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Clinical Characteristics, Management, and Outcomes of Cancer Patients With Coronavirus Disease 2019 Admitted to the ICU

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OBJECTIVES: Adult patients with cancer have a greater likelihood of developing severe illness and death from coronavirus disease 2019 compared with patients without cancer. We sought to characterize the clinical characteristics and outcomes of cancer patients who tested positive for severe acute respiratory syndrome coronavirus 2 and were admitted to the ICU at the peak of the first wave of the pandemic in the United States.

DESIGN: A single-center retrospective cohort study.

SETTING: Two medical-surgical ICUs of a tertiary-care cancer center.

PATIENTS/SUBJECTS: All consecutive adult patients (≥ 18 yr) with current or past (< 2 yr) diagnosis of cancer who were admitted to the ICU with coronavirus disease 2019 between March 1, and June 30, 2020.

INTERVENTIONS: None.

MEASUREMENTS AND MAIN RESULTS: Demographic, clinical, and laboratory data of 89 critically ill cancer patients were extracted from electronic medical records. Median age was 65 years (interquartile range, 57–70 yr), 66% were White, and 58% male. Approximately a third of patients had three or more comorbidities. Fifty-one patients (57%) had solid tumors, and 38 (42%) had hematologic malignancies. Sixty-one patients (69%) received cancer-directed therapy within the previous 90 days. Sixty patients (67%) required mechanical ventilation, 56% required prone positioning, 28% underwent tracheostomy, and 71% required vasopressors. Hospital mortality was 45% (40/89). Among those who required mechanical ventilation, mortality was 53% (32/60). Hospital mortality was significantly higher among patients with hematologic malignancies, higher severity of illness and organ failure scores, need for invasive mechanical ventilation and vasopressor therapy, lower hemoglobin and platelet count, and higher D-dimer levels at ICU admission. ICU and hospital length of stay were 10 and 26 days, respectively. At 9-month follow-up, the mortality rate was 54% (48/89).

CONCLUSIONS: We report the largest case series and intermediate-term follow-up of cancer patients with coronavirus disease 2019 who were admitted to the ICU. Hospital mortality was 45%. Intermediate-term outcome after hospital discharge was favorable.

KEY WORDS: cancer; coronavirus disease 19; critical care; intensive care; outcomes

Early reports in 2020 from China, Europe, and the United States suggested that the likelihood of a severe illness and death from coronavirus disease 2019 (COVID-19) was higher among adult patients with cancer, particularly with hematologic malignancies, breast and lung cancer, and those who were older (> 65 yr), non-White race, and comorbidities, including hypertension, cardiovascular disease, and chronic kidney disease (1–9). Two systematic

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reviews and meta-analysis of studies with follow-up data through July 2020 involving patients with cancer and COVID-19 found pooled case mortality rates ranging from 3.7% to 61.5% (10, 11). Many of the studies included in these meta-analyses analyzed relatively small numbers of patients with COVID-19 and cancer admitted to general hospitals and reported limited intensive care data and only short-term outcomes (< 3 mo).

In this study, we sought to characterize the clinical and laboratory characteristics, course, and outcomes of a cohort of 89 patients with cancer and COVID-19 who were admitted to a dedicated ICU of a cancer center at the peak of the first wave of the pandemic in the United States between March and June 2020.

METHODS AND MATERIALS

We performed a retrospective analysis of adult patients (age ≥ 18 yr) with a current or past (< 2 yr) diagnosis of cancer and confirmed severe acute respiratory syndrome coronavirus 2 (SARS-Co-V-2) infection who were consecutively admitted to the ICU. A total of 89 patients were identified for final analysis.

Setting

All patients were admitted to one of two medical-surgical ICUs of Memorial Sloan Kettering Cancer Center (MSKCC), a 514-bed, major metropolitan referral cancer center between March 16, and June 30, 2020. Due to limited bed availability from surge admissions, an auxiliary 23-bed ICU staffed by medical and surgical intensivists, pulmonary and critical care physicians, and hospitalists was constructed in addition to the preexisting 22-bed main ICU. Only the first index ICU admission with SARS-Co-V-2 infection was included for analysis as a measure of the patients' initial response to the virus, thereby excluding multiple confounding variables such as clinical severity resulting from hospitalization and experimental treatments. Pediatric patients (age < 18 yr), current or former employees, and subjects without a formal diagnosis of cancer were excluded.

