhosis	5 of 585	0.9	2 (0.4)	3 (2.6)
Coronary artery disease	100 of 585	17.1	78 (16.7)	22 (18.8)
Heart failure	45 of 585	7.7	32 (6.8)	13 (11.1)
HIV	3 of 585	0.5	3 (0.6)	0 (0.0)
Total count of home medications (excluding over-the-counter medications) < 5	314 of 585	53.7	268 (57.3)	46 (39.3)
Use of immunosuppressive medication (within last 30 days)				
None	66 of 585	11.3	38 (8.1)	28 (23.9)
Prednisone < 20 mg/d	21 of 585	3.6	15 (3.2)	6 (5.1)
Prednisone $\geq$ 20 mg/d	7 of 585	1.2	5 (1.1)	2 (1.7)
TNF-α inhibitor	2 of 585	0.3	2 (0.4)	0 (0.0)
Other monoclonal antibody	6 of 585	1.0	2 (0.4)	4 (3.4)
Tacrolimus	13 of 585	2.2	11 (2.4)	2 (1.7)
Mycophenolate (MMF, myfortic)	15 of 585	2.6	13 (2.8)	2 (1.7)

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TABLE 1. Characteristics of 585 Hospitalized Patients With COVID-19: Demographics, Clinical Variables, and ER Presentation, Overall and by Cancer Status (continued)

Characteristic	Total No. With Data Available	Total (N = 585), %	Noncancer (n = 468), No. (%)	Cancer (n = 117), No (%)
Methotrexate	3 of 585	0.5	3 (0.6)	0 (0.0)
Other	24 of 585	4.1	5 (1.1)	19 (16.2)
Presenting symptoms				
Fever	367 of 585	62.7	297 (63.5)	70 (59.8)
Cough	387 of 585	66.2	316 (67.5)	71 (60.7)
GI symptoms: diarrhea	130 of 585	22.2	101 (21.6)	29 (24.8)
GI symptoms: nausea or vomiting	107 of 585	18.3	86 (18.4)	21 (18.0)
Myalgias	107 of 585	18.3	97 (20.7)	10 (8.6)
Dyspnea	339 of 585	58.0	276 (59.0)	63 (53.9)
On arrival at emergency room				
Fever (> 38°C)	68 of 484	14.1	54 (14.0)	14 (14.3)
Heart rate ≥ 125 beats/min	42 of 484	8.7	34 (8.8)	8 (8.2)
Systolic blood pressure < 90 mm Hg	0 of 484	0.0	0 (0.0)	0 (0.0)
Respiratory rate > 24 breaths/min	92 of 484	19.0	74 (19.2)	18 (18.4)
Highest level of supplemental O_2 required within first 3 hours				
None	279 of 585	47.7	224 (47.9)	55 (47.0)
Nasal cannula and venturi mask	198 of 585	33.8	152 (32.5)	46 (39.3)
Nonrebreather and high-flow nasal cannula	78 of 585	13.3	68 (14.5)	10 (8.5)
BIPAP or CPAP	8 of 585	1.4	6 (1.3)	2 (1.7)
Invasive mechanical ventilation	22 of 585	3.8	18 (3.8)	4 (3.4)
Initial chest radiology findings				
Clear	83 of 585	14.2	63 (13.5)	20 (17.1)
Unilateral infiltrate	79 of 585	13.5	60 (12.8)	19 (16.2)
Bilateral infiltrates	382 of 585	65.3	311 (66.5)	71 (60.7)
Pleural effusion	34 of 585	5.8	21 (4.5)	13 (11.1)
Other	41 of 585	7.0	32 (6.8)	9 (7.7)
Laboratory findings				
WBC count > 10,000/μL	120 of 534	22.5	92 (21.5)	28 (26.4)
WBC count < 4,000/μL	74 of 534	13.9	47 (11.0)	27 (25.5)
Lymphocyte count < 1,500/μL	433 of 505	85.7	351 (86.2)	82 (83.7)
Neutrophil-to-lymphocyte ratio	507 of 507	6.44 (3.8-11.6)[a]	6.29 (3.9-12.1)[a]	6.54 (3-10.5)[a]
Platelet count < 150,000/μL	136 of 534	25.5	101 (23.6)	35 (33.0)
Serum creatinine ≥ 1.5 mg/dL	115 of 529	21.7	94 (22.2)	21 (19.8)
Serum albumin g/dL	522 of 522	3.3 (2.9-3.7)[a]	3.3 (2.9-3.8)[a]	3.3 (2.8-3.6)[a]
Alanine aminotransferase > 40 U/L	180 of 518	34.8	152 (37.0)	28 (26.2)
AST > 40 U/L	255 of 515	49.5	215 (52.6)	40 (37.7)
Alcanine phosphatase > 140 U/L	53 of 522	10.2	33 (8.0)	20 (18.7)
Total bilirubin > 17.1 μmol/L	83 of 522	15.9	65 (15.7)	18 (16.8)
Glucose, mg/dL	526 of 526	121 (103-160)[a]	121 (103-159.5)[a]	118 (103-170)[a]
D-dimer > 0.5 mg/L	195 of 347	56.2	142 (51.6)	53 (73.6)
Hemoglobin, g/dL	534 of 534	13.2 (11.7-14.5)[a]	13.4 (12.2-14.6)[a]	11.9 (9.9-13.3)[a]
Ferritin > 300 ng/mL	303 of 381	79.5	240 (79.0)	63 (81.8)

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TABLE 1. Characteristics of 585 Hospitalized Patients With COVID-19: Demographics, Clinical Variables, and ER Presentation, Overall and by Cancer Status (continued)

