Prevalence and outcome of COVID-19 infection in cancer patients: a national Veterans Affairs study

Nathanael R. Fillmore, PhD$^{1,2,3,*}$; Jennifer La, PhD$^{1,*}$; Raphael E. Szalat, MD$^{1,3,4,*}$; David P. Tuck$^{1,4}$, MD; Vinh Nguyen, MS$^{1}$; Cenk Yildirim, MS$^{1}$; Nhan V. Do, MD$^{1,4}$; Mary T. Brophy, MD$^{1,4}$; Nikhil C. Munshi; MD$^{1,2,3}$

1. VA Boston Healthcare System, Boston, MA
2. Harvard Medical School, Boston, MA
3. Dana-Farber Cancer Institute, Boston, MA
4. Boston University School of Medicine, Boston, MA

* These authors contributed equally

Corresponding author:
Nikhil C. Munshi, MD
450 Brookline Ave, Boston, MA 02215
617-632-5272
nikhil_munshi@dfci.harvard.edu

Published by Oxford University Press 2020. This work is written by (a) US Government employee(s) and is in the public domain in the US.
Abstract

Background

Emerging data suggest variability in susceptibility and outcome to COVID-19 infection. Identifying risk-factors associated with infection and outcomes in cancer patients is necessary to develop healthcare recommendations.

Methods

We analyzed electronic health records of the US Veterans Affairs healthcare system and assessed the prevalence of COVID-19 infection in cancer patients. We evaluated the proportion of cancer patients tested for COVID-19 who were positive, as well as outcome attributable to COVID-19, and stratified by clinical characteristics including demographics, comorbidities, cancer treatment and cancer type. All statistical tests are two-sided.

Results

Of 22914 cancer patients tested for COVID-19, 1794 (7.8%) were positive. The prevalence of COVID-19 was similar across age. Higher prevalence was observed in African-American (AA) (15.0%) compared to White (5.5%; P<.001) and in patients with hematologic malignancy compared to those with solid tumors (10.9% vs 7.8%; P<.001). Conversely, prevalence was lower in current smokers and patients who recently received cancer therapy (<6 months). The COVID-19 attributable mortality was 10.9%. Higher attributable mortality rates were observed in older patients, those with higher Charlson comorbidity score, and in certain cancer types. Recent (<6 months) or past treatment did not influence attributable mortality. Importantly, AA patients had 3.5-fold higher COVID-19 attributable hospitalization, however had similar attributable mortality.
as White patients.

**Conclusion**

Pre-existence of cancer affects both susceptibility to COVID-19 infection and eventual outcome. The overall COVID-19 attributable mortality in cancer patients is affected by age, comorbidity and specific cancer types, however, race or recent treatment including immunotherapy does not impact outcome.
The COVID-19 infection first reported in China, in December 2019\textsuperscript{1}, has now spread worldwide affecting all demographics and regions. The emerging data suggests variability in susceptibility to the infection and ultimately outcome. A number of patient related factors, socioeconomic conditions, racial and ethnic differences and several comorbidities including obesity, diabetes and cardiovascular diseases have been associated with higher susceptibility and/or risk of mortality.\textsuperscript{2–5} The relatively higher transmission rate and associated greater risk of adverse outcome has highlighted the need to understand the epidemiologic characteristics of COVID-19 prevalence, and the risk factors associated with poor outcome and death, in order to establish the best possible public health policies. Cancer patients are considered to be at higher risk of infection. This risk varies with functional status of the patient, cancer type, and/or treatment modalities utilized.\textsuperscript{6,7} Thus, along with reducing exposure to the virus, other prophylactic as well as cancer-related risk factors may need to be addressed to decrease susceptibility to COVID-19 infection or to mitigate related complications in cancer patients. Small epidemiologic studies mainly from China and USA have also reported increased rates of death in cancer patients related to COVID-19.\textsuperscript{8,9} These observations have informed some changes and re-organization of cancer care worldwide\textsuperscript{10} but larger studies are needed to understand the comprehensive cancer-related issues with COVID-19 infection. Here we investigated the prevalence and outcome of COVID-19 infection among cancer patients in a large cohort of patients from the nationwide Veterans Affairs (VA) healthcare system.

