original reports

Chemotherapy and COVID-19 Outcomes in Patients With Cancer

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abstract

PURPOSE Coronavirus-2019 (COVID-19) mortality is higher in patients with cancer than in the general population, yet the cancer-associated risk factors for COVID-19 adverse outcomes are not fully characterized.

PATIENTS AND METHODS We reviewed clinical characteristics and outcomes from patients with cancer and concurrent COVID-19 at Memorial Sloan Kettering Cancer Center until March 31, 2020 (n = 309), and observed clinical end points until April 13, 2020. We hypothesized that cytotoxic chemotherapy administered within 35 days of a COVID-19 diagnosis is associated with an increased hazard ratio (HR) of severe or critical COVID-19. In secondary analyses, we estimated associations between specific clinical and laboratory variables and the incidence of a severe or critical COVID-19 event.

RESULTS Cytotoxic chemotherapy administration was not significantly associated with a severe or critical COVID-19 event (HR, 1.10; 95% CI, 0.73 to 1.60). Hematologic malignancy was associated with increased COVID-19 severity (HR, 1.90; 95% CI, 1.30 to 2.80). Patients with lung cancer also demonstrated higher rates of severe or critical COVID-19 events (HR, 2.0; 95% CI, 1.20 to 3.30). Lymphopenia at COVID-19 diagnosis was associated with higher rates of severe or critical illness (HR, 2.10; 95% CI, 1.50 to 3.10). Patients with baseline neutropenia 14-90 days before COVID-19 diagnosis had worse outcomes (HR, 4.20; 95% CI, 1.70 to 11.00). Findings from these analyses remained consistent in a multivariable model and in multiple sensitivity analyses. The rate of adverse events was lower in a time-matched population of patients with cancer without COVID-19.

CONCLUSION Recent cytotoxic chemotherapy treatment was not associated with adverse COVID-19 outcomes. Patients with active hematologic or lung malignancies, peri–COVID-19 lymphopenia, or baseline neutropenia had worse COVID-19 outcomes. Interactions among antineoplastic therapy, cancer type, and COVID-19 are complex and warrant further investigation.

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INTRODUCTION

Coronavirus-2019 (COVID-19) has caused a global pandemic.[1] In a retrospective analysis of 5,700 patients hospitalized with COVID-19 (the disease caused by the SARS-CoV-2 virus) in the New York City area, 12% of patients received mechanical ventilation, and 21% died.[2] In an 18-patient retrospective study in China, patients with cancer and COVID-19 seemed to have a higher risk of COVID-19 complications,[3] although a modest sample size hindered investigation of specific cancer-associated risk factors for worse outcomes.[4] A 105-patient study suggested that lung cancer, metastatic disease, and hematologic malignancy may be associated with higher rates of COVID-19–related death and intensive care unit (ICU) admission.[5] The effect of recent cancer treatment, including cytotoxic chemotherapy, on COVID-19 course is unclear. Two large observational studies found no evidence of increased mortality with recent cytotoxic chemotherapy administration.[6,7] By contrast, a 205-patient study found an increased risk of death in patients with COVID-19 who received active chemotherapy,[8] and a 107-patient study from China found that rates of severe respiratory COVID-19 were associated with recent chemotherapy.[9] These studies vary in their end points and in their statistical methods, which makes comparisons challenging.

We reviewed the clinical characteristics and outcomes of 309 patients at Memorial Sloan Kettering Cancer Center (MSKCC) with confirmed SARS-CoV-2 infection in a retrospective observational study. We hypothesized that patients with cancer with COVID-19 who received cytotoxic chemotherapy within 5 weeks of a COVID-19 diagnosis would demonstrate an increased rate of severe or critical COVID-19 events, a composite primary end point adapted from previous studies.[10,11] We also characterized associations between additional prespecified clinical, treatment, and

ASSOCIATED CONTENT

Data Supplement
Protocol

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

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CONTEXT

Key Objective

Coronavirus-2019 (COVID-19) mortality is higher in patients with cancer. This retrospective study examined whether recent receipt of cytotoxic chemotherapy and other cancer-related features are associated with a more severe COVID-19 disease course.

Knowledge Generated

Patients treated with cytotoxic chemotherapy did not have an increased risk of worse COVID-19 course. Patients with a hematologic malignancy, lung cancer, lymphopenia at COVID-19 diagnosis, and/or baseline neutropenia had higher rates of severe or critical illness.

Relevance

Our study will help to guide providers in making decisions about cancer-directed therapy in patients with cancer and COVID-19. Study data may also influence management of patients with lung cancer, hematologic malignancies, or leukopenia at the time of COVID-19 diagnosis.

laboratory factors present in oncology patients and the primary end point. We also examined the impact of these variables on a variety of other end points.