Characteristic	Total No. With Data Available	Total (N = 585), %	Noncancer (n = 468), No. (%)	Cancer (n = 117), No (%)
Erythrocyte sedimentation rate, mm/h	307 of 307	66 (44-92)[a]	67.5 (44-91)[a]	58 (41-95)[a]
C-reactive protein > 10 mg/dL	200 of 387	51.7	159 (51.5)	41 (52.6)
Prothrombin time, seconds	460 of 460	13.5 (12.5-14.8)[a]	13.3 (12.4-14.7)[a]	14.05 (12.8-15.2)[a]
Activated partial thromboplastin time, seconds	450 of 450	31.4 (28.8-34.8)[a]	31.4 (29-34.3)[a]	31.55 (28.1-35.2)[a]
International normalization ratio	460 of 460	1.2 (1.1-1.3)[a]	1.1 (1-1.2)[a]	1.2 (1.1-1.3)[a]
Lactase dehydrogenase, U/L	436 of 436	418.5 (302-555)[a]	430 (317-560)[a]	360 (255-535)[a]
Procalcitonin ≥ 0.5 ng/mL	113 of 411	27.5	83 (25.2)	30 (36.6)

Abbreviations: BIPAP, bilevel positive airway pressure; BMI, body mass index; COVID-19, SARS-CoV-2; CPAP, continuous positive airway pressure; MMF, mycophenolate mofetil; TNF-α, tumor necrosis factor-α.

[a]Median (interquartile range).

abstracted manually from the electronic health record by two oncologists.

Hospitalization events. Hospitalization events that occurred through June 20, 2020, were identified on the basis of a review of clinical progress notes and discharge summaries. Events included cardiovascular sequelae (myocardial infarction, arrhythmias, and heart failure), need for vasopressors, venous thromboembolic events (deep vein thrombosis and pulmonary embolism), new-onset renal replacement therapy, death, and recovery events (extubation among those intubated, and hospital discharge).

Statistical Analyses

Baseline characteristics (demographics, comorbidities, clinical characteristics, and laboratory values), in-hospital treatments, and complications were compared between cancer and noncancer groups. Categorical variables were summarized using counts and percentages, and continuous variables were summarized using medians and interquartile ranges. Our primary outcome was operationalized as the number of days from ED admission date to ICU admission, intubation, or death, with participants censored at the date of event or discharge or June 20, 2020. We examined death as a secondary outcome using Kaplan-Meier plots to explore differences in the risk of death between patients with and without cancer. We examined unadjusted associations between each baseline predictor and our primary composite outcome using marginal Cox proportional hazard models to adjust for clustering by matched observations.[23,24] In models that examined the cancer group separately, we used Cox models that did not account for clustering. Finally, we used multivariable marginal Cox models to estimate the association between cancer status and the composite outcome, adjusting for potential confounders. As a secondary analysis, a multivariable Cox model with the death outcome, separately, was also used. Hazard ratios (HRs) and 95% CIs were calculated for each estimate. The proportional hazards assumption was tested using Schoenfeld residuals. Finally, we used χ^2 tests to examine unadjusted differences in the composite outcome between patients with cancer with hematologic and solid malignancies as well between those who did and did not receive chemotherapy within 90 days of ED presentation. All analyses were conducted in SAS version 9.4 (SAS Institute, Cary, NC). Results were considered statistically significant with a P value level of $< .05$.

RESULTS

Cohort Characteristics

Our study included 585 adult patients who were COVID-19 positive and were admitted to two NYP hospitals. Of these, 117 patients had active malignancy and 468 were matched control patients without cancer. Characteristics of the patients with and without cancer are presented in Table 1. The median age was 71 years, and 55% were male. More patients with cancer were White (47%) compared with patients without cancer (38%). There were more Asian patients in the noncancer group (22.2%) versus the cancer group (11.1%). The majority of patients were nonsmokers (71.2%), with similar percentages of active smokers (2.6% in patients with cancer and 3.9% in patients without cancer). The prevalence of obesity was similar in both groups (23.9% of those with cancer *v* 25.6% of those without cancer). Comorbidities were also similar between the two groups.

COVID-19 Clinical Characteristics

As listed in Table 1, the most common presenting symptoms for patients with and without cancer were cough (60.7% *v* 67.5%), fever (59.8% *v* 63.5%), dyspnea (53.9% *v* 59%), and diarrhea (24.8% *v* 21.6%), respectively. Within the first 3 hours of ED presentation, more patients without cancer required nonrebreather or high-flow nasal cannula (14.5% *v* 8.5%), although patients with and without cancer experienced similar rates of intubation (3.8% *v* 3.4%). Accordingly, patients without cancer had worse initial chest radiology findings with higher rates of

TABLE 2. Characteristics of 117 Hospitalized Patients with COVID-19 and Cancer

Characteristic	No. (n = 117)	Percent
Age, years		
30-49	9	7.7
50-64	21	18.0
65-79	56	47.9
≥ 80	31	26.5
Health conditions		
Cardiac[a]	28	23.9
Lung[b]	13	11.1
Renal	9	7.7
Cirrhosis	3	2.6
Hypertension	62	53.0
No. of health conditions		
0	44	37.6
1	42	35.9
2	21	18.0
≥ 3	10	8.6
Cancer type		
Hematologic diagnoses	42	35.9
Acute leukemia	6	5.1
Chronic leukemia	19	16.2
Lymphoma	7	6.0
Myeloma	10	8.6
Solid tumor diagnoses	75	64.1
Breast	15	12.8
GI	19	16.2
Genitourinary	22	18.8
Gynecologic	6	5.1
Thoracic	1	0.9
Stage (solid tumor)		
S1-S3	22	29.3
Metastatic	26	34.7
Missing	27	36.0
Cancer treatment		
Cytotoxic[c]	52	44.4
Hormone or other[d]	32	27.4
Radiation	14	12.0
Surgery	21	18.0
Time from diagnosis of cancer to admission, months		
< 6	35	29.9
6-12	15	12.8
≥ 12	54	46.2
Missing	13	11.1
Time from chemotherapy to admission < 90 days	43	36.8

Abbreviation: COVID-19, SARS-CoV-2.

[a]Cardiac includes coronary artery disease and heart failure.

[b]Lung includes chronic obstructive pulmonary disease and asthma.

[c]Cytotoxic: chemotherapy and/or immunosuppressive medicines, including targeted agents.

[d]Hormone or other includes active surveillance.

bilateral infiltrates (66.5% *v* 60.7%) compared with patients with cancer. With regard to laboratory findings, patients with cancer had more leukopenia (25.5% *v* 11%), thrombocytopenia (33% *v* 23.6%), anemia, and elevated D-dimer (73.6% *v* 51.6%) compared with controls without cancer.

