Assessing Unique Risk Factors for COVID-19 Complications Among Cancer Patients: A Multi-ethnic Cohort Study

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Abstract
A myriad of organ-specific complications have been observed with COVID-19. While racial/ethnic minorities have been disproportionately burdened by this disease, our understanding of the unique risk factors for complications among a diverse population of cancer patients remains limited. This is a multi-institutional, multi-ethnic cohort study evaluating COVID-19 complications among cancer patients. Patients with an invasive cancer diagnosis and confirmed SARS-CoV-2 infection were identified from March to November 2020. Demographic and clinical data were obtained and a multivariate logistic regression was employed to evaluate the impact of demographic and clinical factors on COVID-19 complications. The study endpoints were evaluated independently and included any complication, sepsis, pulmonary complications and cardiac complications. A total of 303 patients were evaluated, of whom 48% were male, 79% had solid tumors, and 42% were Hispanic/Latinx (Hispanic). Malignant hematologic cancers were associated with a higher risk of sepsis (OR 3.93 (95% CI 1.58–9.81)). Male patients had a higher risk of sepsis (OR 4.42 (95% CI 1.63–11.96)) and cardiac complications (OR 2.02 (95% CI 1.05–3.89)). Hispanic patients had a higher odds of any complication (OR 2.31 (95% CI 1.18–4.51)) and other race was associated with a higher odds of cardiac complications (OR 2.41 (95% CI 1.01–5.73)). Clinically, fever, cough, and ≥2 co-morbidities were independently significantly associated with any complication. This analysis evaluated covariates that can significantly predict a myriad of complications among a multi-ethnic cohort of cancer patients. The conclusions drawn from this analysis elucidate a mechanistic understanding of differential illness severity from COVID-19.

Key Words COVID-19 · Cancer · Racial/ethnic minorities

Introduction
In the United States, the current COVID-19 pandemic has disproportionately affected minority communities [1]. Despite this observation, racial/ethnic minorities remain underrepresented in published COVID-19 clinical research studies [2, 3]. Research to date has shown that certain demographic factors, such as race/ethnicity, have an impact on clinical severity and outcomes [4–8]. Among the general population infected with SARS-CoV-2, Hispanic/Latinx (Hispanic) ethnicity was observed to be strongly associated with a need for mechanical ventilation [9], whereas non-white ethnicity is strongly associated with critical care admission [8]. However, the impact of race and ethnicity in a cancer specific population remains underexamined. Patients with cancer may be particularly vulnerable to the morbidity and mortality associated with...
COVID-19 disease given underlying co-morbidities and potential immunosuppression from their disease and its treatment.

Individuals with an invasive cancer diagnosis and COVID-19 have been found to have an increased risk of all-cause mortality [10]. Given that COVID-19 can manifest with a myriad of complications, this study leverages a multi-institutional, multi-ethnic cohort to identify the unique risk factors for COVID-19 complications among a diverse population of patients with cancer.

Methods

This is a multi-institutional, multi-ethnic cohort study among patients with cancer. Patients with an invasive cancer diagnosis and a positive serologic or molecular SARS-CoV-2 test result were identified at participating sites (the University of California San Francisco (UCSF), and the University of California San Diego (UCSD)). Demographic and clinical data were collected manually from the electronic health record from March 1 to November 30, 2020, and populated in a REDCap database [11, 12]. This study was deemed exempt from review by the UCSF institutional review board (IRB) and received local IRB approval at UCSD.

Outcomes

We evaluated demographic, disease and treatment factors for their effects on four independent primary endpoints attributed to a COVID-19 diagnosis: “any complication”, sepsis, pulmonary complications, and cardiac complications were identified through manual chart review. Pulmonary complications were defined as respiratory failure, pneumonitis, acute respiratory distress syndrome (ARDS), pulmonary embolism, pleural effusion, or empyema. Cardiovascular complications were defined as hypotension, myocardial infarction, other cardiac ischemia, atrial fibrillation, ventricular fibrillation, other cardiac arrhythmia, cardiomyopathy, congestive heart failure, deep venous thrombosis, superficial venous thrombosis, cerebrovascular accident, or thrombosis. Patients with documented septicemia in the electronic health record were denoted as sepsis events. Lastly “other” complications were collected including gastrointestinal, bleeding, neurologic, systemic, or renal. Patients with “other”, sepsis, pulmonary complications, or cardiac complications were reported as “any complication”. Severity of COVID-19 outcomes for this study cohort defined as outpatient, hospitalization (non-ICU), ICU admission, and mortality is reported separately [13].