PATIENTS AND METHODS

Patient Selection

We included all patients with cancer followed at MSKCC and found to have a confirmed positive SARS-CoV-2 test in the inpatient or outpatient setting between March 8, 2020, the date of the first confirmed patient infection at our institution, and March 31, 2020. Patients were excluded if they did not have a confirmed history of histologic diagnosis of cancer in the electronic medical record (EMR) and/or if there was insufficient follow-up documentation to determine the severity of their COVID-19 clinical course. SARS-CoV-2 status was determined using a nasopharyngeal swab to determine the presence of virus-specific RNA (MSK US Food and Drug Administration Emergency Use Authorization–approved laboratory-developed test and GeneXpert; Cepheid, Sunnyvale, CA). In institutional validation data, the tests used to determine the presence of SARS-Cov-2 RNA demonstrated a limit of detection of 250-500 copies/mL, an analytical sensitivity of 97%, and an analytical specificity of 100%.

We used all available documentation until April 13, 2020, the final date of follow-up, to monitor clinical outcomes. MSKCC's institutional review board approved this study and waived the need for informed consent.

Data Collection

Demographics, laboratory data, medications, including anticancer therapy, and laboratory values were automatically extracted from the MSKCC EMR. Clinical data, including cancer details, comorbidities, symptoms at presentation, severity of COVID-19, treatment outside of MSKCC, and other hospitalization details, were extracted and checked by licensed physicians using quality-controlled abstraction methods (Data Supplement). The primary study end point consisted of a severe or critical COVID-19 event defined by one or more of the following criteria: documented hypoxemia (oxygen saturation by pulse oximetry $\leq$ 93%), tachypnea (respiratory rate $\geq$ 30 breaths/minute), respiratory failure (arterial partial pressure of oxygen/fraction of inspired oxygen ratio $<$ 300), admission to the ICU for intubation, or all-cause death.[10,11] For those who recovered from COVID-19, cessation of symptoms was determined by the first date on which there was provider (physician, nurse practitioner, physician assistant, or registered nurse) documentation of complete symptom resolution (Data Supplement).

To estimate the baseline rate of adverse events in the population, a cohort of patients with cancer who tested negative for SARS-CoV-2 during the study time frame was analyzed for incidence of tachypnea, hypoxemia, ICU admission, organ failure, and all-cause death (the same components used in the study primary end point). Data for these patients were obtained without manual curation from a standardized input institutional database linked to the EMR, which includes provider-charted input for vital signs, oxygen support, and need for invasive ventilation or ICU admission. The validity of these data were confirmed by cross-validation (Data Supplement).

Statistical Analysis

The primary study hypothesis was that cytotoxic chemotherapy within 35 days of COVID-19 diagnosis is associated with an increased hazard ratio (HR) of a severe or critical COVID-19 event. We repeated this investigation with longer (90 days) and shorter (14 days) cytotoxic chemotherapy treatment intervals from COVID-19 diagnosis. In prespecified secondary analyses (Data Supplement), HRs were similarly established using Cox proportional hazards regression models to define the association between severe

or critical COVID-19 and each cancer-related variable as well as potential confounder covariates: age > 60 years, sex (male), obesity (BMI > 30 kg/m^2), smoking history (former/current), pre-existing conditions, and Eastern Cooperative Oncology Group performance status (PS) ≥ 2 or Karnofsky PS < 80%. All HRs were formulated by dividing the hazard rate of patients positive for SARS-CoV-2 with the specific covariate characteristic by the hazard rate of patients positive for SARS-CoV-2 without the respective covariate characteristic. The Benjamini-Hochberg method was applied to adjust for multiplicity with a false discovery rate α of .10. For all analyses, censoring occurred at the time of documented symptom recovery or at the final observation end date of April 13, 2020, if patients continued in the study without documentation of a severe or critical COVID-19 event.

In a subsequent multivariable analysis, all covariates from the univariable analyses with $P < .10$ were analyzed together with potential confounders (age, sex, smoking, BMI, comorbid conditions, and performance status) in a Cox multivariable regression to test the association between each covariate and the primary end point in a single model. Variance inflation factors were defined for each covariate to assess for collinearity. Associations between variables were also assessed using paired χ^2 analysis.

Cox multivariable regression with the same covariates used in the primary analysis was also performed in defined patient subgroups, including patients with active disease, patients with inactive disease, patients treated with cytotoxic chemotherapy, and patients not treated with cytotoxic chemotherapy. The primary and secondary analyses were also repeated in sensitivity analyses using time from COVID-19 diagnosis as an alternate time onset point and three possible alternate end points: primary composite end point, time to ICU admission or death, or death.