Clinical Testing and Management Approaches

All the enrolled patients were confirmed SARS-Co-V-2 positive by reverse-transcriptase polymerase chain reaction (RT-PCR) assay of a nasopharyngeal swab. Only in-house laboratory-confirmed cases were included. During the study period, an institution-wide comprehensive screening program for SARS-CoV-2 was implemented where all patients were routinely tested at hospital admission and every 72 hours thereafter. All employees in contact with patients positive or being screened for SARS-Co-V-2 were mandated to don N95 respirator masks and gowns to minimize transmission.

The hospital adopted an early intubation strategy for impending respiratory failure during the first 4 weeks. Aerosol-generating procedures including noninvasive positive pressure ventilation, bronchoscopy, and sputum induction were also avoided to decrease the risk of SARS-Co-V-2 transmission for healthcare providers. Among patients who were intubated, pressure control ventilation and targeted tidal volume of 6 mL/kg predicted body weight and moderate to high positive end-expiratory pressure was standard practice. Proning (self or during mechanical ventilation) was implemented for all eligible patients. Each patient was ventilated for a waiting period of 4 weeks before tracheostomy was considered.

Data Collection

Demographic, clinical, laboratory, cancer-directed therapies (medical, surgical, or radiation therapy) within the past 90 days of hospitalization, COVID-19–directed therapies, and outcome data were manually abstracted from the electronic medical record into a Research Electronic Data Capture survey questionnaire, and all patient identifiers were removed. Laboratory data included complete blood count (including absolute neutrophil count [ANC] and absolute lymphocyte count [ALC]), liver and kidney function tests, coagulation tests (including D-dimer, fibrinogen), lactic acid dehydrogenase (LDH), and inflammatory and immune function biomarkers (C-reactive protein [CRP], procalcitonin, interleukin [IL]–6). Information was validated by three independent reviewers (M.K.M.D., N.K., S.M.P.). The study was approved by the Institutional Review Board (IRB) at MSKCC (IRB number 20-175).

Data Analysis

Simple descriptive statistics were used to report baseline demographics, clinical characteristics, and outcomes. Categorical values were reported as frequency and

percentages, whereas continuous variables were reported as medians with interquartile ranges. We used independent sample *t* tests and nonparametric Mann-Whitney *U* tests to compare survivors and nonsurvivors according to type of cancer, severity of illness or need for organ support, and laboratory findings at hospital and ICU admission and laboratory variables among those who did and did not require invasive mechanical ventilation. All statistical analyses were performed using SPSS Version 26 (IBM Corp., Armonk, NY). *p* values of less than 0.05 were considered as statistically significant.

RESULTS

Between March 1, 2020, and June 30, 2020, there were 4,884 unique inpatient admissions to MSKCC. Of these, 420 adult patients (8.6%) tested positive for SARS-Co-V-2 by RT-PCR. Of the 420 patients, 89 (21.2%) had a current or past diagnosis of cancer and were admitted to the ICU with COVID-19 (**Fig. 1**).

Patient Characteristics (*n* = 89)

The demographic and clinical characteristics of the study patients are shown in **Table 1**. The median age was 65 years (interquartile range [IQR], 57–70 yr), 58% were male, and 66% were of White ethnicity. Median body mass index was 26 (IQR, 22–30). Among the 89 patients, the most common comorbidity was hypertension in 49% followed by diabetes mellitus in 32%, chronic obstructive pulmonary disease in 15%, and coronary artery disease in 8%. One in three patients (33%) had more than three comorbid conditions. Fifty-four percent had a history of smoking. The most common presenting symptoms were fever (61%), dyspnea (72%), and cough (52%). Eight patients (9%) had neutropenia (ANC < 1,500/μL) at ICU admission.

Cancer Characteristics and Cancer-Directed Therapies

The cancer characteristics and cancer-directed therapies are listed in **Table 2**. Fifty-seven percent of patients had solid tumors, and 43% had hematologic malignancies. The most common solid tumors were thoracic (25%), gastrointestinal (20%), and breast (16%) cancers. Leukemia (42%) and lymphoma (37%) were the most common hematologic malignancies. Eighty percent of patients had metastatic cancer. Fourteen