\textbf{Methods}
Patients

This analysis was conducted using data from the VA Corporate Data Warehouse, which centralizes EHR data for patients seen at VA facilities nationwide. The study population is defined as veterans with cancer who were tested for COVID-19 at the VA. Cancer patients were identified as patients with at least one occurrence of an International Classification of Diseases (ICD) code for cancer between January 1, 2010 and May 4, 2020. Non-melanoma skin cancer and benign tumors were excluded. This study was performed under a protocol approved by the VA Boston Healthcare System Research and Development Committee.

Study Variables and Outcomes

Patient demographics, COVID-19 laboratory tests, comorbidities, cancer type, cancer treatment, and outcomes were identified through structured data in the EHR. Patients were considered positive for COVID-19 if they had at least one positive test result, and negative if all COVID-19 test results were negative. Based on manual review of laboratory test names, COVID-19 tests were identified using regular expressions matching either ".*covid.*" or ".*corona.*2019.*", and excluding ".*not.covid.19.*". COVID-19 tests that were cancelled or did not have a positive or negative result recorded were excluded from consideration. The Charlson comorbidity index and presence of individual comorbidities were derived from ICD codes in the year prior to each patient’s first COVID-19 test using the `comorbidity` package in R. BMI was calculated from each patient’s most recently recorded weight and height prior to their first COVID-19 test. Smoking status was defined using health factors. The VA hospital
each patient was tested in was extracted from structured data and mapped to geographical region using the mapping in Supplementary Methods. Cancer type was determined based on ICD codes in the study period, and patients may have multiple cancer types. Only cancer types with ≥200 patients are shown. The systemic therapies for cancer considered in this study were based on a list of approved cancer drugs tabulated by the NCI. Patients were identified as being on active or recent treatment for cancer at the time of COVID-19 testing if they received systemic therapy for cancer in the 6 months prior to their first test for COVID-19, and only treatments in this time frame were considered to determine the type of therapy received. As regards outcomes, hospitalization was defined as any inpatient visit after the patient’s first COVID-19 test, and ICU admission was defined as a subset of hospitalizations where the specialty ward is either “Surgical ICU” or “Medical ICU”. Respiratory support was determined based on the presence of a current procedural terminology (CPT) or ICD procedure code for intubation (CPT 94002, 94003, 94004, 94005, ICD-10 Z99.1, Z99.11, Z99.12) or mechanical ventilation (CPT 31500, ICD-10 J95.851) after the patient’s first COVID-19 test. Missing data existed for race, ethnicity, and smoking status and was coded as a separate level in all analyses.

Statistical Analysis
We evaluated the proportion of COVID-19 positive patients among those tested, along with 95% confidence intervals, and stratified by demographics, comorbidities, cancer treatment and cancer type. We also evaluated the proportion of patients experiencing each outcome among COVID-19 positive and negative patients, and defined the
COVID-19 attributable risk of each outcome as the difference of these two proportions. We used chi-squared tests to assess differences in proportion. Odds ratio (OR) as to COVID-19 positive status by cancer type was assessed using univariate and multivariate logistic regression, adjusting for race, ethnicity, and smoking status in the multivariate models. All statistical tests were two-sided and a P value of less than .05 was considered statistically significant.

**Results**

**Susceptibility to COVID-19 infection in cancer patients**

We identified 22914 patients with history of cancer who were tested for COVID-19 infection on or before May 4, 2020, of whom 1794 patients (7.8%) reported positive (Figure 1A). The prevalence of COVID-19 among those tested was similar across all ages (<50 years to ≥80 years; P=.16), although older patients with cancer were tested for COVID-19 more frequently (Supplementary Table 1). Importantly, there was a statistically significant difference in prevalence of infection across race and ethnicity, with 15.0% of African Americans (AA) but only 5.5% of White patients testing positive for COVID-19 (P<.001), and 10.9% of Hispanic/Latino patients vs 7.7% of non-Hispanic/Latino patients testing positive (P<.001). Higher prevalence was observed in patients with hematologic malignancy compared to those with solid tumors (10.9% vs 7.8%; P<.001). We also observed a statistically significantly lower prevalence in cancer patients who were current smokers compared to former smokers or those who never smoked (5.3% vs 9.5%; P<.001). Compared to the overall sample (7.8% positive), there was a small but statistically significant negative association between susceptibility to
COVID-19 and concomitant congestive heart failure (6.7% positive; P<.001), peripheral vascular disease (6.5%; P<.001), chronic obstructive pulmonary disease (6.3%; P<.001), and moderate/severe liver disease (5.1%; P=.02). Higher body mass index (BMI) was associated with increased prevalence of infection (P<.001). During the period of observation, COVID-19 was much more frequent in the North Atlantic (14.8%) than other regions (6.3% Continental, 7.9% Midwest, 2.4% Pacific, 3.2% Southeast; P<.001). Differences in susceptibility across race persisted within each region and in individual VA hospital sites (Supplementary Tables 2 and 3).