Laboratory analysis that compared baseline (most recent value obtained between 14 and 90 days before SARS-CoV-2 RNA positive test) and peri–COVID-19 (closest value to date of SARS-CoV-2 RNA test within 3 days of positive test) values was also performed using paired Wilcoxon signed rank tests. We also compared peri–COVID-19 laboratory values between patients who did and did not meet the primary end point using Mann-Whitney *U* tests. All statistical analyses were performed using R version 3.6.1 software as well as packages survival_3.1-12 and rms_5.1-4 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

The total sample size assessed in the study was 309 patients; 14 from an initial 323-patient cohort positive for SARS-CoV-2 were excluded because of a lack of a confirmed histologic diagnosis of cancer and/or insufficient documentation, including the absence of follow-up to determine the severity of COVID-19 clinical course. In the assessed cohort, 147 patients (47.6%) were admitted to a hospital, 31 (10.0%) died, and 120 (38.8%) developed the primary end point of severe or critical COVID-19. In a time-matched cohort of patients who tested negative for SARS-CoV-2, 303 (33.0%; binomial 95% CI, 30.0% to 36.2%) of 917 were admitted, 57 (6.2%; binomial 95% CI, 4.7% to 8.0%) died, and 154 (17%; binomial 95% CI, 14.4% to 19.4%) met criteria for the primary composite end point (Data Supplement).

Patient characteristics according to disease severity are listed in Table 1 and the Data Supplement. The mean time from start of symptoms to the end of the observation period in patients with COVID-19 was 24.1 days (standard deviation, 6.7 days). The mean time from start of symptoms to a severe or critical event in those patients was 12.6 days (standard deviation, 8.3 days). In the SARS-CoV-2–positive cohort, 102 (33.0%) of 309 patients received cytotoxic chemotherapy within 5 weeks of COVID-19 diagnosis. No association was observed in univariable analysis between treatment with cytotoxic chemotherapy within 35 days of COVID-19 diagnosis and severe or critical COVID-19 (HR, 1.10; 95% CI, 0.73 to 1.60; $P = .74$; Fig 1). Treatment with immunotherapy within 35 days was not associated with the primary end point (HR, 1.80; 95% CI, 0.89 to 3.50; $P = .11$), although the number of patients who received immunotherapy was small (n = 18). When treatment administration windows were adjusted to 14- or 90-day intervals from COVID-19 diagnosis, the absence of association between chemotherapy or immunotherapy treatment and COVID-19 severe or critical infection was preserved (Data Supplement). In a sensitivity analysis, receipt of targeted therapy within 35 days was associated with a trend toward increased risk of ICU stay or death after diagnosis of COVID-19 (HR, 2.2; 95% CI, 1.1 to 4.3; $P = .02$). The results of our sensitivity analyses were otherwise similar to that of the primary analysis (Data Supplement).

A total of 314 of patients (34.2%) who tested negative for SARS-CoV-2 received cytotoxic chemotherapy within 35 days of testing. Of these patients, 48 (15.3%; binomial 95% CI, 11.5% to 19.8%) developed severe or critical illness (Data Supplement), similar to the event incidence in this cohort as a whole. Of 416 patients treated with cytotoxic chemotherapy and tested for SARS-CoV-2, 102 (24.5%; binomial 95% CI, 20.5% to 29.0%) tested positive. A comparable 207 (25.6%; binomial 95% CI, 22.6% to 28.7%) of the remaining 810 patients tested positive for SARS-CoV-2.

In univariable analysis, diagnosis of hematologic malignancy was associated with severe or critical COVID-19 (HR, 1.90; 95% CI, 1.30 to 2.80; $P < .01$). On further examination, this finding was largely driven by a group of eight patients with acute myeloid leukemia (10.8% of total), 7 of whom (87.5%) developed critical illness (Table 1). Lung cancer was associated with an increased HR for severe or critical COVID-19 (HR, 2.00; 95% CI, 1.20 to 3.30;

$P = .01$), although patients with lung metastases did not show a higher risk for the primary outcome (HR, 1.30; 95% CI, 0.81 to 2.10; $P = .27$). Cancer remission, compared with active disease, was associated with a trend toward better outcomes (HR, 0.63; 95% CI, 0.41 to 0.98; $P = .04$).

Lymphopenia peri–COVID-19 diagnosis, but not at baseline, was associated with worse outcome (HR, 2.10; 95% CI, 1.50 to 3.10; $P < .01$). Baseline neutropenia was also associated with a trend toward poor outcome (HR, 4.20; 95% CI, 1.70 to 11.00; $P < .01$). Four patients met criteria for baseline neutropenia. Three of these patients had active acute myeloid leukemia, and the remaining patient had primary CNS lymphoma. Peri–COVID-19 neutropenia was not significantly associated with poor outcome (HR, 1.70; 95% CI, 0.85 to 3.60; $P = .13$).