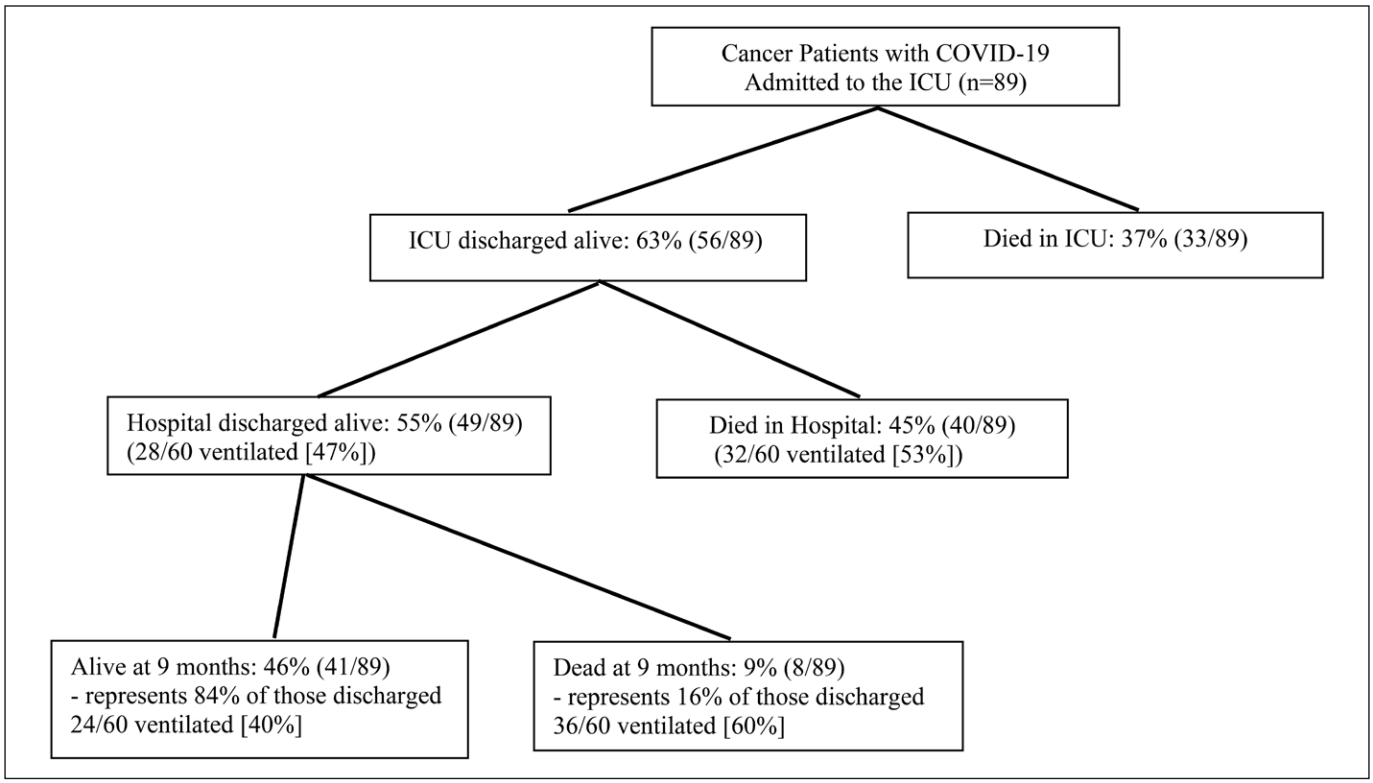

Figure 1. Flow chart of the enrolled patients. ICU, hospital, and 9-month outcomes of patients with coronavirus disease 2019 (COVID-19) and cancer admitted to the ICU.

TABLE 1.
Demographics, Clinical Characteristics, and Treatment of Patients With Cancer Admitted to the ICU With Coronavirus Disease 2019