Statistical Analysis

Descriptive statistics were employed to summarize the baseline demographic and clinical characteristics of the study cohort. The frequency of clinical presentation characteristics were stratified by COVID-19 complications. A multivariate logistic regression model was generated to evaluate the relationship between patient-level covariates such as cancer history, cancer status, sex, race, age, BMI, treatment history, co-morbidity and COVID-19 presentation. The number of co-morbidities was calculated through manual chart review. The odds ratio for the independent primary endpoints were determined. Facility and environmental factors were controlled for in the model as splines by including average number of COVID-19 cases in the last 7 days per facility.

Results

Patient Characteristics

The study cohort included 303 patients with an invasive cancer diagnosis and a positive serologic or molecular SARS-CoV-2 test result. The clinical and demographic characteristics of patients are summarized overall and by outcome in Table 1. Overall, 147 (48%) were identified as male and 118 (29%) were older adults (≥65 years old). The patient race/ethnicity distribution included 104 (34%) non-Hispanic (NH) white, 21 (7%) NH Black patients, 126 (42%) Hispanic, 27 (9%) Asian, and 25 (8%) other/unknown. The primary language for a subset 71 (23%) of patients was Spanish. The insurance distribution for the study cohort was 75 (25%) Medicaid, 104 (34%) Medicare, 95 (31%) commercial, or other 29 (10%). A total of 106 (35%) had a body mass index (BMI) ≥30 and 182 (60%) had ≥2 co-morbidities. The baseline chronic diseases among the study cohort included pulmonary disease n = 71 (23%), cardiovascular disease n = 150 (50%), renal disease n = 39 (13%), and autoimmune disease n = 13 (4%).