We further investigated cancer types and prevalence of COVID-19 (Figure 1B) and observed higher prevalence in patients with hematologic malignancy (10.9%) in comparison to patients with solid tumors (7.8%, P<.001). Among specific cancer type, we observed statistically significantly higher frequency of COVID-19 among patients with prostate cancer (10.0%, P<.001), while statistically significantly lower frequency among patients with esophagus (3.3%, P=.003), hepatocellular carcinoma (HCC) (4.2%, P<.001), lung (4.3%, P<.001), cutaneous squamous cell carcinoma (CSSC) (4.7%, P<.001), lymphoma (5.2%, P<.001), squamous cell head and neck cancer (SCCHN) (5.5%, P<.001), bone cancer (6.3%, P=.004), and urothelial cancer (6.5%, P=.01), among others. To understand the relationship of race and cancer type, we assessed the odds of COVID-19 infection by cancer type, adjusting for race, ethnicity and smoking status (Supplementary Table 4). Although the univariate analysis showed that patients with prostate cancer had a higher risk of COVID-19 infection, this was no longer the case after adjustment, suggesting the higher prevalence observed in prostate cancer may be affected by race, ethnicity, and/or smoking status. On the other hand, patients
with esophageal cancer, HCC, lung cancer, lymphoma, SCCHN, bone cancer, melanoma, and other cancers continued to have a lower risk of COVID-19 infection even after adjusting for these factors.

Next, we evaluated the impact of active cancer treatment on susceptibility to COVID-19 infection and observed that patients receiving cancer therapy within the last 6 months had statistically significantly lower prevalence (6.2%) of COVID-19 compared to those who received therapy >6 months ago (7.8%) or never received therapy (8.1%; P=.002). Moreover, compared to the overall cohort (7.8%), patients receiving immune checkpoint inhibitors (2.7%, P<.001) or chemotherapy (4.6%, P<.001) within the last 6 months had statistically significantly lower prevalence of COVID-19 while patients on hormonal therapy (8.1%, P=.76) or targeted therapy (6.6%, P=.11) did not have statistically significantly different prevalence.

**Outcome of COVID-19 infection in cancer patients**

We next evaluated the impact of COVID-19 infection on outcome in cancer patients and calculated the difference between frequency in positive vs negative as the COVID-19 attributable contribution. Overall, compared to COVID-19 negative cancer patients, COVID-19 positive cancer patients have higher frequency of hospitalizations (31.5% versus 43.8% respectively; an excess of 12.3% COVID-19 attributable), ICU admissions (7.8% vs 19.7% respectively; 11.9% COVID-19 attributable), respiratory support (1.3% vs 7.9% respectively; 6.6% COVID-19 attributable). COVID-19 attributable death was 10.9% with 14.0% death in COVID-19 positive compared to 3.1% in COVID-19 negative patients (**Figure 2**).
To further assess the impact of patient and disease-related features on COVID-19 attributable outcomes, we evaluated each of the demographic and comorbidity strata described above (Figure 3A and 4A). In general outcomes occur more frequently among COVID-19 positive cancer patients, however the difference attributable to COVID-19 infection varies widely across strata. COVID-19 attributable mortality is strongly associated with age, ranging from 0.2% among patients <50 years old to 20.5% among patients ≥80 years old (P<.001). Presence of other comorbidities is also associated with increased COVID-19 attributable death, ranging from 3.0% among patients with Charlson score 0, to 15.0% among patients with Charlson score ≥5 (P<.001). COVID-19 attributable ICU admissions were more common in obese patients (14.3%) than in patients with normal BMI (5.9%, P<.001), as is need for respiratory support (8.9% vs 4.8%, P=.01); however attributable mortality was not higher (10.5% in obese, 13.5% in normal; P=.22). Interestingly, COVID-19 attributable mortality was lower in current smokers (6.5%) compared to former/never smokers (12.0%; P=.002).