Variables	All Patients (*N* = 89)	Survivors (*N* = 49)	Nonsurvivors (*N* = 40)
Age, yr, median (interquartile range)	65 (57–70)	67 (58–71)	63 (56–70)
Gender male, *n* (%)	52 (58)	32 (65)	20 (50)
Race, White, *n* (%)	59 (66)	32 (65)	27 (68)
Body mass index, median (interquartile range)	26 (22–30)	27 (23–30)	25 (21–29)
Comorbidities, *n* (%)			
Smoking history	48 (54)	24 (49)	24 (60)
Hypertension	44 (49)	26 (53)	18 (45)
Diabetes mellitus	28 (32)	15 (31)	13 (33)
Chronic obstructive pulmonary disease/asthma	13 (15)	6 (12)	7 (18)
Coronary artery disease	7 (8)	4 (8)	3 (8)
≥ 3 comorbid conditions	29 (33)	15 (38)	14 (29)
Presenting symptoms, *n* (%)			
Fever	53 (60)	32 (65)	21 (53)
Dyspnea	64 (72)	34 (69)	30 (75)
Cough	46 (52)	29 (59)	17 (43)
Neutropenia at ICU admission (absolute neutrophil count < 1,500/μL), *n* (%)	8 (9)	2 (4)	6 (15)
Lymphopenia (absolute lymphocyte count < 1,000/μL), *n* (%)	26 (29)	13 (27)	13 (33)
Mortality Probability Model-II score at ICU admission, median (interquartile range)	34 (23–62)	29 (22–49)	54 (27–74)
Sequential Organ Failure Assessment score at ICU admission, median (interquartile range)	6 (3–9)	5 (3–8)	8 (4–10)
Coronavirus disease 2019 therapies, *n* (%)			
Hydroxychloroquine	66 (74)	39 (80)	27 (68)
Azithromycin	54 (61)	32 (65)	22 (55)
Convalescent plasma	26 (29)	11 (22)	15 (38)
Remdesivir	18 (20)	6 (12)	12 (30)
Tocilizumab	13 (15)	4 (8)	9 (23)
N-acetylcysteine	14 (16)	4 (8)	10 (25)
Corticosteroids	49 (55)	29 (59)	20 (50)

patients (16%) with solid tumors who had undergone surgical resection within the past 2 years had no evidence of disease at the time of their hospitalization for COVID-19. Nearly 70% were receiving cancer-directed therapies within the previous 90 days. The most common was cytotoxic chemotherapy (50%), followed by targeted therapy (25%), immunotherapy (22%), radiation therapy (22%), surgery (13%), and hormonal therapy in 5%. A similar number of hematologic malignancy and solid tumor patients received cytotoxic chemotherapy and targeted agents.

COVID-19 Therapies

During the first 2 months of the pandemic, hydroxychloroquine and azithromycin were the primary

TABLE 2.
Cancer Characteristics and Cancer-Directed Therapies

Cancer Characteristics	ICU Patients (*N* = 89)	Survivors (*N* = 49)	Nonsurvivors (*N* = 40)
Types of cancer, *n* (%)			
Hematologic	38 (43)	16 (33)	22 (55)
Leukemia	16 (42)	7 (14)	9 (23)
Lymphoma	14 (37)	4 (8)	10 (25)
Plasma cell dyscrasias	6 (16)	3 (6)	3 (8)
Others	2 (5)	2 (4)	0 (0)
Solid tumor	51 (57)	33 (67)	18 (45)
Thoracic	13 (25)	7 (14)	6 (15)
Gastrointestinal	10 (20)	8 (16)	2 (5)
Breast	8 (16)	5 (10)	3 (8)
Genitourinary	5 (10)	4 (8)	1 (3)
Head and neck	5 (10)	4 (8)	1 (3)
Gynecologic	3 (6)	0 (0)	3 (8)
Neurologic	3 (6)	3 (6)	0 (0)
Sarcoma	3 (6)	1 (3)	2 (5)
Melanoma	1 (2)	1 (2)	0 (0)
Stage of cancer, *n* (%)			
No evidence of disease (solid)[a]	14 (27)	11 (22)	3 (8)
Localized solid (nonmetastatic)	4 (8)	4 (8)	0 (0)
Metastatic solid	33 (65)	18 (37)	15 (38)
Hematologic malignancy, progressive disease	29 (76)	11 (22)	18 (45)
Cancer-Directed Therapies Within the Previous 90 d	***N* = 60**	***N* = 33**	***N* = 27**
Medical therapies, *n* (%)			
Cytotoxic chemotherapy	30 (50)	14 (42)	16 (59)
Targeted treatment	15 (25)	8 (24)	7 (26)
Immunotherapy	13 (22)	4 (12)	9 (33)
Hormonal	3 (5)	1 (3)	2 (7)
Surgery, *n* (%)	8 (13)	7 (21)	1 (4)
Radiation therapy, *n* (%)	13 (22)	10 (30)	3 (11)
Multimodality treatment, *n* (%)	10 (17)	5 (15)	5 (19)

[a]These patients had undergone surgical resection for cancer within the past 2 yr and were being followed for recurrence.

treatments in 74% and 58%, respectively. Following emergency use authorization by the Food and Drug Administration, there was a subsequent rise in the use of investigational medications including convalescent plasma in 29%, remdesivir in 20%, tocilizumab (IL-6 inhibitor) in 16%, and N-acetylcysteine in 16% (Table 1).