TABLE 1. Summary of Patient Characteristics by COVID-19 Severity

Characteristic	All, No. (%)	Maximum COVID-19 Severity, No. (%)	
		Mild	Severe or Critical
No. of patients	309	189	120
Demographic			
Male	159 (51.5)	94 (59.1)	65 (40.9)
Female	150 (48.5)	95 (63.3)	55 (36.7)
White	198 (64.1)	119 (60.1)	79 (39.9)
Black	48 (15.5)	31 (64.6)	17 (35.4)
Asian	25 (8.1)	16 (64.0)	9 (36.0)
Other	18 (5.8)	11 (61.1)	7 (38.9)
Age ≤ 60 years	158 (51.1)	111 (70.3)	47 (29.7)
Age > 60 years	151 (48.9)	78 (51.7)	73 (48.3)
Selected comorbidities[a]			
BMI ≤ 30 kg/m^2	212 (68.6)	136 (64.2)	76 (35.8)
BMI > 30 kg/m^2	92 (29.8)	51 (55.4)	41 (44.6)
Never smoked tobacco	165 (53.4)	110 (66.7)	55 (33.3)
Current or former smoker	121 (39.1)	63 (52.1)	58 (47.9)
Chronic obstructive lung disease	16 (5.2)	7 (43.8)	9 (56.3)
Hypertension	120 (38.8)	64 (53.3)	56 (46.7)
Thromboembolism	36 (11.7)	16 (44.4)	20 (55.6)
Cancer overview			
Solid malignancy	232 (75.1)	157 (67.7)	75 (32.3)
Hematologic malignancy	74 (23.9)	31 (41.9)	43 (58.1)
Lung	29 (9.4)	12 (41.4)	17 (58.6)
Breast	54 (17.5)	34 (63.0)	20 (37.0)
Any metastasis	118 (38.2)	75 (63.6)	43 (36.4)
Lung metastasis	50 (16.2)	27 (54.0)	23 (46.0)
No evidence of disease (remission)	88 (28.5)	64 (72.7)	24 (27.3)
Recent anticancer therapy[b]			
Any antineoplastic	170 (55.0)	102 (60.0)	68 (40.0)
Cytotoxic chemotherapy	102 (33.0)	62 (60.8)	40 (39.2)
Targeted therapy	49 (15.9)	28 (57.1)	21 (42.9)
Immunotherapy	18 (5.8)	10 (55.6)	8 (44.4)
Combination targeted therapy and immunotherapy	4 (1.3)	3 (75.0)	1 (25.0)
Combination cytotoxic chemotherapy and immunotherapy	8 (2.6)	3 (37.5)	5 (62.5)
Combination cytotoxic chemotherapy and targeted therapy	19 (6.1)	9 (47.4)	10 (52.6)

Abbreviation: BMI, body mass index.

[a]Comorbidities, cancer type, and cancer therapy are not mutually exclusive. Missing data for race and smoking status not shown.

[b]Recent anticancer therapy is defined as therapy administered within 35 days of SARS-CoV-2 test.

We further evaluated covariates that demonstrated statistical significance ($P < .10$) in a cumulative multivariable Cox proportional hazards model (Fig 2). Statistical significance was maintained for each previously significant covariate, except for age (HR, 1.39; 95% CI, 0.94 to 2.06; $P = .10$) and cancer in remission (HR, 0.78; 95% CI, 0.48 to 1.27; $P = .32$). Variance inflation factors and χ^2 strength of association testing between paired covariates are summarized in the Data Supplement.

In the subgroup of patients with active malignancy, covariates that demonstrated statistical significance in the multivariable model of the primary analysis remained significant (Data Supplement). Patients with active malignancy who were also treated with chemotherapy within