African Americans have increased COVID-19 attributable hospitalization (20.9%) compared to White patients (5.9%), a 3.5 fold difference (P<.001) (Figure 4 and Supplementary Table 5). However, despite the higher COVID-19 prevalence as well as increased COVID-19 attributable hospitalization, we do not observe a statistically significant difference in any of the other more serious COVID-19 attributable outcomes, including mortality (12.0% in AA vs 10.8% in White; P=.50), respiratory support (6.0% in AA vs 7.6% in White; P=.23), or ICU admissions (13.7% in AA vs 10.2% in White; P=.08). Similarly, we do not observe a statistically significant difference in COVID-19 attributable outcomes for Hispanic/Latino compared to Non-Hispanic/Latino
Outcomes were variable based on type of cancer (Figures 3B and 4B). COVID-19 attributable deaths were observed in most but not all cancer types, with the highest attributable mortality in acute leukemia (25.6%), male genital (20.8%), and thyroid cancer (19.9%). COVID-19 attributable mortality is similar in patients recently treated for cancer (≤6 months ago, 14.2%) compared to those treated >6 months ago (13.1%) or never treated with systemic therapy (10.1%; P=.25). There is a suggestive relationship between type of treatment and outcome attributable to COVID-19 infection. In patients receiving ICI within the last 6 months, COVID-19 attributable mortality (7.1%) is less than half that observed in patients receiving chemotherapy (14.0%), hormone therapy (16.2%), or targeted therapy (14.1%), though statistical significance is not reached because of fewer observed deaths (7.1% in ICI vs 14.7% in not-ICI; P=.53).

Discussion
We investigated a large cohort of cancer patients evaluated for COVID-19 at the VA Healthcare System from across the United States in order to identify risk factors for COVID-19 susceptibility and outcomes in cancer patients. The overall frequency of COVID-19 positivity was 7.8% of tested patients. As of May 16th, 2020, according to the United States Center for Disease Control, the national positivity rate for COVID-19 infection in the US among patients aged of 18 and older is 13.5% with 126,627 positive patients out of 928,366 tested patients. Thus, the prevalence of COVID-19 among cancer patients appeared to be lower than in the general population. However, the real prevalence of COVID-19 remains uncertain, as a substantial number of patients are not
or have not been tested, particularly in the context of asymptomatic disease.

Nevertheless, the observed lower prevalence of COVID-19 in cancer patients might be explained either by higher access to testing within the VA healthcare system and/or higher rates of testing in cancer patients in general.

Perhaps the most striking observation in our data is the statistically significant racial and ethnic disparity in prevalence of COVID-19 infection. African-American (15.0%) and Hispanic (10.9%) cancer patients had statistically significantly higher rates of COVID-19 infection in comparison to White cancer patients (5.5%), and also had higher rates of hospitalization. The biological and/or social basis for this observation, also recently reported in the general population,17–19 remains unclear. Overall, the observation of this disparity across all the regions of the country and site-by-site (Supplementary Tables 2 and 3) rules out the possible role of regional conditions in explaining this difference. COVID-19 was more frequent among patients with prostate cancer which is also more frequent in African-American patients,20 although after adjusting for race, ethnicity, and smoking status, this difference is no longer observed. The possible explanations requiring further investigation include socio-economic factors or genetic predisposition. Importantly, although AA cancer patients were more frequently admitted to the hospital, with equal access to care in the VA healthcare system, similar mortality rate was observed between AA and White cancer patients. Similar trend was also observed in Hispanic/Latino population. These results suggest distinct factors modulating COVID-19 susceptibility and the related-outcome.

The statistically significantly reduced prevalence of COVID-19 infection in cancer patients with current smoking history, compared to those who have quit smoking or
never smoked, is intriguing. This observation is also confirmed by observed reduced frequency of COVID-19 infection among patients with lung (4.3%, P<.001), SCCHN (5.5%, P<.001), and urothelial (6.5%, P=.01) cancers, all malignancies associated with smoking. These differences might also be related to race or ethnicity (Supplementary Tables 5 and 6), or to socio-economic factors. An earlier preliminary report has also suggested association of active smoking with lower rates of COVID-19 infections.\textsuperscript{21} This negative association requires further investigation. The role of nicotine, local epithelial cell changes or inflammatory environment may play a role.\textsuperscript{22,23} We did not observe a substantial impact of cardiopulmonary and other comorbidities as well as age of patients on rate of infection (Figure 1), which may suggest that pre-existence of cancer could outweigh the other comorbidities in regard to susceptibility to COVID-19. Moreover, it is possible that sick patients and patients under active cancer treatment may have been more cautious and thus less exposed to COVID-19, and this may affect the vulnerability. While we are unable to directly quantify severity of cancer illness in our dataset, we included two proxies for severity of disease that are available: whether or not each patient was recently treated for cancer (≤6 months ago), treated >6 months ago, or never treated with systemic therapy, which serves to some extent as a proxy for severity; and the Charlson score which reflects severity of overall health condition prior to COVID-19 diagnosis. Our analysis reveals statistically significantly lower rate of infection in patients treated ≤6 months ago, though no difference in COVID-19 attributable mortality or other outcomes, and higher rates of infection in patients with higher Charlson score was observed.