Patient Characteristics at ICU Admission, Organ Support, and Length of Stay

Overall, the median Mortality Probability Model (MPM)–II and Sequential Organ Failure Assessment (SOFA) scores at ICU admission were 34 (23–62) and 6 (3–9), respectively (**Table 3**). The median MPM-II and SOFA

TABLE 3.
Severity of Illness, Organ Support, and Outcomes

Variables	*N* = 89	Survivors (*N* = 49)	Nonsurvivors (*N* = 40)	*p*
Mortality Probability Model-II score at ICU admission, median (interquartile range)	34 (23–62)	29 (22–49)	54 (27–74)	**0.007**
Sequential Organ Failure Assessment score at ICU admission, median (interquartile range)	6 (3–9)	5 (3–8)	8 (4–10)	**0.004**
Pre-ICU LOS, median (interquartile range)	2 (1–6)	2 (1–6)	2 (1–5)	NS
Pao_2/Fio_2 ratio at ICU admission, median (interquartile range)	157 (98–217)	156 (98–217)	169 (96–221)	NS
Mechanical ventilation, *n* (%)	60 (67)	28 (47)	32 (53)	**0.025**
Prone positioning, *n* (%)	50 (56)	27 (55)	23 (58)	**0.034**
Tracheostomy, *n* (%)	17 (28)	9 (19)	8 (20)	NS
Vasopressor therapy, *n* (%)	63 (71)	29 (59)	34 (85)	**0.01**
Renal replacement therapy, *n* (%)	10 (11)	4 (8)	6 (15)	NS
Hemodialysis, *n*	2			
Continuous renal replacement therapy, *n*	8			
ICU LOS, median (interquartile range)	10 (4–21)	10 (3–21)	10 (5–23)	NS
Hospital LOS, median (interquartile range)	26 (13–45)	29 (17–59)	17 (9–39)	**0.009**

LOS = length of stay, NS = not significant.
Boldface values are statistically significant.

scores for the hematologic malignancy were 41 (25–58) and 8 (4–9), respectively; the corresponding scores for the solid tumor patients were 31 (22–69) and 5 (3–8), respectively. Sixty patients (67%) required mechanical ventilation for a mean duration of 22 days; 71% (63/89) required vasopressor therapy, and 11% (10/89) underwent hemodialysis or renal replacement percentages therapy. Median ICU length of stay (LOS) was 10 days (range, 4–21 d), and median hospital LOS was 26 days (range, 13–45 d). Self-proning and prone ventilation were used in 56% of patients. Among those who required mechanical ventilation, tracheostomy was performed in 28% (17/60).

ICU and Hospital Mortality Among Survivors and Nonsurvivors

Overall, the ICU and hospital mortality rates were 37% and 45%, respectively (Fig. 1). Hospital mortality was significantly higher among patients with hematologic malignancies compared with those with solid tumors (55% vs 45%; $p = 0.034$). Compared with survivors, the median MPM-II and SOFA scores at ICU admission were significantly higher in the nonsurvivors (54 [27–74] vs 29 [22–49]; $p = 0.007$ and 8 [4–10] vs 5 [3–8]; $p = 0.004$, respectively). Nonsurvivors had significantly greater rates of requiring mechanical ventilation (53% vs 47%; $p = 0.025$) and vasopressors (85% vs 59%; $p = 0.01$) than survivors (Table 3). Among the 40 patients who died in the hospital, five (13%) had subsequent ICU admissions. Of the 49 patients who were discharged from the hospital alive, 41 (84%) were still alive at 9 months (Fig. 1).

Laboratory Findings at Hospital and ICU Admission Among Survivors and Nonsurvivors

At hospital admission, the median hemoglobin level was significantly lower in those who died compared with those who survived (10.20 g/dL [8.50–12.30 g/dL] vs 11.90 g/dL [10.45–13.55 g/dL]). Although the median values of D-dimer, ferritin, procalcitonin, CRP, and lactic acid were higher and ANC, ALC, platelet count, and fibrinogen level were lower in the nonsurvivors, the results were not statistically significant (**Supplemental Table A**, http://links.lww.com/CCX/A789).

At ICU admission, the median hemoglobin and platelet count were significantly lower in those who died compared with those who survived (9.0 g/dL [8.20–10.50 g/dL] vs 11.10 g/dL [9.85–12.15 g/dL] and

153/mm^3 [76–217/mm^3] vs 219/mm^3 [120–312/mm^3], respectively). There was no statistically significant difference in the median values for the ANC, ALC, fibrinogen, LDH, ferritin, CRP, IL-6, lactic acid, or creatinine. However, D-dimer and procalcitonin levels were significantly higher in nonsurvivors compared with survivors (3.19 [1.75–5.61] vs 1.78 [0.89–2.94] and 0.46 [0.12–3.77] vs 0.18 [0.06–0.59], respectively) (Supplemental Table A, http://links.lww.com/CCX/A789).