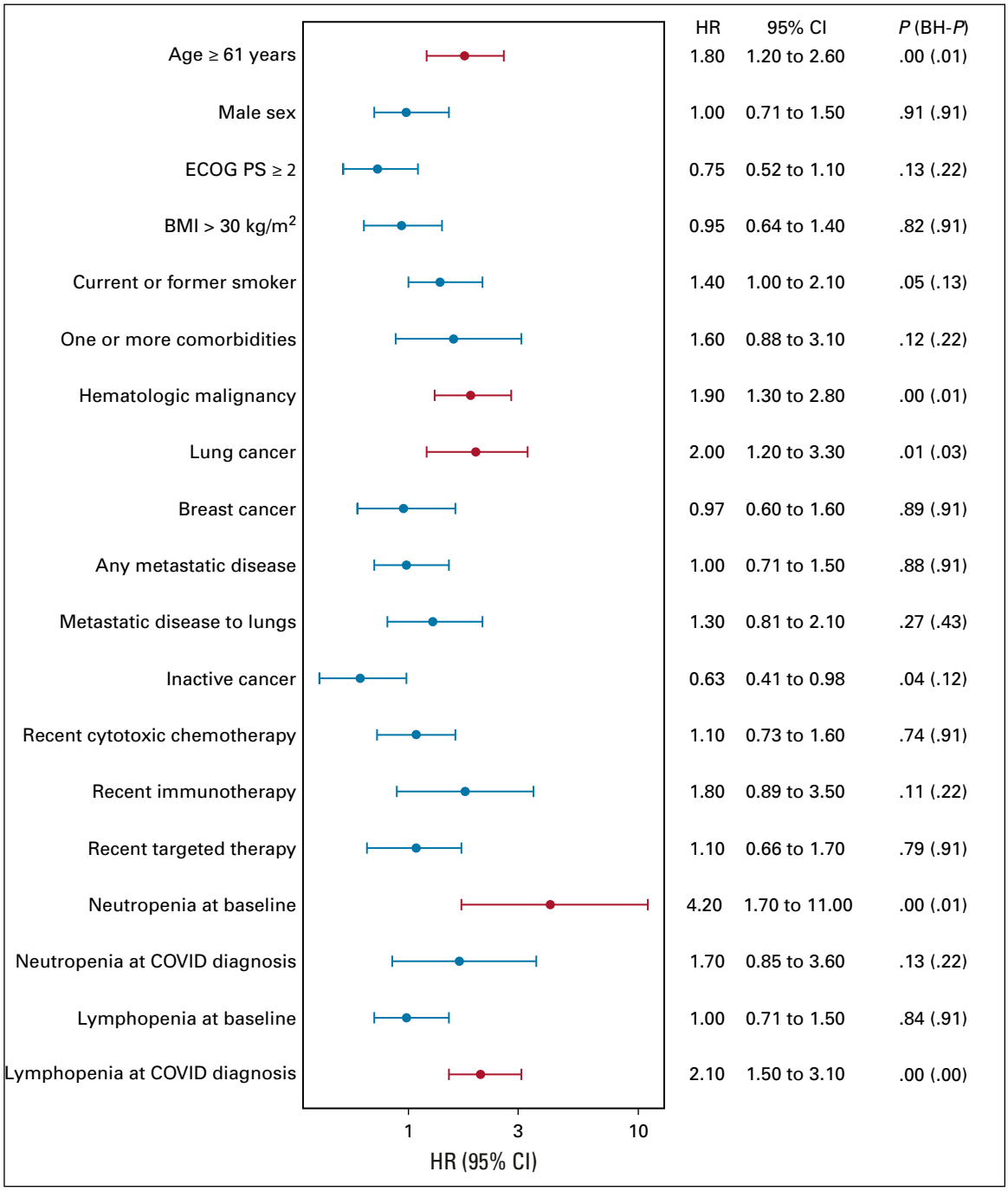

FIG 1. Risk factors for severe COVID-19 in patients with cancer. Hazard ratios (HRs) and 95% CIs for risk factors for severe COVID-19 infection using a time-to-event analysis. Red bars indicate that criteria were met for statistical significance with a Benjamini-Hochberg–adjusted false discovery rate $P < .10$ (BH-*P*). BMI, body mass index; ECOG PS, Eastern Cooperative Oncology Group performance status.