The majority of patients had solid tumors (n = 240, 79%) while the remaining had malignant hematologic cancers (n = 63, 21%). The cancer type distribution is summarized in the supplementary Table 1. Among the study cohort, at the time of COVID-19 diagnosis, 140 (46%) patients were in remission, 80 (26%) had stable disease or response on current therapy, and 54 (18%) had documented cancer progression on most recent clinical evaluation in the medical record. A total of 84 (28%) patients were considered immunosuppressed at time of COVID-19 diagnosis. The majority (n = 171, 56%) of patients had
| Table 1 Patient characteristics | Total | COVID-19 Outcomes |
|--------------------------------|-------|-------------------|
|                                | N     | row % | column % | N | row % | N | row % | N | row % | N | row % | N | row % | N | row % |
| **Total**                      | 303   | 100.0 |          | 184 | 60.7 | 119 | 39.3 | 273 | 90.1 | 30 | 9.9 | 212 | 70   | 91 | 30   | 246 | 81.2 | 57 | 18.8 |
| **Facility**                   |       |       |          |     |       |     |       |     |       |     |       |     |       |     |       |     |       |     |       |
| UC San Diego Health            | 139   | 100   | 45.9     | 90  | 64.7 | 49  | 35.3 | 133 | 95.7 | 6  | 4.3 | 108 | 77.7 | 31 | 22.3 | 121 | 87.1 | 18 | 12.9 |
| UC San Francisco Health        | 164   | 100   | 54.1     | 94  | 57.3 | 70  | 42.7 | 140 | 85.4 | 24 | 14.6 | 104 | 63.4 | 60 | 36.6 | 125 | 76.2 | 39 | 23.8 |
| **Gender**                     |       |       |          |     |       |     |       |     |       |     |       |     |       |     |       |     |       |     |       |
| Female                         | 156   | 100   | 51.5     | 96  | 61.5 | 60  | 38.5 | 149 | 95.5 | 7  | 4.5 | 113 | 72.4 | 43 | 27.6 | 134 | 85.9 | 22 | 14.1 |
| Male                           | 147   | 100   | 48.5     | 88  | 59.9 | 59  | 40.1 | 124 | 84.4 | 23 | 15.6 | 99  | 67.3 | 48 | 32.7 | 112 | 76.2 | 35 | 23.8 |
| **Age**                        |       |       |          |     |       |     |       |     |       |     |       |     |       |     |       |     |       |     |       |
| < 65                           | 185   | 100   | 61.1     | 118 | 63.8 | 67  | 36.2 | 169 | 91.4 | 16 | 8.6 | 135 | 73   | 50 | 27   | 155 | 83.8 | 30 | 16.2 |
| >=65–100                       | 118   | 100   | 38.9     | 66  | 55.9 | 52  | 44.1 | 104 | 88.1 | 14 | 11.9 | 77  | 65.3 | 41 | 34.7 | 91  | 77.1 | 27 | 22.9 |
| **Race**                       |       |       |          |     |       |     |       |     |       |     |       |     |       |     |       |     |       |     |       |
| Non-Hispanic (NH) White        | 104   | 100   | 34.3     | 73  | 70.2 | 31  | 29.8 | 98  | 94.2 | 6 | 5.8 | 79  | 76   | 25 | 24   | 89  | 85.6 | 15 | 14.4 |
| NH Black                       | 21    | 100   | 6.9      | 12  | 57.1 | 9  | 42.9 | 17  | 81   | 4 | 19  | 15  | 71.4 | 6 | 28.6 | 16  | 76.2 | 5  | 23.8 |
| Hispanic/Latinx                | 126   | 100   | 41.6     | 70  | 55.6 | 56  | 44.4 | 115 | 91.3 | 11 | 8.7 | 84  | 66.7 | 42 | 33.3 | 104 | 82.5 | 17 | 17.5 |
| Asian                          | 27    | 100   | 8.9      | 13  | 48.1 | 14 | 51.9 | 21  | 77.8 | 6 | 22.2 | 16  | 59.3 | 11 | 40.7 | 18  | 66.7 | 9  | 33.3 |
| Other/Unknown                  | 25    | 100   | 8.3      | 16  | 64   | 9  | 36   | 22  | 88   | 3 | 12  | 18  | 72   | 7 | 28   | 19  | 76   | 6  | 24  |
| **BMI**                        |       |       |          |     |       |     |       |     |       |     |       |     |       |     |       |     |       |     |       |
| 0 to 30                        | 197   | 100   | 65.0     | 121 | 61.4 | 76  | 38.6 | 179 | 90.9 | 18 | 9.1 | 141 | 71.6 | 56 | 28.4 | 164 | 83.2 | 33 | 16.8 |
| >=30                           | 106   | 100   | 35.0     | 63  | 59.4 | 43 | 40.6 | 94  | 88.7 | 12 | 11.3 | 71  | 67   | 35 | 63   | 82  | 77.4 | 24 | 22.6 |
| **Insurance**                  |       |       |          |     |       |     |       |     |       |     |       |     |       |     |       |     |       |     |       |
| Medicaid                       | 75    | 100   | 24.8     | 43  | 57.3 | 32 | 42.7 | 66  | 88   | 9 | 12  | 51  | 68   | 24 | 32   | 62  | 82.7 | 13 | 17.3 |
| Medicare                       | 104   | 100   | 34.3     | 52  | 50   | 52 | 50   | 87  | 83.7 | 17 | 16.3 | 64  | 61.5 | 40 | 38.5 | 76  | 73.1 | 28 | 26.9 |
| Commercial                     | 95    | 100   | 31.4     | 69  | 72.6 | 26 | 27.4 | 91  | 95.8 | 4 | 4.2 | 77  | 81.1 | 18 | 18.9 | 84  | 88.4 | 11 | 11.6 |
| Other                          | 29    | 100   | 9.6      | 20  | 69   | 9  | 31   | 29  | 100  | 20 | 69   | 9  | 31   | 24  | 82.8 | 5  | 17.2 |