Laboratory Findings at Hospital Admission and Need for Invasive Mechanical Ventilation

IL-6 level was significantly higher and nearly twice as high at hospital admission among the patients who required invasive mechanical ventilation compared with those who did not require mechanical ventilation (76 [36–181] vs 40 [15.6–96.2]; $p = 0.04$). No other laboratory variable at hospital admission was associated with the need for mechanical ventilation (**Supplemental Table B**, http://links.lww.com/CCX/A790).

DISCUSSION

To our knowledge, we report the largest case series and longer follow-up of cancer patients who presented with critical illness and laboratory-confirmed SARS-Co-V-2 infection to a tertiary-care cancer referral center during the first wave of the pandemic in the United States between March 1, and June 30, 2020. Our ICU study cohort represented 21% of the SARS-Co-V-2–positive inpatient population admitted during that period.

Despite the cancer diagnosis and immunosuppressive state associated with malignancy, our ICU mortality rate of 37% is slightly lower than the median ICU mortality rate of 41.6% reported in an initial systematic review and meta-analysis of 24 observational studies involving 10,150 patients with and without cancer hospitalized with COVID-19 who required intensive care through the end of May 2020 (12). In an updated systematic review and meta-analysis of 52 studies involving 43,128 patients admitted to ICU with COVID-19 through the end of September 2020, the same authors found an ICU mortality rate of 35.5% (13). Of note, several studies included in these systematic reviews and meta-analysis involved patients with and without cancer who remained hospitalized at the end of the study period, precluding analysis of their intermediate (> 3 mo) and long-term (> 6 mo) outcomes. We continued to follow our patients for a longer period post hospital discharge and found that 84% of these patients were still alive at 9 months.

Our study showed that patients with hematologic malignancies had a significantly higher mortality compared with those with solid tumors (55% vs 45%), in agreement with previous studies (2, 6, 9, 14). Hematologic malignancies such as leukemias and lymphomas are more commonly associated with greater degrees of immune deficiency because of the malignancy itself, anticancer treatments, or from hematopoietic stem cell transplantation (14). Additionally, patients with hematologic malignancies hospitalized with COVID-19 have been shown to have higher SARS-Co-V-2 viral load compared with other cancer types (15), and higher viral load independently predicts mortality. Majority of hematologic malignancy patients (76%) had progressive disease, whereas 65% of solid tumor patients had metastatic disease. Nearly 70% of our cancer patients received cancer-directed therapies within the previous 90 days of their hospitalization for COVID-19. Contrary to the notion that chemotherapy or immunotherapy for cancer may hinder the ability to combat a COVID-19 viral infection, our data suggest that the receipt of anticancer therapy within 90 days of hospitalization was not associated with increased mortality, as similarly reported by other investigators (3, 6, 9).

The greater severity of illness and organ failure as measured by MPM-II and SOFA scores, respectively, at ICU admission conferred the need for mechanical ventilation and vasopressor therapy. This correlates with prior studies that use SOFA score as a marker for sepsis and reflects the degree of multiple organ dysfunction in severe COVID-19 (16). However, there are relatively few studies that evaluate these ICU metrics in cancer patients with COVID-19 to offer as a comparison. To our knowledge, no group has reported MPM-II scores at ICU admission as a mortality evaluation tool during the pandemic. Elevated SOFA scores, however, have been noted as a marker for severity and mortality in critically ill COVID-19 patients (17–19).

Nonsurvivors had a lower hemoglobin and platelet count and higher D-dimer levels at ICU admission compared with survivors, similar to previous reports (20–22). As a major physiologic reaction for viral infections, the lymphocyte count (ALC) surprisingly did not have a statistical effect on ICU mortality, although there was a trend to suggest that higher ALC counts conferred survival.

Anemia and thrombocytopenia are common findings in cancer patients at admission to our institution. We discovered that, unique to our cohort of cancer patients admitted to the ICU with COVID-19, anemia at hospital and ICU admission was associated with higher mortality. We postulate that anemia may be a marker of advanced cancer, bone marrow suppression, chronic disease, and in COVID-19 patients, related to the alteration in iron metabolism and reduced availability of iron for erythropoiesis and production of hemoglobin (23). Similar to other studies, higher D-dimer levels were correlated with severity of COVID-19, possibly implicating the role of microvascular thrombosis in the pathogenesis of acute respiratory distress syndrome (ARDS) and multiple organ failure in these patients (22).