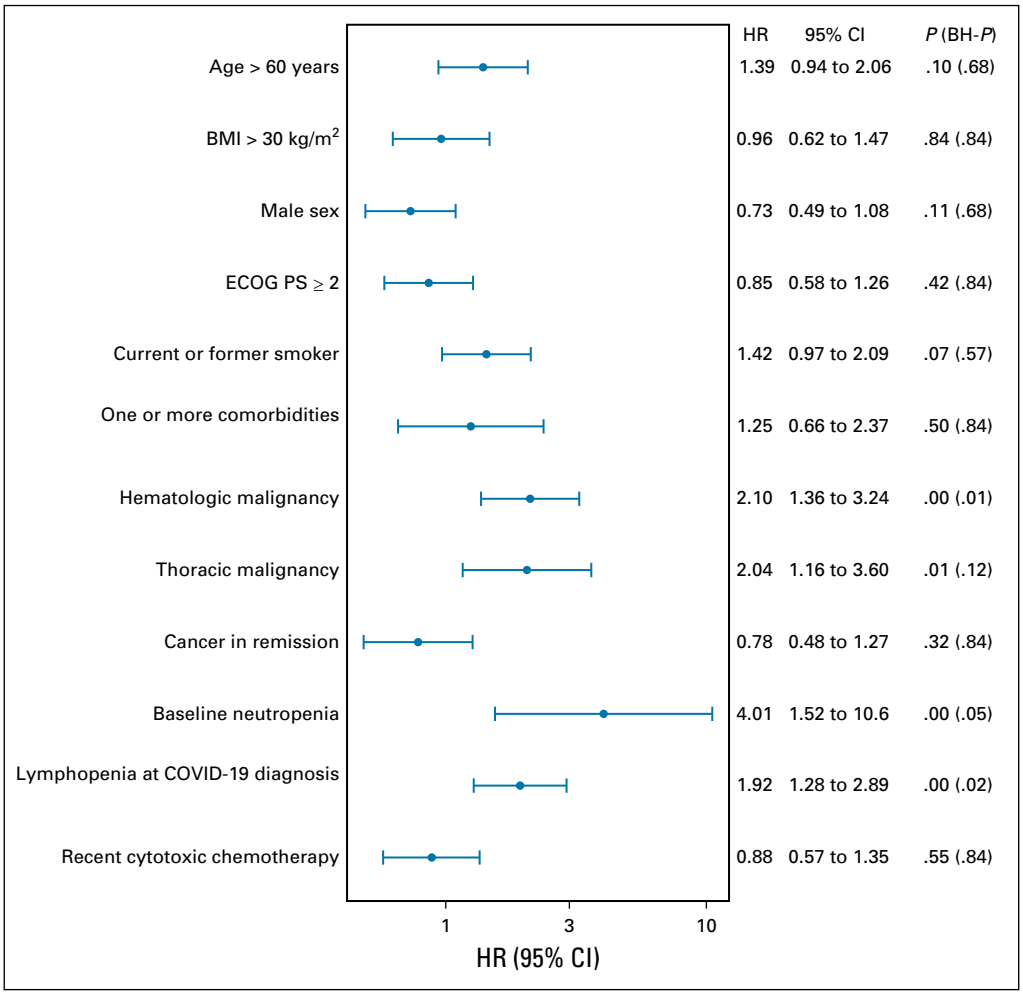

FIG 2. Multivariable Cox regression analysis of significant covariates from univariable analyses. Multivariable analysis with suspected COVID-19–related comorbidities and significant variables from the univariable primary and secondary analyses in Figure 1. Bars represent hazard ratio (HRs) with 95% CIs. BH-*P*, Benjamini-Hochberg–adjusted *P* value; BMI, body mass index; ECOG PS, Eastern Cooperative Oncology Group performance status.

35 days of COVID-19 diagnosis did not demonstrate a significantly increased risk of adverse COVID-19 outcomes (HR, 0.87; 95% CI, 0.57 to 1.30; Data Supplement). Characteristics of patients treated with chemotherapy are shown in the Data Supplement.

Absolute neutrophil count (ANC) at time of diagnosis was elevated in patients who developed severe or critical COVID-19 infection (Fig 3A; Data Supplement). Thirteen (92.9%) of 14 patients with an ANC > 5,000/μL had a solid malignancy. Interleukin-6 (IL-6), lactate dehydrogenase (LDH), D-dimer, AST, troponin I, and procalcitonin were significantly elevated at the time of COVID-19 diagnosis in patients who developed severe or critical illness (Fig 3A). Many laboratory markers were significantly elevated from a pre-infection baseline in the setting of COVID-19, including absolute lymphocyte count (ALC), AST, ALT, and LDH (Fig 3B; Data Supplement).

Thirty-six patients (11.7%) had a history of thromboembolism; 20 of those patients (55.6%) developed severe or critical COVID-19. The symptom, radiology, and cardiology profiles of our patients (Data Supplement) were otherwise similar to those of patients without cancer reported in other studies.[12]

DISCUSSION

Our study validates previous reports that have suggested a high incidence of severe or critical events (38.8%) in patients with cancer and COVID-19. Of note, the study demonstrates that patients treated with cytotoxic chemotherapy administered between 90 and 14 days before SARS-CoV-2 test positivity did not have an increased HR for the composite end point, ICU admission, or death in separate analyses. This finding was substantiated in a subgroup analysis of patients with active malignancies and in multiple sensitivity analyses using alternate time onset and end points. These findings contrast with those of a smaller study from China[8] that suggested worse outcomes with chemotherapy despite a similar end point of severe COVID-19 but align with larger studies that found no effect of chemotherapy on COVID-19–associated mortality in patients with cancer in the United States, Spain, Canada,[6] and the United Kingdom.[7] In our study, patients treated with cytotoxic chemotherapy also did not seem to be more likely to test positive for SARS-CoV-2.