Outcome of cancer patients infected by COVID-19 was characterized by higher
rates of mortality. Although the frequency of COVID-19 positivity was lower in patients receiving cancer related therapy within 6 months of the COVID-19 infection, the overall mortality was not statistically significantly different in comparison to no treatment or treatment prior to 6 months groups. These mortality rates are higher than the mortality rates reported in the global population\textsuperscript{8,24} and confirm higher vulnerability of cancer patients to COVID-19 infection. Therapies including conventional chemotherapy, targeted therapies with small molecules or monoclonal antibodies were associated with higher mortality rates in this study. ICI treatment was associated with a lower rate of infection, however, only a small number of patients are in this group suggesting both caution in interpreting this data and also a need for further focused investigation in patients receiving ICI therapy and with COVID-19 positivity. The lower mortality rate in patients receiving this treatment confirms the recent report about the impact of this therapy on COVID-19 outcome.\textsuperscript{25} Higher rates of mortality were observed in elderly patients, patients with higher Charlson score, underweight patients and patients with comorbidities, mainly cardiovascular and renal disease (\textit{Figure 3}). While hematological malignancies were associated with higher rates of infection, similar COVID-19 attributable mortality was observed in comparison to solid malignancies (\textit{Figure 3 and Supplementary Table 7}). Fatality rate related to each cancer type was variable with breast, male genital, acute leukemia and thyroid cancer being associated with highest rate of COVID-19 related mortality (\textit{Figure 3}).

Our study has several limitations. First, the veteran population is primarily male and hence the study represents various trends and associations whose interpretations are restricted to male. Second, patients tested outside the VA system would not be
included in this analysis. However, this number is likely to be very small as most patients who get cancer care in the VA do return for their healthcare needs to the VA. Third, it is possible that analyses are confounded by indication for testing. However, we believe that our comparison of those who tested positive to those who tested negative remains relevant, especially because COVID-19 testing criteria at VA hospitals was informed by centralized guidance from the VA Central Office, increasing consistency of testing criteria nationally.²⁷

In conclusion, the presence of cancer changes the susceptibility to COVID-19 infection and affects overall outcome. The overall disease behavior is modulated by patient-related as well as cancer-related factors which needs to be considered in development of COVID-19 preventative strategies as well as modulation of cancer therapies to optimize the patient care. Importantly, having equal access to care is an important component to improving overall outcome.

Funding

This work was supported by the VA Office of Research and Development, Cooperative Studies Program (NRF, NVD, MTB), the VA Merit Review Award 1I01BX001584 (NCM), and NIH grants P01-155258-07 and P50-100707 (NCM).

Notes
Role of the funder: The funder had no role in the design of the study; the collection, analysis, and interpretation of the data; the writing of the manuscript; and the decision to submit the manuscript for publication.

Disclosures: NCM is consultant for BMS, Janssen, OncoPep, Amgen, Abbvie and Takeda and on the board of directors for OncoPep. The remaining authors declare no competing financial interests.

Disclaimer: The views expressed are those of the authors and do not necessarily reflect the position or policy of the Department of Veterans Affairs or the United States government.

Data availability

The data underlying this article cannot be shared publicly due to VA policy. The data will be shared on reasonable request to the corresponding author.