Previously described as a proinflammatory marker in severe pneumonia and ARDS (24), IL-6 levels were studied in select centers to justify the potential use of IL-6 receptor-targeted therapies (siltuximab, tocilizumab, and sarilumab) to mitigate COVID-19 respiratory failure. Our data correlated well with concurrent studies (25, 26) in that the IL-6 values of our patients requiring mechanical ventilation were roughly double to those who were not intubated. Of note, the median IL-6 levels of our study patients were significantly higher than other COVID-19 respiratory failure cohorts (26, 27). IL-6 levels at the concentrations found in our study are several-fold higher (likely in the background of malignancy) and are comparable with cytokine release syndromes, severe sepsis states, and ARDS unrelated to COVID-19 (28).

Our study has several limitations including the retrospective design, analysis of a heterogeneous group of patients with cancer, and conduct at a single specialized cancer referral center. Thus, we were not able to compare our oncology patients with COVID-19 with patients without a cancer diagnosis. Additionally, some cases had incomplete documentation of clinical symptoms, missing laboratory testing, or both. However, given the need to provide objective data and the urgent timeline, we did not approach patients to obtain additional history or biologic samples for laboratory measurements. Furthermore, because of our focus on the critical care needs of patients with the greatest severity of illness, our sample size is small and prone to selection bias. Due to the retrospective study design, not all inflammatory and coagulation markers for COVID-19 (e.g., CRP, ferritin, IL-6, D-dimer) were obtained in all patients at hospital admission. Therefore, their role might be underestimated in predicting in-hospital death. We did not specifically analyze the impact of early intubation or use of experimental therapeutics on mortality. Furthermore, we did not collect data on how many patients who were discharged alive from the hospital went on to resume antineoplastic therapy, as this was beyond the scope of our study. Finally, it is possible that critically ill patients with established goals of care that were not consistent with admission to an ICU were not included in this report. Specifically, this includes patients who received care on the general medical ward that focused on comfort measures only.

In conclusion, our study confirms the high mortality (45%) of cancer patients with COVID-19 who required ICU admission, particularly for those who require mechanical ventilation (53%) during the first wave of the COVID-19 pandemic in the United States. However, among critically ill cancer patients who survive to hospital discharge, the intermediate-term outcome appears favorable and justifies the aggressive management and ICU admission of this highly vulnerable patient population.

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All authors had full access to all data (including statistical reports and tables) in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Drs. Dang and Pastores contributed to conception and design. Drs. Dang, Bhatt, and Pastores contributed to provision of study materials or patients. All authors contributed to collection and assembly of data. All authors contributed to data analysis and interpretation.