Of 102 patients treated with cytotoxic chemotherapy, only 14 (13.7%) had a diagnosis of hematologic malignancy; our conclusions with regard to cytotoxic chemotherapy may not

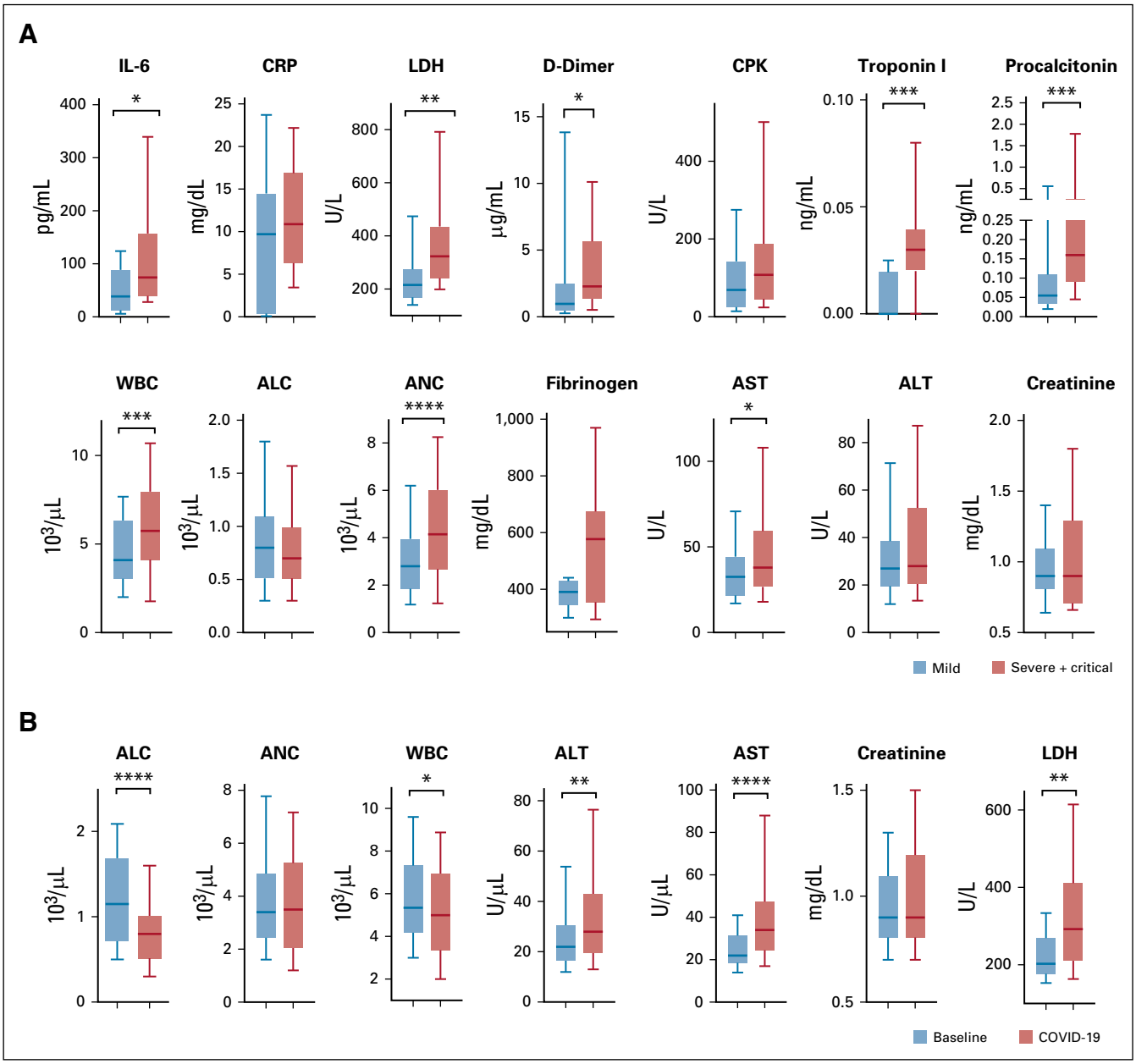

FIG 3. Laboratory abnormalities in patients with COVID-19. Boxplots (indicating quartiles and 10th-90th percentiles) are shown for the respective laboratory values obtained. (A) Samples from peri–COVID-19 laboratory values stratified by severity of COVID-19 infection (mild *v* severe or critical). Statistical significance assessed using Mann-Whitney *U* test. (B) Samples stratified by time point. Baseline includes the most recent laboratory values obtained within a 14- to 90-day period before the date of COVID-19 diagnosis. COVID-19 includes peri–COVID-19 values. Statistical significance was assessed using the Wilcoxon signed rank test. Note that patients with chronic lymphocytic leukemia were excluded from this analysis. $*P < .05$, $**P < .01$, $***P < .001$, $****P < .0001$. ALC, absolute lymphocyte count; ANC, absolute neutrophil count; CPK, creatine phosphokinase; CRP, C-reactive protein; IL-6, interleukin-6; LDH, lactate dehydrogenase.

apply to this subgroup. In patients with a diagnosis of hematologic malignancy treated with cytotoxic chemotherapy, seven (50%) developed severe or critical illness. Patients who received tyrosine kinase inhibitors (TKIs) showed an increased HR for time from COVID-19 diagnosis to ICU admission or death in a sensitivity analysis. This treatment group was notably heterogeneous, composed of patients receiving different oral and intravenous TKIs. Nine (18.4%) of 49 patients treated with a TKI had lung cancer. Additional investigation is warranted in this population to delineate the true risk of TKIs in the cancer population infected with SARS-CoV-2.