Cancer-Specific Characteristics

Cancer-specific characteristics are listed in Table 2. Seventy-four percent of patients with cancer were older than 65 years, and 74% of patients had zero to one comorbidity in addition to their cancer. The most common type of cancer was genitourinary (18.8%), followed by GI (16.2%), chronic leukemia (16.2%), and breast (12.8%). Nearly one half of patients (45%) were receiving active cancer therapy, including cytotoxic or immunosuppressive treatment, and 37% of patients had received cytotoxic treatment within 90 days of their ED admission.

In-Hospital Treatments and Complications

Patients both with and without cancer received hydroxychloroquine in similar proportions (57.3% *v* 56.8%), and more patients with cancer received remdesivir (8.6% *v* 4.3%). Observed complications (Appendix Table A1, online only), including myocardial infarction (3.4% *v* 5.3%), vasopressor requirements (20.5% *v* 23.3%), and bacteremia (7.7% *v* 8.6%), were similar for patients with and without cancer, respectively. Venous thromboembolic events were slightly higher in the cancer group (11.1%) compared with the noncancer group (8.6%).

COVID-19 Outcomes

As of June 20, 2020, similar proportions of patients with and without cancer with COVID-19 had died. We observed 29 deaths (24.8%) among hospitalized patients with cancer compared with 100 deaths (21.4%; $P = .894$) among patients without cancer. There was no difference in death or composite outcome (death, intubation, or ICU admission) among patients with or without cancer (Figs 1A and 1B). In addition, there were no differences in composite outcome between hematologic and solid malignancies in terms of ICU admissions, intubation, or death ($P = .283$). Furthermore, there was no difference in outcome if patients were treated with cytotoxic therapy within 90 days of admission ($P = .446$). Kaplan-Meier plots (Figs 2A and 2B) support these conclusions. We found no differences in mortality or composite outcome on the basis of patient hospital location (Appendix Figs A1A and A1B, online only), suggesting a similar quality of care at both institutions.

Predictors of Morbidity and Mortality

Unadjusted predictors of morbidity and mortality over the entire study cohort are listed in Appendix Table A2 (online only) The clinical factors that are associated with worse outcome include age (HR, 1.15 [95% CI, 1.03 to 1.28]) and obesity (HR, 1.64 [95% CI, 1.21 to 2.21]). Patients who

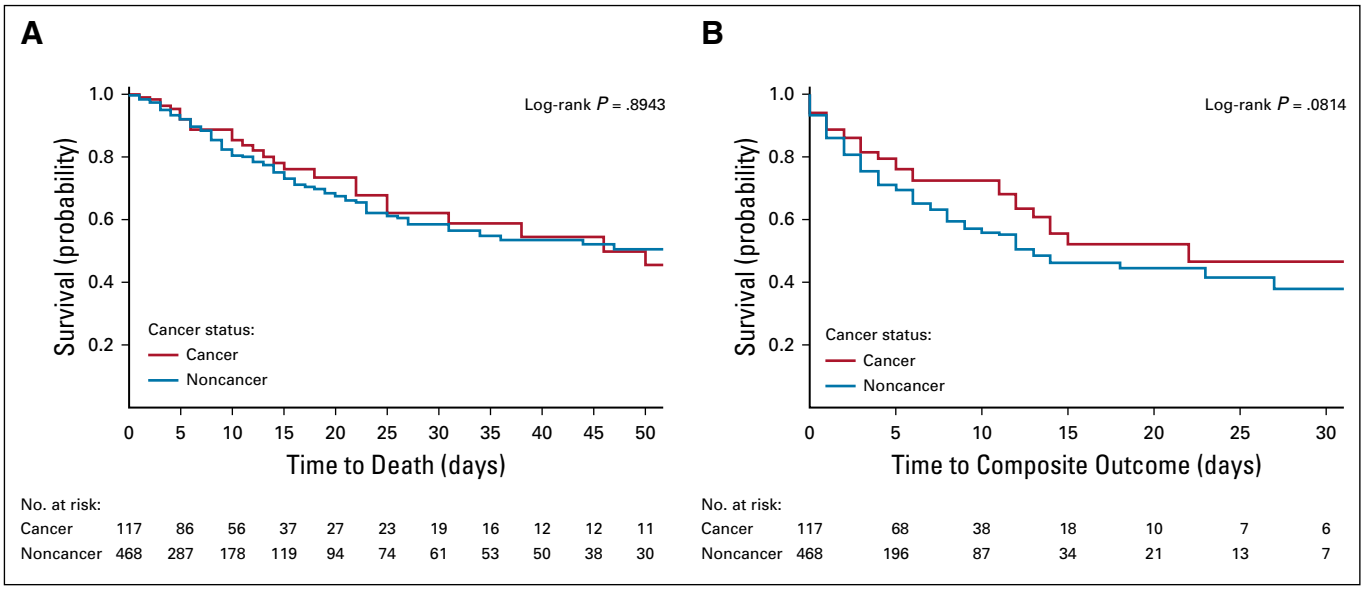

FIG 1. (A) Mortality between cancer and noncancer groups. (B) Composite outcome (death, intubation, or intensive care unit admission) between cancer and noncancer groups.

presented with dyspnea (HR, 1.34 [95% CI, 1.06 to 1.71]), tachycardia (HR, 1.83 [95% CI, 1.07 to 3.14]), tachypnea (HR, 1.98 [95% CI, 1.5 to 2.62]), and bilateral lung infiltrates (HR, 1.97 [95% CI, 1.42 to 2.75]) were also predicted to have worse outcomes. The results for the cancer cohort and the noncancer controls are listed in Appendix Table A2. In patients without cancer, elevated AST (HR, 1.78 [95% CI, 1.32 to 2.39]), hyperbilirubinemia (HR, 1.42 [95% CI, 1.01 to 2.01]), and D-dimer elevation (HR, 1.68 [95% CI, 1.13 to 2.5]) predicted worse outcomes compared with patients with cancer. Cytotoxic treatment (HR, 0.99 [95% CI, 0.52 to 1.88]) or treatment within 90 days of admission (HR, 1.23 [95% CI, 0.65 to 2.35]) were not associated with worse outcomes. In a multivariable marginal Cox model, age continued to be a predictor of both composite outcome (HR, 1.19 [95% CI, 1.04 to 1.36]) and death (HR, 2.05 [95% CI, 1.72 to 2.42]), and obesity was significant only for the composite outcome (HR, 1.85 [95% CI, 1.37 to 2.50]; Table 3).