References

1. Zhu N, Zhang D, Wang W, et al. A Novel Coronavirus from Patients with Pneumonia in China, 2019. N Engl J Med. 2020;382(8):727-733. doi:10.1056/NEJMoa2001017

2. Kumar A, Arora A, Sharma P, et al. Is diabetes mellitus associated with mortality and severity of COVID-19? A meta-analysis. Diabetes Metab Syndr. 2020;14(4):535-545. doi:10.1016/j.dsx.2020.04.044

3. Goyal P, Choi JJ, Pinheiro LC, et al. Clinical Characteristics of Covid-19 in New York City. N Engl J Med. Published online April 17, 2020. doi:10.1056/NEJMc2010419
4. Richardson S, Hirsch JS, Narasimhan M, et al. Presenting Characteristics, Comorbidities, and Outcomes Among 5700 Patients Hospitalized With COVID-19 in the New York City Area. JAMA. Published online April 22, 2020. doi:10.1001/jama.2020.6775

5. 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(10229):1054-1062. doi:10.1016/S0140-6736(20)30566-3

6. Flowers CR, Seidenfeld J, Bow EJ, et al. Antimicrobial prophylaxis and outpatient management of fever and neutropenia in adults treated for malignancy: American Society of Clinical Oncology clinical practice guideline. J Clin Oncol. 2013;31(6):794-810. doi:10.1200/JCO.2012.45.8661

7. Elfaituri MK, Morsy S, Tawfik GM, et al. Incidence of Infection-related mortality in cancer patients: Trend and survival analysis. JCO. 2019;37(15_suppl):e23095-e23095. doi:10.1200/JCO.2019.37.15_suppl.e23095

8. Guan W-J, Ni Z-Y, Hu Y, et al. Clinical Characteristics of Coronavirus Disease 2019 in China. N Engl J Med. 2020;382(18):1708-1720. doi:10.1056/NEJMoa2002032

9. Liang W, Guan W, Chen R, et al. Cancer patients in SARS-CoV-2 infection: a nationwide analysis in China. Lancet Oncol. 2020;21(3):335-337. doi:10.1016/S1470-2045(20)30096-6

10. van de Haar J, Hoes LR, Coles CE, et al. Caring for patients with cancer in the COVID-19 era. Nat Med. 2020;26(5):665-671. doi:10.1038/s41591-020-0874-8

11. Mehta V, Goel S, Kabarriti R, et al. Case Fatality Rate of Cancer Patients with COVID-19 in a New York Hospital System. Cancer Discov. Published online May 1,
12. COVID-19 More Frequent, Severe in Cancer Patients. Cancer Discov. Published online April 20, 2020. doi:10.1158/2159-8290.CD-20-0516

13. Gasparini A. comorbidity: An R package for computing comorbidity scores. JOSS. 2018;3(23):648. doi:10.21105/joss.00648

14. Melzer AC, Pinsker EA, Clothier B, et al. Validating the use of veterans affairs tobacco health factors for assessing change in smoking status: accuracy, availability, and approach. BMC Med Res Methodol. 2018;18(1):39. doi:10.1186/s12874-018-0501-2

15. National Cancer Institute. A to Z List of Cancer Drugs. Accessed May 15, 2020. https://www.cancer.gov/about-cancer/treatment/drugs

16. Centers for Disease Control and Prevention. COVIDView: A Weekly Surveillance Summary of U.S. COVID-19 Activity. Published online May 22, 2020. Accessed May 22, 2020. https://www.cdc.gov/coronavirus/2019-ncov/covid-data/pdf/covidview-05-22-2020.pdf

17. Azar KMJ, Shen Z, Romanelli RJ, et al. Disparities In Outcomes Among COVID-19 Patients In A Large Health Care System In California. Health Aff (Millwood). Published online May 21, 2020:101377/hlthaff202000598. doi:10.1377/hlthaff.2020.00598

18. Chowkwanyun M, Reed AL. Racial Health Disparities and Covid-19 - Caution and Context. N Engl J Med. Published online May 6, 2020. doi:10.1056/NEJMp2012910

19. Price-Haywood EG, Burton J, Fort D, Seoane L. Hospitalization and Mortality among Black Patients and White Patients with Covid-19. N Engl J Med. Published
online May 27, 2020. doi:10.1056/NEJMs2011686

20. McGinley KF, Tay KJ, Moul JW. Prostate cancer in men of African origin. Nat Rev Urol. 2016;13(2):99-107. doi:10.1038/nrurol.2015.298

21. Rossato M, Russo L, Mazzocut S, Di Vincenzo A, Fioretto P, Vettor R. Current Smoking is Not Associated with COVID-19. Eur Respir J. Published online April 29, 2020. doi:10.1183/13993003.01290-2020