| **Cancer type**                |       |       |          |     |       |     |       |     |       |     |       |     |       |     |       |     |       |     |       |
| Solid Tumor                    | 240   | 100   | 79.2     | 150 | 62.5 | 90 | 37.5 | 224 | 93.3 | 16 | 6.7 | 174 | 72.5 | 66 | 27.5 | 197 | 82.1 | 43 | 17.9 |
| Malignant Hematologic Cancer   | 63    | 100   | 20.8     | 34  | 54   | 29 | 46   | 49  | 77.8 | 14 | 22.2 | 38  | 60.3 | 25 | 39.7 | 49  | 77.8 | 14 | 22.2 |
| **Smoking history**            |       |       |          |     |       |     |       |     |       |     |       |     |       |     |       |     |       |     |       |
| Never Smoker                   | 210   | 100   | 69.3     | 131 | 62.4 | 79 | 37.6 | 195 | 92.9 | 15 | 7.1 | 152 | 72.4 | 58 | 42.6 | 176 | 83.8 | 34 | 16.2 |
| Prior or current smoker        | 93    | 100   | 30.7     | 53  | 57   | 40 | 43   | 78  | 83.9 | 15 | 16.1 | 60  | 64.5 | 33 | 35.5 | 70  | 75.3 | 23 | 24.7 |
| **Cancer status**              |       |       |          |     |       |     |       |     |       |     |       |     |       |     |       |     |       |     |       |
| Unknown                        | 29    | 100   | 9.6      | 16  | 55.2 | 13 | 44.8 | 24  | 82.8 | 5 | 17.2 | 17  | 58.6 | 12 | 41.4 | 21  | 72.4 | 8  | 27.6 |
| Table 1 (continued) |
|---------------------|
| | Total | COVID-19 Outcomes |
| | | Any complications | Sepsis | Pulmonary complications | Cardiac complications |
| | | N row % | column % | N row % | N row % | N row % | N row % |
| Remission/no evidence of disease | 140 100 | 46.2 | 86 61.4 | 54 38.6 | 130 92.9 | 10 7.1 | 101 71.4 | 39 27.9 | 117 83.6 | 23 16.4 |
| Active disease with response/stable disease | 80 100 | 26.4 | 13 61.9 | 8 38.1 | 18 85.7 | 3 14.3 | 15 71.4 | 6 28.6 | 16 76.2 | 5 23.8 |
| Active disease with disease progression | 54 100 | 17.8 | 37 62.7 | 22 37.3 | 54 91.5 | 5 8.5 | 41 69.5 | 18 30.5 | 49 83.1 | 10 16.9 |
| Influenza vaccine status | | | | | | | | | | | |
| Not vaccinated | 94 100 | 31.0 | 57 60.6 | 37 39.4 | 85 90.4 | 9 9.6 | 65 69.1 | 29 30.9 | 76 80.9 | 18 19.1 |
| Prior vaccination | 143 100 | 47.2 | 87 60.8 | 56 39.2 | 128 89.5 | 15 10.5 | 104 72.7 | 39 27.3 | 121 84.6 | 22 15.4 |
| Unknown | 66 100 | 21.8 | 40 60.6 | 26 39.4 | 60 90.9 | 6 9.1 | 43 65.2 | 23 34.8 | 49 74.2 | 17 25.8 |
| Primary language | | | | | | | | | | | |
| English | 219 100 | 72.3 | 145 66.2 | 74 33.8 | 199 90.9 | 20 9.1 | 163 74.4 | 56 25.6 | 184 84.3 | 35 16.9 |
| Spanish | 71 100 | 23.4 | 35 49.3 | 36 50.7 | 64 90.1 | 7 9.9 | 42 59.2 | 29 40.8 | 55 77.5 | 16 22.5 |
| Other | 13 100 | 4.3 | 4 30.8 | 9 69.2 | 10 76.9 | 3 23.1 | 7 53.8 | 6 46.2 | 7 53.8 | 6 46.2 |
| Marital status | | | | | | | | | | | |
| Single/Legally separated/Divorced/Widowed | 124 100 | 40.9 | 70 56.5 | 54 43.5 | 111 88.7 | 13 10.5 | 86 69.4 | 38 30.6 | 103 83.1 | 21 16.9 |
| Married/In relationship/Significant other | 172 100 | 56.8 | 108 62.8 | 64 37.2 | 155 90.1 | 17 9.9 | 120 69.8 | 52 30.2 | 137 79.7 | 35 20.3 |
| Unknown/Declined | 7 100 | 2.3 | 6 85.7 | 1 14.3 | 5 71.4 | 2 28.6 | 4 57.1 | 2 42.9 | 5 71.4 | 4 28.6 |
| Employment status | | | | | | | | | | | |
| Unemployed | 132 100 | 43.6 | 64 48.5 | 68 51.5 | 109 82.6 | 23 17.4 | 76 57.6 | 56 42.4 | 99 75 33 25 |
| Currently employed | 79 100 | 26.1 | 57 72.2 | 22 27.8 | 76 96.2 | 3 3.8 | 65 82.3 | 14 17.7 | 68 86.1 | 11 13.9 |
| Unknown | 92 100 | 30.4 | 63 68.5 | 29 31.5 | 88 95.7 | 4 4.3 | 71 77.2 | 21 22.8 | 79 85.9 | 13 14.1 |
| Immunosuppressed status | | | | | | | | | | | |
| Not immunosuppressed | 219 100 | 72.3 | 137 62.6 | 82 37.4 | 202 92.2 | 17 7.8 | 158 72.1 | 61 27.9 | 177 80.8 | 42 19.2 |
| Immunosuppressed | 84 100 | 27.7 | 47 56 | 37 44 | 71 84.5 | 13 15.5 | 54 64.3 | 30 35.7 | 69 82.1 | 15 17.9 |
| History of pulmonary disease | | | | | | | | | | | |
| Not present | 232 100 | 76.6 | 148 63.8 | 84 36.2 | 211 90.9 | 21 9.1 | 172 74.1 | 60 25.9 | 194 83.6 | 38 16.4 |
| Present | 71 100 | 23.4 | 36 50.7 | 35 49.3 | 62 87.3 | 9 12.7 | 40 56.3 | 31 43.7 | 52 73.2 | 19 26.8 |
| History of cardiovascular disease | | | | | | | | | | | |
| Not present | 153 100 | 50.5 | 102 66.7 | 51 33.3 | 141 92.2 | 12 7.8 | 117 76.5 | 36 23.5 | 129 84.3 | 24 15.7 |
| Present | 150 100 | 49.5 | 82 54.7 | 68 45.3 | 132 88 | 18 12 | 95 63.3 | 55 36.7 | 117 78 | 33 22 |
| History of renal disease | | | | | | | | | | | |
| Not present | 264 100 | 87.1 | 164 62.1 | 100 37.9 | 243 92 | 21 8 | 186 70.5 | 78 29.5 | 215 81.4 | 49 18.6 |
| Present | 39 100 | 12.9 | 20 51.3 | 19 48.7 | 30 76.9 | 9 23.1 | 26 66.7 | 13 33.3 | 31 79.5 | 8 20.5 |
Table 1 (continued)