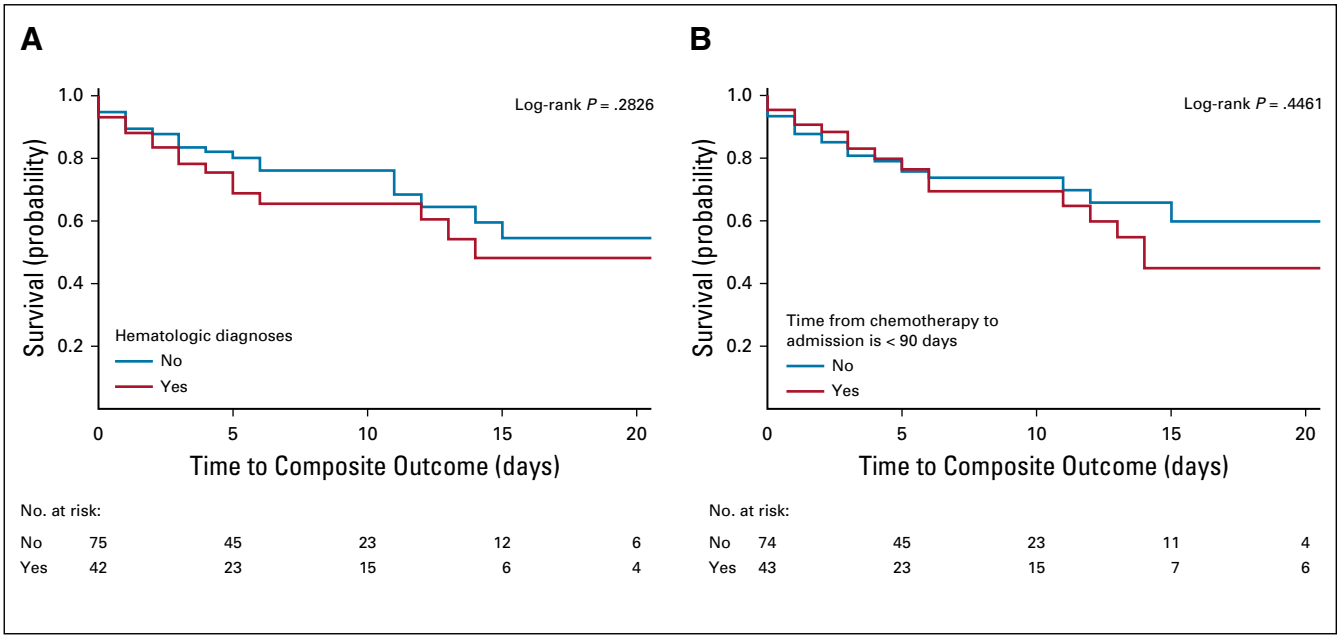

FIG 2. (A) Composite outcome (death, intubation, or intensive care unit ([ICU] admission) between hematologic and solid malignancies groups. (B) Composite outcome (death, intubation, or ICU admission) between patients who did and did not receive chemotherapy within 90 days of admission.

TABLE 3. Adjusted Association Between Cancer Status and Risk of Composite Outcome and Death for 585 Hospitalized Patients With COVID-19

	Composite Outcome[a]		Death	
Risk Factor	**aHR**	**95% CI**	**aHR**	**95% CI**
Age	1.19	1.04 to 1.36[b]	2.04	1.72 to 2.42[b]
Cancer	0.80	0.57 to 1.13	0.98	0.58 to 1.67
Sex	1.35	0.96 to 1.90	1.22	0.85 to 1.77
Ethnicity				
Black	0.80	0.45 to 1.41	1.40	0.74 to 2.64
Asian	1.08	0.77 to 1.52	1.30	0.71 to 2.36
Other	1.19	0.86 to 1.65	1.36	0.85 to 2.19
Not reported	0.91	0.59 to 1.41	1.65	0.84 to 3.24
Smoking history (ref = Never smoked)				
Former smoker	0.86	0.66 to 1.12	0.67	0.44 to 1.01
Current smoker	0.71	0.24 to 2.04	0.58	0.17 to 2.03
Obesity (BMI $\geq$ 30 kg/m^2 [$\geq$ 28 kg/m^2 for Asians])	1.85	1.37 to 2.50[b]	1.35	0.92 to 1.97
Diabetes	0.88	0.63 to 1.21	1.17	0.70 to 1.95
Hypertension	0.95	0.65 to 1.38	0.97	0.67 to 1.41
Chronic obstructive pulmonary disease	1.33	0.82 to 2.16	1.16	0.80 to 1.68
Coronary artery disease	0.98	0.67 to 1.43	1.20	0.75 to 1.92
Heart failure	0.80	0.53 to 1.21	1.09	0.63 to 1.89

Abbreviations: aHR, adjusted hazard ratio; BMI, body mass index; COVID-19, SARS-CoV-2; ref, reference.
[a]Composite outcome = intensive care unit, intubation, or death.
[b]$P < .05$.

DISCUSSION

We demonstrate that COVID-19 hospitalized patients with active malignancies have comparable morbidity and mortality to COVID-19–infected hospitalized patients without cancer. In contrast to previous findings, we observed no differences in the risk of ICU admission, intubation, or death between patients with and without cancer. Our findings suggest that active malignancy may not be a contributive risk factor for the unfavorable prognosis of COVID-19 in patients with cancer.