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REFERENCES

1. Liang W, Guan W, Chen R, et al: Cancer patients in SARS-CoV-2 infection: A nationwide analysis in China. *Lancet Oncol* 2020; 21:335–337
2. Yang K, Sheng Y, Huang C, et al: Clinical characteristics, outcomes, and risk factors for mortality in patients with cancer and COVID-19 in Hubei, China: A multicentre, retrospective, cohort study. *Lancet Oncol* 2020; 21:904–913
3. Lee LY, Cazier JB, Angelis V, et al; UK Coronavirus Monitoring Project Team: COVID-19 mortality in patients with cancer on chemotherapy or other anticancer treatments: A prospective cohort study. *Lancet* 2020; 395:1919–1926
4. Kuderer NM, Choueiri TK, Shah DP, et al; COVID-19 and Cancer Consortium: Clinical impact of COVID-19 on patients with cancer (CCC19): A cohort study. *Lancet* 2020; 395:1907–1918
5. Rivera DR, Peters S, Panagiotou OA, et al; COVID-19 and Cancer Consortium: Utilization of COVID-19 treatments and clinical outcomes among patients with cancer: A COVID-19 and Cancer Consortium (CCC19) cohort study. *Cancer Discov* 2020; 10:1514–1527
6. Robilotti EV, Babady NE, Mead PA, et al: Determinants of COVID-19 disease severity in patients with cancer. *Nat Med* 2020; 26:1218–1223
7. Wang Q, Berger NA, Xu R: Analyses of risk, racial disparity, and outcomes among US patients with cancer and COVID-19 infection. *JAMA Oncol* 2021; 7:220–227
8. He W, Chen L, Chen L, et al: COVID-19 in persons with haematological cancers. *Leukemia* 2020; 34:1637–1645
9. Fu C, Stoeckle JH, Masri L, et al: COVID-19 outcomes in hospitalized patients with active cancer: Experiences from a major New York City Health Care System. *Cancer* 2021; 127:3466–3475
10. Giannakoulis VG, Papoutsi E, Siempos II: Effect of cancer on clinical outcomes of patients with COVID-19: A meta-analysis of patient data. *JCO Glob Oncol* 2020; 6:799–808
11. Saini KS, Tagliamento M, Lambertini M, et al: Mortality in patients with cancer and coronavirus disease 2019: A systematic review and pooled analysis of 52 studies. *Eur J Cancer* 2020; 139:43–50
12. Armstrong RA, Kane AD, Cook TM: Outcomes from intensive care in patients with COVID-19: A systematic review and meta-analysis of observational studies. *Anaesthesia* 2020; 75:1340–1349
13. Armstrong RA, Kane AD, Kursumovic E, et al: Mortality in patients admitted to intensive care with COVID-19: An updated systematic review and meta-analysis of observational studies. *Anaesthesia* 2021; 76:537–548
14. Passamonti F, Cattaneo C, Arcaini L, et al; ITA-HEMA-COV Investigators: Clinical characteristics and risk factors associated with COVID-19 severity in patients with haematological malignancies in Italy: A retrospective, multicentre, cohort study. *Lancet Haematol* 2020; 7:e737–e745
15. Westblade LF, Brar G, Pinheiro LC, et al: SARS-CoV-2 viral load predicts mortality in patients with and without cancer who are hospitalized with COVID-19. *Cancer Cell* 2020; 38:661–671.e2
16. Richards-Belle A, Orzechowska I, Gould DW, et al: COVID-19 in critical care: Epidemiology of the first epidemic wave across England, Wales and Northern Ireland. *Intensive Care Med* 2020; 46:2035–2047
17. Zhou F, Yu T, Du R, et al: Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: A retrospective cohort study. *Lancet* 2020; 395:1054–1062
18. Liu S, Yao N, Qiu Y, et al: Predictive performance of SOFA and qSOFA for in-hospital mortality in severe novel coronavirus disease. *Am J Emerg Med* 2020; 38:2074–2080
19. Raschke RA, Agarwal S, Rangan P, et al: Discriminant accuracy of the SOFA score for determining the probable mortality of patients with COVID-19 pneumonia requiring mechanical ventilation. *JAMA* 2021; 325:1469–1470
20. Oh SM, Skendelas JP, Macdonald E, et al: On-admission anemia predicts mortality in COVID-19 patients: A single center, retrospective cohort study. *Am J Emerg Med* 2021; 48:140–147
21. Yang X, Yang Q, Wang Y, et al: Thrombocytopenia and its association with mortality in patients with COVID-19. *J Thromb Haemost* 2020; 18:1469–1472
22. Zhang L, Yan X, Fan Q, et al: D-dimer levels on admission to predict in-hospital mortality in patients with COVID-19. *J Thromb Haemost* 2020; 18:1324–1329
23. Bellmann-Weiler R, Lanser L, Barket R, et al: Prevalence and predictive value of anemia and dysregulated iron homeostasis in patients with COVID-19 infection. *J Clin Med* 2020; 9:E2429
24. Schütte H, Lohmeyer J, Rosseau S, et al: Bronchoalveolar and systemic cytokine profiles in patients with ARDS, severe pneumonia and cardiogenic pulmonary oedema. *Eur Respir J* 1996; 9:1858–1867
25. Herold T, Jurinovic V, Arnreich C, et al: Elevated levels of IL-6 and CRP predict the need for mechanical ventilation in COVID-19. *J Allergy Clin Immunol* 2020; 146:128–136.e4
26. Zhang J, Hao Y, Ou W, et al: Serum interleukin-6 is an indicator for severity in 901 patients with SARS-CoV-2 infection: A cohort study. *J Transl Med* 2020; 18:406
27. Stukas S, Hoiland RL, Cooper J, et al: The association of inflammatory cytokines in the pulmonary pathophysiology of respiratory failure in critically ill patients with coronavirus disease 2019. *Crit Care Explor* 2020; 2:e0203
28. Leisman DE, Ronner L, Pinotti R, et al: Cytokine elevation in severe and critical COVID-19: A rapid systematic review, meta-analysis, and comparison with other inflammatory syndromes. *Lancet Respir Med* 2020; 8:1233–1244