Patients with lung cancer showed an increased HR for the primary end point, consistent with other studies.[5] Lung cancer may portend a poorer prognosis for patients with COVID-19 because of decreased lung capacity, pulmonary vascular compromise, or interstitial or parenchymal

damage related to cancer and prior treatments. Mortality from influenza and other respiratory viruses has been shown to be higher in patients with lung cancer compared with patients with other cancer types.[13] Patients with lung cancer are also more likely to have a history of smoking and comorbid conditions, such as chronic obstructive pulmonary disease, although these were not independent risk factors for severe COVID-19 in our analysis.

Patients with hematologic malignancy, particularly acute myeloid leukemia, demonstrated higher HR for severe or critical COVID-19. This finding supports trends observed in patients with COVID-19 and hematologic cancers in China.[5]

Cytotoxic chemotherapy administration was, unsurprisingly, associated with active cancer (Data Supplement). Approximately one third of the patients included in this study (n = 88 of 309) had no evidence of disease (cancer remission) at the time of COVID-19 diagnosis. Overall, patients with no evidence of disease had a milder COVID-19 course (Table 1). In the subgroup of patients with inactive malignancies, older patients and those with lymphopenia at the time of their COVID-19 diagnosis showed higher rates of adverse events, as seen in noncancer populations.[12] In contrast, in a subgroup analysis of patients with active malignancy, those with lung or hematologic malignancies, baseline neutropenia, and lymphopenia at the time of COVID-19 diagnosis had worse outcomes.

Twenty (55.6%) of 36 patients with a history of thromboembolism developed severe or critical COVID-19. Anticoagulation treatment and bleeding events during COVID-19 hospitalization are listed in the Data Supplement, with no clear trend between either of these factors and severe or critical COVID-19. Additional investigation into the risk of severe COVID-19 events posed by cancer-associated thromboembolism is needed.

Laboratory analyses revealed several notable findings. Although nonspecific, elevations in inflammatory markers have been associated with severe infection and require prospective validation.[14,15] We observed elevations in ANC and ANC/ALC ratio in patients with increased COVID-19 severity, as observed by others,[16] particularly in patients with solid malignancy. Patients with SARS-CoV-2 infection often exhibit lymphopenia and elevated IL-6 levels concurrently with symptoms, suggesting an immunomodulatory effect on T lymphocytes.[17]

The study has several limitations. The generalizability of our results is limited by the unique structure of MSKCC, a dedicated cancer center with a closed emergency department that serves predominantly patients who are followed longitudinally at the institution. These patients may report symptoms earlier in the course of illness, and MSKCC has a dedicated COVID-19 nursing response team, which ensures close follow-up with patients after diagnosis. In addition, we did not include race or socioeconomic status in our model, which may further limit the generalizability of these results to a diverse national population of patients with cancer. Additional investigation with a larger sample size will be required to determine whether chemotherapy differentially affects patients of diverse races who contract SARS-CoV-2. The long-term ramifications of COVID-19 on patients with cancer are still unknown. The study population is notably heterogeneous, comprising many subpopulations with sparse representation in the study (Data Supplement). Subgroup analyses, therefore, were relatively underpowered to detect significant covariates in specific disease subsets and in patients with certain treatment types. For example, a relatively small number of patients (n = 18) were treated with immunotherapy. Because oncologic treatment was not randomized, it is possible that selection bias affected our results. Although multivariable analyses do not suggest that cytotoxic chemotherapy is a risk factor for worse COVID-19 outcomes in the presence of active cancer and thoracic or hematologic cancer as variables, it is possible that other factors not included in our model may affect these results. Our study used time-to-event statistical testing, a broad composite end point, and focused on an urban population, which may account for differences in findings compared with other reports. As the landscape of COVID-19 research evolves, further prospective, randomized investigation is warranted to explore how SARS-CoV-2 interacts with specific cancer subtypes and to further characterize the risk of adverse events in patients with COVID-19 undergoing different cancer therapies.

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EQUAL CONTRIBUTION

J.J., M.B.F., M.L., A.J.S., B.W., and V.N. contributed equally.

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AUTHORS' DISCLOSURES OF POTENTIAL CONFLICTS OF INTEREST AND DATA AVAILABILITY STATEMENT

Disclosures provided by the authors and data availability statement (if applicable) are available with this article at DOI https://doi.org/10.1200/JCO.20.01307.

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Final approval of manuscript: All authors

Accountable for all aspects of the work: All authors

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AUTHORS' DISCLOSURES OF POTENTIAL CONFLICTS OF INTEREST

Chemotherapy and COVID-19 Outcomes in Patients With Cancer

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