By matching for age, sex, and number of comorbidities, we evaluated the impact of COVID-19 in patients with and without cancer who had a similar comorbidity burden. We found that age was a significant independent predictor of both the composite outcome and mortality in patients with COVID-19. Similarly, the case fatality rate of COVID-19 was believed to be higher in Italy than China because of the older Italian population.[25] In contrast to this study, in which 75% of patients had two or more comorbidities,[25] the majority of our patients had limited comorbid conditions (75% had one or fewer). This may explain why other medical conditions were not independently associated with a worse composite outcome or death.

Obesity, which accounted for 25% of our patient population, was found to be independently associated with an increased risk of composite outcome and death in both unadjusted and adjusted models. The prevalence of obesity in the United States is rising, and its impact in the context of COVID-19 specifically has not been well described. In France, a small study of 124 patients with COVID-19 found a strong correlation between higher body mass index (BMI) and need for invasive mechanical ventilation as a marker for disease severity.[27] In NYC, a BMI of $>$ 25 kg/m^2 was associated with a risk of hospital admission with COVID-19, but only a BMI $>$ 40 kg/m^2 predicted critical illness, which accounted for 6% of the population studied.[28] Obesity is a well-known pro-inflammatory condition, and immune dysregulation may be a reason why obesity is linked with poor outcomes.[29-31]

In addition, a difference in demographics, including ethnicity and socioeconomic status, as well as discrepancies in health care system practices, may account for the reduced mortality we observed in our hospitalized patients with cancer when compared with others.[13] Although the majority of our population identified as White, there was no association between ethnicity and outcome when adjusted for other factors. Other confounding factors, such as smoking, which may adversely affect outcomes from COVID-19[11,32] and was not accounted for in previous studies,[13] may further explain the differences in patient outcome. In our study, we did not find any statistical significance in patients who were current smokers (HR, 0.75 [95% CI, 0.29 to 1.98]); however, this likely reflects a small subset of patients who were active smokers when analyzed.

Currently, there are limited published data regarding presenting symptoms and hospital complications rates in patients with COVID-19 and cancer. In our matched cohort, presenting symptoms and serious hospital complication rates in patients with and without cancer were similar, including vasopressor requirements, bacteremia and venous thromboembolism. Tachycardia, dyspnea, and bilateral infiltrates were all associated with an increased risk of composite outcome. We observed a lower incidence of infection in both groups, which may have contributed to improved outcomes compared with other data sets.[11]

Although previous reports have suggested that COVID-19–positive patients with hematologic malignancies have worse outcomes than do patients with solid tumors,[11,13] our data showed no differences between the two groups. A predominance of chronic lymphocytic leukemia on active treatment within our hematologic population could account for the improved outcomes. A recent publication characterized protective anti-inflammatory benefits of Bruton's tyrosine kinase inhibitors in patients with hematologic malignancy and COVID-19 infection.[33] Furthermore, we did not observe differences in ICU admission, intubation, or death between patients with cancer who received cytotoxic chemotherapy or immunosuppressive therapy within 3 months of hospitalization versus more than 3 months, consistent with previous data.[13,34]

Our study has some limitations. The observational nature of this study does not allow us to determine causality. Although sizable, our cancer cohort was heterogeneous and limited to hospitalized patients, thus reducing generalizability to patients with cancer in the outpatient setting. We did not account for socioeconomic status or differences in health care systems that may explain the variations in our results compared with others. Although it is not clear how these imbalances could affect the interpretation of our results, we acknowledge that these imbalances could bias our data and must be considered. Finally, given the long length of study of many hospitalized patients with COVID-19, some outcomes may not have been observed at the date of analysis.

In summary, we showed that hospitalized patients with COVID-19 and cancer have a similar presentation and have similar rates of complications and death compared with patients without cancer. COVID-19–infected patients with cancer were reported initially to have worse outcomes; however, these studies were not controlled for comorbidities[15,35,36] that have been shown to significantly influence outcomes.[2,12,15] Our findings suggest that older age is the most contributive risk factor for poor outcomes in patients with COVID-19 and that a diagnosis of cancer itself, or its treatment, may not influence severe outcomes.

Our data have important implications about the impact of COVID-19 on patients with cancer. We should consider the consequences of limiting care for patients with cancer on cancer-specific outcomes and mortality in the context of COVID-19. During the COVID-19 pandemic, we may be able to deliver anticancer care safely to patients who are younger with limited comorbidities; however, it is important to balance the risks and benefits of safely delivering cancer-directed therapy. We may consider a more conservative approach in older patients with metastatic cancer and multiple comorbidities, for whom the efficacy of continued lines of therapy may be limited. Conversely, we would consider cautious continuation of therapy in patients with fewer comorbidities and in whom therapy is associated with significant benefit. Our findings do not mitigate the importance of the continued screening and heightened vigilance that will be required to deliver safe quality care to our patients.

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COVID-19 Severity and Outcomes in Patients With Cancer: A Matched Cohort Study