| Autoimmune disease | COVID-19 Outcomes | Pulmonary complications | Cardiac complications |
|---------------------|-------------------|-------------------------|-----------------------|
|                     | Total             | N row %                 | N row %               | N row %                 | N row %                 | N row %                 | N row %                 |
|                     | Any complications | 0                      | 1                     | 0                      | 1                     | 0                      | 1                     |
| Autoimmune disease  |                   |                         |                       |                         |                       |                         |                       |
| Not present         | 260 (93)          | 78 (35)                 | 17 (8)                | 10 (3)                 | 2 (1)                 | 1 (1)                 |
| Present             | 30 (10)           | 2 (7)                   | 1 (1)                 | 2 (1)                  | 1 (1)                 | 1 (1)                 |
| Co-morbidity        |                   |                         |                       |                         |                       |                         |                       |
| 0 to 1              | 119 (41)          | 14 (12)                 | 1 (1)                 | 2 (2)                  | 1 (1)                 | 1 (1)                 |
| 2 to 6              | 176 (60)          | 18 (10)                 | 1 (1)                 | 2 (2)                  | 1 (1)                 | 1 (1)                 |
| Concomitant medications |               |                         |                       |                         |                       |                         |                       |
| Corticosteroids     | 6 (2)             | 1 (1)                   | 1 (1)                 | 1 (1)                  | 1 (1)                 | 1 (1)                 |
| ACE inhibitors      | 6 (2)             | 1 (1)                   | 1 (1)                 | 1 (1)                  | 1 (1)                 | 1 (1)                 |
| Angiotensin receptor blockers |   |                         |                       |                         |                       |                         |                       |
| Anti-virals         |                   |                         |                       |                         |                       |                         |                       |
| Aspirin             |                   |                         |                       |                         |                       |                         |                       |
| Ibuprofen, naproxen, or other NSAIDs |   |                         |                       |                         |                       |                         |                       |
| Treatment history   |                   |                         |                       |                         |                       |                         |                       |
| Surgery             |                   |                         |                       |                         |                       |                         |                       |
| Radiation Therapy   |                   |                         |                       |                         |                       |                         |                       |
| Chemical treatments |                   |                         |                       |                         |                       |                         |                       |
| Hormone Therapy     |                   |                         |                       |                         |                       |                         |                       |
| Targeted Therapy    |                   |                         |                       |                         |                       |                         |                       |