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APPENDIX

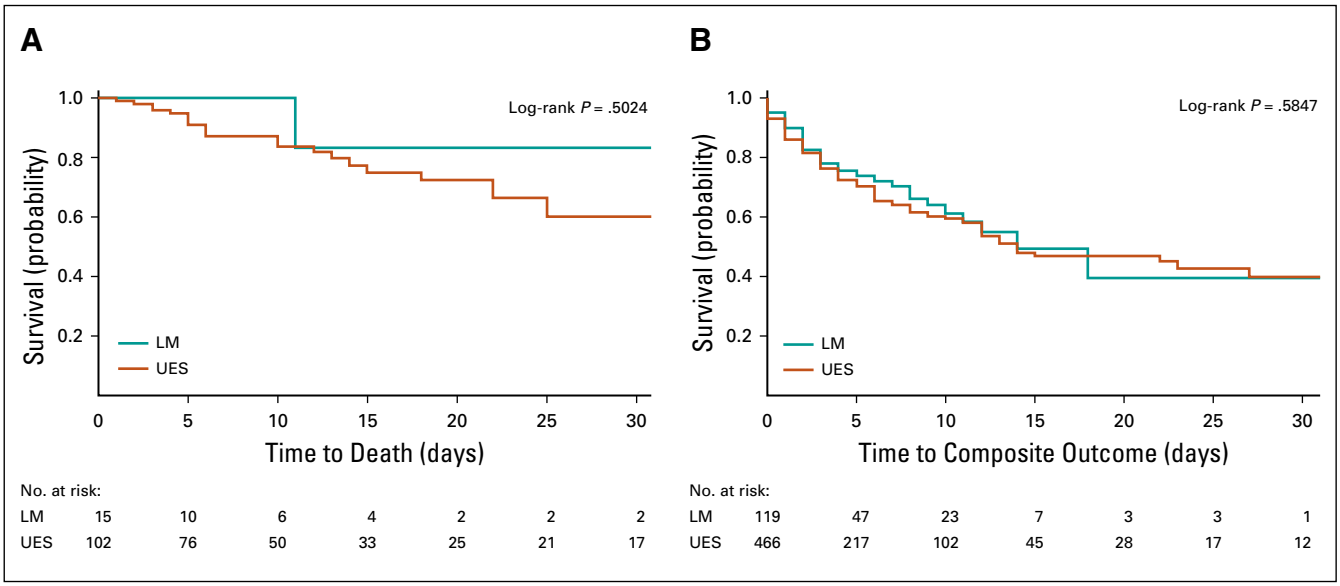

FIG A1. (A) Mortality by hospital location. (B) Composite outcome (death, intubation, or intensive care unit admission) by hospital location. LM, New York/Presbyterian -Lower Manhattan Hospital; UES, New York/Presbyterian-Upper East Side Hospital.

TABLE A1. Characteristics of 585 Hospitalized Patients With COVID-19: In-Hospital Complications and Treatments, Overall and by Cancer Status

Patient Characteristics	Total No. With Data Available	All (N = 585), %	Noncancer (n = 468), No. (%)	Cancer (n = 117), No. (%)
In-hospital treatment				
Hydroxychloroquine	333 of 585	56.9	266 (56.8)	67 (57.3)
Remdesivir	30 of 585	5.1	20 (4.3)	10 (8.6)
Oral corticosteroids	133 of 585	22.7	115 (24.6)	18 (15.4)
In-hospital complications				
Days from admission to intubation	134 of 585	2 (1-4)[a]	2 (1-4)[a]	2.5 (1-6)[a]
Myocardial infarction	29 of 585	5.0	25 (5.3)	4 (3.4)
Atrial arrhythmia	61 of 585	10.4	53 (11.3)	8 (6.8)
Heart failure	23 of 585	3.9	14 (3.0)	9 (7.7)
Need for vasopressor	133 of 584	22.8	109 (23.3)	24 (20.5)
Need for inotrope	13 of 584	2.2	11 (2.4)	2 (1.7)
Bacteremia	49 of 585	8.4	40 (8.6)	9 (7.7)
Viral coinfection	4 of 585	0.7	1 (0.2)	3 (2.6)
Venous thromboembolic events	53 of 585	9.1	40 (8.6)	13 (11.1)
Disseminated intravascular coagulation	1 of 585	0.2	1 (0.2)	0 (0.0)
Rhabdomyolysis	8 of 585	1.4	8 (1.7)	0 (0.0)
New-onset renal replacement therapy	56 of 585	9.6	46 (9.8)	10 (8.6)
Deaths through June 20, 2020	129 of 585	22.1	100 (21.4)	29 (24.8)
Recovery				
Extubated	66 of 585	11.3	57 (12.2)	9 (7.7)
Discharged[b]	439 of 585	75.0	354 (75.6)	85 (72.6)

Abbreviation: COVID-19, SARS-CoV-2.

[a]Median (interquartile range).

[b]Includes discharged and transferred.

TABLE A2. Risk of Having Composite Outcome (intensive care unit/intubation/death) Associated With Demographic Characteristics, Clinical Characteristics, Emergency Room Presentation, and In-Hospital Complications and Treatments for 585 Hospitalized Patients With COVID-19

Patient Characteristics	Overall HR (95% CI)	Cancer HR (95% CI)	Noncancer HR (95% CI)
Demographics on admission			
Cancer	0.74 (0.53 to 1.03)		
Age	1.15 (1.03 to 1.28)[a]	1.01 (0.81 to 1.27)	1.18 (1.06 to 1.32)
Male	1.25 (0.91 to 1.71)	1.64 (0.84 to 3.19)	1.16 (0.84 to 1.6)
Ethnicity (ref = White)			
Black	0.68 (0.4 to 1.17)	1.42 (0.61 to 3.3)	0.47 (0.23 to 0.97)
Asian	1.04 (0.73 to 1.48)		1.00 (0.7 to 1.43)
Other	1.1 (0.8 to 1.52)	1.1 (0.54 to 2.25)	1.05 (0.75 to 1.46)
Not reported	0.89 (0.55 to 1.43)		0.76 (0.42 to 1.35)
Health care worker	1.26 (0.75 to 2.14)		1.23 (0.73 to 2.08)
Admitted from (ref = Home)			
Rehabilitation/nursing home	1.31 (0.93 to 1.84)	1.13 (0.49 to 2.59)	1.42 (1.01 to 1.99)
Other hospital	0.54 (0.14 to 2.14)		0.68 (0.22 to 2.1)
Other/undomiciled	0.59 (0.26 to 1.35)	0.74 (0.22 to 2.54)	0.46 (0.16 to 1.33)
Smoking history (ref = Never smoked)			
Former smoker	0.98 (0.75 to 1.29)	0.98 (0.5 to 1.95)	1.01 (0.74 to 1.38)
Current smoker	0.75 (0.29 to 1.98)	0.98 (0.5 to 1.95)	0.63 (0.22 to 1.79)
Obesity (BMI ≥ 30 kg/m^2 [≥ 28 kg/m^2 for Asians])	1.64 (1.21 to 2.21)[a]	3 (1.49 to 6.04)[a]	1.44 (1.03 to 2.00)[a]
Diabetes	0.98 (0.7 to 1.36)	1.45 (0.75 to 2.82)	0.89 (0.63 to 1.25)
Hypertension	1.11 (0.79 to 1.57)	1.15 (0.6 to 2.2)	1.09 (0.75 to 1.58)
Chronic obstructive pulmonary disease	1.4 (0.96 to 2.04)	1.5 (0.63 to 3.59)	1.39 (0.92 to 2.11)
Asthma	1.48 (0.98 to 2.23)	1.5 (0.63 to 3.59)	1.44 (0.86 to 2.42)
End-stage renal disease	0.28 (0.08 to 1.02)		0.29 (0.09 to 0.98)[a]
Cirrhosis	0.63 (0.12 to 3.4)		No events
Coronary artery disease	1.08 (0.76 to 1.53)	0.66 (0.3 to 1.45)	1.21 (0.86 to 1.69)
Heart failure	0.91 (0.63 to 1.31)		1.10 (0.7 to 1.74)
HIV	No events		No events
Total count of home medications (excluding over-the-counter medications) ≥ 5	1.02 (0.76 to 1.35)	0.77 (0.4 to 1.45)	1.13 (0.85 to 1.51)
Use of immunosuppressive medication (within last 30 days)		1.69 (0.85 to 3.37)	
None	0.89 (0.63 to 1.25)		1.01 (0.65 to 1.56)
Prednisone < 20 mg/d	1.63 (0.94 to 2.83)		1.26 (0.7 to 2.26)
Prednisone ≥ 20 mg/d	1.01 (0.56 to 1.82)		
Other monoclonal antibody	1.89 (0.73 to 4.91)		0.86 (0.15 to 5.03)
Tacrolimus	0.21 (0.03 to 1.58)		0.22 (0.03 to 1.62)
Mycophenolate (MMF, myfortic)	0.56 (0.13 to 2.41)		0.57 (0.13 to 2.41)
Methotrexate	2.19 (0.28 to 16.94)		2.08 (0.27 to 16.09)
Other[b]	1.09 (0.62 to 1.91)		2.09 (0.97 to 4.48)
Presenting symptoms			
Fever	1.11 (0.88 to 1.41)	1.36 (0.71 to 2.62)	1.04 (0.82 to 1.33)
Cough	0.91 (0.65 to 1.26)	1.18 (0.61 to 2.27)	0.83 (0.61 to 1.13)
Diarrhea	0.67 (0.46 to 0.96)	1.27 (0.63 to 2.56)	0.54 (0.35 to 0.83)[a]
Nausea or vomiting	0.72 (0.51 to 1.01)	0.69 (0.27 to 1.78)	0.72 (0.5 to 1.04)

(continued on following page)

TABLE A2. Risk of Having Composite Outcome (intensive care unit/intubation/death) Associated With Demographic Characteristics, Clinical Characteristics, Emergency Room Presentation, and In-Hospital Complications and Treatments for 585 Hospitalized Patients With COVID-19 (continued)

Patient Characteristics	Overall HR (95% CI)	Cancer HR (95% CI)	Noncancer HR (95% CI)
Myalgias	0.83 (0.59 to 1.16)	1.23 (0.43 to 3.46)	0.75 (0.53 to 1.05)
Dyspnea	1.34 (1.06 to 1.71)[a]	1.68 (0.87 to 3.24)	1.25 (0.95 to 1.64)
On arrival at emergency room			
Fever (> 38°C)	1.14 (0.8 to 1.63)	0.66 (0.23 to 1.88)	1.28 (0.89 to 1.86)
Heart rate ≥ 125 beats/min	1.83 (1.07 to 3.14)[a]	0.75 (0.18 to 3.11)	2.15 (1.27 to 3.65)[a]
Respiratory rate > 24 breaths/min	1.98 (1.5 to 2.62)[a]	1.54 (0.75 to 3.2)	2.12 (1.57 to 2.87)[a]
Highest level of supplemental O_2 required within first 3 hours (ref = None)	[a]	[a]	[a]
Nasal cannula and venturi mask	1.98 (1.37 to 2.85)	3.35 (1.52 to 7.38)	1.65 (1.01 to 2.71)
Nonrebreather and high-flow nasal cannula	4.01 (2.65 to 6.08)	3.5 (1.41 to 8.71)	4.22 (2.66 to 6.71)
Initial chest radiology findings			
Clear	0.42 (0.27 to 0.64)[a]	0.56 (0.22 to 1.44)	0.37 (0.23 to 0.62)[a]
Unilateral infiltrate	0.64 (0.42 to 0.98)	0.39 (0.12 to 1.27)	0.76 (0.5 to 1.14)
Bilateral infiltrates	1.97 (1.42 to 2.75)[a]	2.64 (1.25 to 5.58)[a]	1.75 (1.22 to 2.51)[a]
Pleural effusion	1.46 (0.85 to 2.49)	1.31 (0.55 to 3.16)	1.79 (0.95 to 3.38)
Other	1.15 (0.72 to 1.83)	1.51 (0.46 to 4.93)	1.06 (0.72 to 1.56)
Laboratory findings			
WBC count > 10,000/μL	1.71 (1.24 to 2.35)[a]	1.68 (0.86 to 3.27)	1.74 (1.25 to 2.44)[a]
WBC count < 4,000/μL	0.9 (0.64 to 1.26)	0.69 (0.31 to 1.52)	1.11 (0.79 to 1.57)
Lymphocyte count < 150,000/μL	1.05 (0.67 to 1.63)	0.68 (0.31 to 1.52)	1.25 (0.72 to 2.16)
Neutrophil-to-lymphocyte ratio	1.01 (1.01 to 1.01)[a]	1.01 (1 to 1.01)[a]	1.02 (1.01 to 1.04)[a]
Platelet count < 150,000/μL	1.24 (0.95 to 1.63)	1.99 (1.04 to 3.81)[a]	1.08 (0.8 to 1.48)
Serum creatinine ≥ 1.5 mg/dL	1.45 (1.01 to 2.06)	1.82 (0.87 to 3.79)	1.36 (0.96 to 1.95)
Serum albumin, g/dL	0.82 (0.64 to 1.04)	0.88 (0.59 to 1.34)	0.78 (0.62 to 0.99)[a]
Alanine aminotransferase > 40 U/L	1 (0.74 to 1.35)	1 (0.49 to 2.06)	0.98 (0.69 to 1.39)
AST > 40 U/L	1.66 (1.32 to 2.08)[a]	1.3 (0.69 to 2.46)	1.78 (1.32 to 2.39)[a]
Alanine phosphatase > 140 U/L	1.11 (0.72 to 1.7)	1.27 (0.63 to 2.58)	1.11 (0.69 to 1.78)
Total bilirubin > 17.1 μmol/L	1.29 (0.98 to 1.7)	0.96 (0.42 to 2.19)	1.42 (1.01 to 2.01)[a]
Glucose, mg/dL	1.001 (1.000 to 1.003)[a]	1 (1 to 1.01)[a]	1.001 (1.000 to 1.002)
D-dimer > 0.5 mg/L	1.51 (1.02 to 2.23)[a]	1.1 (0.41 to 3)	1.68 (1.13 to 2.5)[a]
Hemoglobin, g/dL	0.98 (0.93 to 1.05)	0.9 (0.79 to 1.03)	1.00 (0.93 to 1.07)
Ferritin > 300 ng/mL	1.5 (0.85 to 2.65)	5.73 (0.78 to 42.27)	1.24 (0.73 to 2.13)
Erythrocyte sedimentation rate, mm/h	1 (0.99-1)[c]	1 (0.98-1.01)[c]	1.00 (0.994-1.005)[c]
C-reactive protein > 10 mg/dL	1.73 (1.24 to 2.43)[a]	2.27 (1.01 to 5.1)[a]	1.63 (1.21 to 2.2)[a]
Prothrombin time, seconds	1.01 (0.99 to 1.04)	1 (0.95 to 1.05)	1.03 (1.01 to 1.06)[a]
Activated partial thromboplastin time, seconds	1.03 (1.01 to 1.05)[a]	1.04 (0.99 to 1.09)	1.03 (1.01 to 1.05)[a]
International normalization ratio	1.08 (0.83 to 1.41)	1.01 (0.61 to 1.7)	1.24 (0.94 to 1.64)
Lactase dehydrogenase, U/L (10-unit increase)	1.001 (1.000 to 1.002)[a]	1 (1 to 1)	1.001 (1.001 to 1.002)[a]
Procalcitonin ≥ 0.5 ng/mL	1.5 (1.04 to 2.15)[a]	2.02 (1.02 to 3.98)[a]	1.39 (0.92 to 2.09)
In-hospital treatment			
Hydroxychloroquine	1.8 (1.22 to 2.65)[a]	2.96 (1.39 to 6.28)[a]	1.55 (0.95 to 2.54)
Remdesivir	1.28 (0.78 to 2.08)	0.92 (0.35 to 2.4)	1.68 (0.86 to 3.31)
Oral corticosteroids	3.24 (2.39 to 4.38)[a]	1.57 (0.75 to 3.25)	3.67 (2.55 to 5.28)[a]