Table 1: COVID-19 Outcomes, Pulmonary complications, and Cardiac complications by Autoimmune disease, Co-morbidity, and Concomitant medications.
prior surgery and a smaller subset had prior radiation therapy (n = 77, 25%). A large proportion of patients (n = 207, 68%) had prior systemic therapy including myelosuppressive therapy (n = 128, 42%), hormone therapy (n = 48, 16%), and targeted therapy (n = 61, 20%).

COVID-19 Presentation Characteristics

As shown in Table 2, the initial COVID-19 presentation characteristics varied by organ-specific complications. The majority of patients presented afebrile (n = 166, 55%), with active cough (n = 176, 58%), symptomatic (n = 204, 67%), and without a known COVID-19 exposure (n = 265, 88%). A subset (n = 22, 7%) had asymptomatic screening testing. Among the 137 (45%) patients who presented with fever, 68 (50%) had complications overall, 19 (14%) had sepsis, 56 (41%) had pulmonary complications, and 28 (20%) had cardiac complications. Among the 176 (58%) patients with cough, 90 (51%) had any complication, 22 (13%) had sepsis, 73 (42%) had pulmonary complication, and 44 (25%) had cardiac complications. The frequency of presentation varied over time with the peak presentation occurring in July 2021 (n = 71, 23%).

Multivariate Logistic Regression

As shown in Table 3, patients with malignant hematologic cancers had a significantly higher risk of sepsis (OR 3.93 (95% CI 1.58–9.81)). Male patients had a greater risk of sepsis (OR 4.42 (95% CI 1.63–11.96)) and cardiac complications (OR 2.02 (95% CI 1.05–3.89)). There was a clear association between race/ethnicity and the risk of complications. Specifically, Hispanic patients had a higher risk of any complication (OR 2.31 (95% CI 1.18–4.51)) and other minority race group (non-Hispanics and non-whites) was associated with a higher odds of cardiac complications (OR 2.41 (95% CI 1.01–5.73)). Clinically, fever, cough, and ≥2 co-morbidities were independently significantly associated with any complication. Having ≥2 co-morbidities was also observed to be significantly associated with sepsis (OR 4.16 (95% CI 1.24–13.96)) and pulmonary complications (OR 2.48 (95% CI 1.27–4.84)). The effect of facility level COVID-19 7 day prior positivity rate was not significant in the model.

Discussion

This study suggests that the clinical and demographic characteristics of cancer patients at time of initial COVID-19 presentation affects the likelihood of subsequent complications. In this analysis, Hispanic patients were observed to have twice the risk of developing any complication from COVID-19 compared to NH white patients. This increased risk has also been observed on a population level. As of July 2021, the Centers for Disease Control reports that Hispanic persons have twice the rate of COVID-19 and almost three times the rate of hospitalization due to COVID-19 compared to NH white persons [14]. The unique risks among Hispanic cancer patients with COVID-19 observed in this study confirmed previous reports by Grivas and colleagues who observed that Hispanic ethnicity was associated with higher COVID-19 illness severity compared to NH white patients [15].

This study also observed that male patients had four times the risk of sepsis after COVID-19 infection. A “sex-bias” in COVID-19 illness severity and mortality has previously been reported [12]. In a meta-analysis published by Desai and colleagues, cancer subtype (hematologic versus solid) and male sex were identified as factors that contribute to higher mortality estimates for hospitalized patients with cancer and COVID-19 [15]. In a pooled analysis of 2968 cancer patients, male sex was identified as having a higher risk of severe illness and death attributable to COVID-19 [17]. Sex-based differences in sepsis outcomes have also previously been reported, with women having a significantly better prognosis in the setting of sepsis [18]. These observations suggest that the previously reported increased COVID-19 associated mortality among male patients may be driven by an increased risk for sepsis after COVID-19 infection. In this study cohort, 21 (7%) patients had deaths attributed to COVID-19, though mortality was found to be associated with an active cancer diagnosis and advanced age (65+) rather than male sex [13]. A future analysis with a larger sample size will need to further examine this association.

Other clinical factors were shown to predict risk for complications such as multi-morbidity (≥2 co-morbidities) which was observed to be independently significantly associated with any complication, sepsis, and pulmonary complications. The notion that multimorbidity leads to adverse outcomes at time of COVID-19 infection has also been suggested by prior research. Moey and colleagues identified that patients with cancer and comorbid cardiovascular disease are at an increased risk of COVID-19 associated mortality [19]. The COVID-19 and Cancer Consortium (CCC19) study identified cardiovascular and pulmonary comorbidities to predict higher risk of COVID-19 severity among cancer patients with active disease [15]. Similarly, Borno and colleagues reported that patients in this study cohort with multi-morbidity had higher odds of hospitalization (citation).

Additionally, this analysis demonstrated that unique clinical presentation factors such as fever and cough may be associated with organ-specific complications. A systematic review and meta-analysis of 148 COVID-19 research studies identified fever and cough as the most common symptoms among adults infected with SARS-CoV2 [19]. The present
| Table 2 | COVID-19 Presentation characteristics |
|---------|---------------------------------------|
|         | Total | COVID-19 Outcomes | Any complications | Sepsis | Pulmonary complications | Cardiac complications |
|         |       |                  | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
|         | N  | row % | column % | N  | row % | N | row % | N  | row % | N  | row % | N  | row % | N  | row % |
| Total   | 303 | 100.0 | 100.0 | 184 | 60.7 | 119 | 39.3 | 273 | 90.1 | 30 | 9.9 | 212 | 70 | 91 | 30 | 246 | 81.2 | 57 | 18.8 |
| Fever   |      |        |        |     |      |     |      |     |      |     |      |     |      |     |      |     |      |     |      |     |      |
| Afebrile| 166 | 100.0 | 54.8  | 115 | 69.3 | 51  | 30.7 | 155 | 93.4 | 11 | 6.6 | 131 | 78.9 | 35 | 21.1 | 137 | 82.5 | 29 | 17.5 |
| Fever   | 137  | 100.0 | 45.2  | 69  | 50.4 | 68  | 49.6 | 118 | 86.1 | 19 | 13.9 | 81  | 59.1 | 56 | 40.9 | 109 | 79.6 | 28 | 20.4 |
| Cough   |      |        |        |     |      |     |      |     |      |     |      |     |      |     |      |     |      |     |      |     |      |
| No cough| 176  | 100.0 | 41.9  | 86  | 51.1 | 90  | 40.9 | 154 | 87.5 | 22 | 12.5 | 103 | 85.8 | 32 | 14.2 | 132 | 75   | 44 | 25 |
| Cough   |      |        |        |     |      |     |      |     |      |     |      |     |      |     |      |     |      |     |      |     |      |
| Month of confirmed infection | (2020) | | | | | | | | | | | | | | | | | | | |
| March   | 25   | 100.0 | 8.3   | 11  | 44   | 14  | 56  | 20  | 80   | 5  | 20  | 14   | 56  | 11 | 44  | 17  | 68   | 8  | 32  |
| April   | 21   | 100.0 | 6.9   | 13  | 61.9 | 8   | 38.1 | 19  | 90.5 | 2  | 9.5 | 14   | 66.7 | 7  | 33.3 | 17  | 81   | 4  | 19  |
| May     | 25   | 100.0 | 8.3   | 16  | 64   | 9   | 36  | 25  | 100  | 18 | 72  | 7    | 28  | 21  | 84  | 4    | 16  |     |
| June    | 51   | 100.0 | 16.8  | 28  | 54.9 | 23  | 45.1 | 43  | 84.3 | 8  | 15.7 | 35   | 68.6 | 16 | 31.4 | 39  | 76.5 | 12 | 23.5 |
| July    | 71   | 100.0 | 23.4  | 50  | 70.4 | 21  | 29.6 | 65  | 91.5 | 6  | 8.5 | 53   | 74.6 | 18 | 25.4 | 61  | 85.9 | 10 | 14.1 |
| August  | 56   | 100.0 | 18.5  | 33  | 58.9 | 23  | 41.1 | 51  | 91.1 | 5  | 8.9 | 38   | 67.9 | 18 | 32.1 | 44  | 78.6 | 12 | 21.4 |
| September | 32  | 100.0 | 10.6  | 23  | 71.9 | 9   | 28.1 | 29  | 90.6 | 3  | 9.4 | 25   | 78.1 | 7  | 21.9 | 28  | 87.5 | 4  | 12.5 |
| October | 19   | 100.0 | 6.3   | 10  | 52.6 | 9   | 47.4 | 18  | 94.7 | 1  | 5.3 | 14   | 73.7 | 5  | 26.3 | 17  | 89.5 | 2  | 10.5 |
| November | 3   | 100.0 | 1.0   | 3   | 100  | 3   | 100  | 1   | 33.3 | 2  | 66.7 | 2    | 66.7 | 1  | 33.3 |     |      |     |      |
| Symptomatic infection | | | | | | | | | | | | | | | | | | | | |
| Asymptomatic | 99  | 100.0 | 32.7  | 77  | 77.8 | 22  | 22.2 | 92  | 92.9 | 7  | 7.1  | 80   | 80.8 | 19 | 19.2 | 85  | 85.9 | 14 | 14.1 |
| Symptomatic | 204 | 100.0 | 67.3  | 107 | 52.5 | 97  | 47.5 | 181 | 88.7 | 23 | 11.3 | 132  | 64.7 | 72 | 35.3 | 161 | 78.9 | 43 | 21.1 |
| Known exposure | | | | | | | | | | | | | | | | | | | | |
| Not known | 265 | 100.0 | 87.5  | 159 | 60   | 106 | 40  | 235 | 88.7 | 30 | 11.3 | 183  | 93.9 | 21 | 4.9  | 211 | 79.6 | 54 | 20.4 |
| Known   | 38   | 100.0 | 12.5  | 25  | 65.8 | 13  | 34.2 | 38  | 100  | 29 | 76.3 | 9    | 23.7 | 35 | 92.1 | 3   | 7.9 |     |
study observed that symptoms of fever independently predict a higher odds of any complications and pulmonary complications. Robilotti and colleagues have previously reported that fever and cough are associated with a higher risk of hospitalization and severe respiratory illness among cancer patients [21]. Moreover, presence of cough in this study cohort was identified as a predictor of ICU hospitalization [13].