(continued on following page)

TABLE A2. Risk of Having Composite Outcome (intensive care unit/intubation/death) Associated With Demographic Characteristics, Clinical Characteristics, Emergency Room Presentation, and In-Hospital Complications and Treatments for 585 Hospitalized Patients With COVID-19 (continued)

Patient Characteristics	Overall HR (95% CI)	Cancer HR (95% CI)	Noncancer HR (95% CI)
In-hospital complications			
Myocardial infarction	2.74 (1.74 to 4.31)[a]	2.24 (0.69 to 7.31)	2.84 (1.72 to 4.68)[a]
Atrial arrhythmia	2.78 (2.05 to 3.77)[a]	1.75 (0.68 to 4.5)	2.93 (2.24 to 3.84)[a]
Heart failure	1.98 (1.2 to 3.28)[a]	0.87 (0.3 to 2.53)	3.51 (2.25 to 5.47)[a]
Need for vasopressor	12.27 (8.41 to 17.89)[a]		11.93 (7.49 to 19.01)[a]
Need for inotrope	3.14 (2.29 to 4.31)[a]	2.33 (0.56 to 9.73)	3.39 (2.16 to 5.33)[a]
Bacteremia	4.26 (3.2 to 5.66)[a]	3.02 (1.38 to 6.61)[a]	4.76 (3.41 to 6.65)[a]
Viral	3.48 (1.69 to 7.16)[a]		1.65 (1.13 to 2.42)[a]
Venous thromboembolic events	1.91 (1.45 to 2.51)[a]	3.45 (1.63 to 7.31)[a]	1.45 (0.5 to 4.17)[a]
Rhabdomyolysis	1.53 (0.52 to 4.52)[a]		2.50 (1.58 to 3.97)
New-onset renal replacement therapy	2.83 (1.88 to 4.26)[a]	4.90 (2.2 to 10.91)[a]	1.55 (0.95 to 2.54)[a]
Cancer-specific characteristics			
Hematologic diagnoses (ref = Yes)		0.71 (0.37 to 1.35)	
Stage (ref = Metastatic)			
S1-S3		0.9 (0.34 to 2.43)	
Missing		0.81 (0.29 to 2.32)	
Cancer treatment (ref = No treatment)			
Cytotoxic		0.99 (0.52 to 1.88)	
Hormone or other		1.43 (0.73 to 2.8)	
Surgery		0.80 (0.31 to 2.06)	
Radiation		0.19 (0.03 to 1.37)	
Time from diagnosis of cancer to admission, months (ref = 12 or more)		[a]	
< 6		1.75 (0.83 to 3.69)	
6-12		3.39 (1.32 to 8.7)	
Time from chemotherapy to admission < 90 days (ref = No)		1.23 (0.65 to 2.35)	

Abbreviations: BMI, body mass index, COPD, chronic obstructive pulmonary disease; COVID-19, SARS-CoV-2; HR, hazard ratio; MMF, mycophenolate mofetil; ref, reference.

[a]*P* values < .05.

[b]Other immunosuppressive medications include hydrocortisone, abraxane and atezolizumab, bendamustine and obinutuzumab, capecitabine, and so forth.

[c]Median (interquartile range).