This study’s primary strength is that it leverages an ethnically diverse cohort to identify risk factors for COVID-19 complications. Evaluating predictors of independent complications begins to provide a mechanistic understanding of differences in mortality previously reported among cancer patients with a COVID-19 diagnosis. The primary weakness of this analysis is its retrospective nature and limited sample size. Tumor types were grouped as solid or malignant hematologic cancers, therefore unique risk factors by disease type could not be elucidated in this dataset. Additionally, this study has limited follow-up therefore did not evaluate long-term complications of COVID-19 among cancer patients. Despite these limitations, to our knowledge this is the first analysis to evaluate multiple organ-specific complications among a diverse patient population.

## Conclusions

This analysis evaluated covariates that can significantly predict a myriad of complications among a multi-ethnic cohort of cancer patients. The conclusions drawn from this analysis elucidate a mechanistic understanding of differential illness severity from COVID-19. Observations from this analysis may help inform mitigation strategies to reduce adverse outcomes among minority populations. Future research will evaluate complications by tumor type and identify risk factors for long-term complications from COVID-19 among cancer patients.

### Author Contributions

HTB prepared primary manuscript; all co-authors provided critical feedback; MOK and IT provided statistical analysis; SY, JCH, OH, RRMc, PR, HR, MR, CW and SZ collected data.

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### Declarations

Conflict of interest Authors have no conflict of interest to disclose.

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