22. Leung JM, Yang CX, Sin DD. COVID-19 and Nicotine as a Mediator of ACE-2. Eur Respir J. Published online April 29, 2020. doi:10.1183/13993003.01261-2020

23. Russo P, Bonassi S, Giacconi R, Malavolta M, Tomino C, Maggi F. COVID-19 and Smoking. Is Nicotine the Hidden Link? Eur Respir J. Published online April 27, 2020. doi:10.1183/13993003.01116-2020

24. World Health Organization. Coronavirus disease (COVID-2019) situation reports. Accessed May 25, 2020. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports/

25. Luo J, Rizvi H, Egger JV, Preeshagul IR, Wolchok JD, Hellmann MD. Impact of PD-1 blockade on severity of COVID-19 in patients with lung cancers. Cancer Discov. Published online May 12, 2020. doi:10.1158/2159-8290.CD-20-0596

26. Zullig LL, Jackson GL, Dorn RA, et al. Cancer incidence among patients of the U.S. Veterans Affairs Health Care System. Mil Med 2012; 177: 693–701.

27. Veterans Health Administration - Office of Emergency Management. COVID-19 Response Plan: Incident-specific Annex to the VHA High Consequence Infection (HCI) Base Plan. Version 16 March 23, 2020

https://www.va.gov/opa/docs/VHA_COVID_19_03232020_vF_1.pdf.
Figure legends

Figure 1: COVID-19 prevalence among cancer patients.
Percent of COVID-19 positive patients among cancer patients tested for COVID-19 is shown with Panel A showing overall data and data stratified by age, race, ethnicity, smoking, BMI, Charlson score, comorbidity, and region. Panel B shows data stratified by cancer type, cancer group, treatment time, and treatment type. The dashed line indicates the overall percent positive (7.8%). The two rows at top show the number of COVID-19 positive patients, and the total number of cancer patients tested. In addition to the percent positive in each group, a 95% confidence interval and P value are shown, based on a chi-squared test for difference in proportions (two-sided). * P < .05; ** P < .01; *** P < .001. BMI = body mass index, AMI = acute myocardial infarction, CHF = congestive heart failure, PVD = peripheral vascular disease, COPD = chronic obstructive pulmonary disease, MLD = mild liver disease, DIAB = diabetes without complications, DIABWC = diabetes with complications, REND = renal disease, MSLD = moderate or severe liver disease, HCC = hepatocellular carcinoma, CSCC = cutaneous squamous-cell carcinoma, MDS = myelodysplastic syndromes, SCCHN = squamous cell carcinoma of the head and neck, RCC = renal cell carcinoma, Heme = hematological malignancy, Solid = solid tumor, ICI = immune checkpoint inhibitor.

Figure 2: Outcome of cancer patients with COVID-19.
Percent of patients experiencing hospitalization, ICU visits, respiratory support, and death in COVID-19 positive (light red) and negative (light blue) cancer patients are represented. The COVID-19 attributable risk of experiencing each outcome, i.e., the
difference of the percent experiencing each outcome in COVID-19 positive compared to negative patients is also shown (dark red), along with 95% confidence intervals. ICU = intensive care unit.

**Figure 3: COVID-19 attributable mortality among cancer patients.**

COVID-19 attributable mortality defined as the difference in the percent mortality in COVID-19 positive compared to negative patients, is shown, along with 95% confidence intervals. Panel A shows overall data and data stratified by age, race, ethnicity, smoking, BMI, Charlson score, comorbidity, and region. Panel B shows data stratified by cancer type, cancer group, treatment time, and treatment type. The dashed line shows the COVID-19 attributable mortality in the overall cohort (14.4%), and the dotted line marks 0, the point where there is no COVID-19 attributable mortality. The four rows at top show the number of COVID-19 positive patients who died, the total number of COVID-19 positive patients, the number of COVID-19 negative patients who died, and the total number of COVID-19 negative patients. ICU = intensive care unit, BMI = body mass index, AMI = acute myocardial infarction, CHF = congestive heart failure, PVD = peripheral vascular disease, COPD = chronic obstructive pulmonary disease, MLD = mild liver disease, DIAB = diabetes without complications, DIABWC = diabetes with complications, REND = renal disease, MSLD = moderate or severe liver disease, HCC = hepatocellular carcinoma, CSCC = cutaneous squamous-cell carcinoma, MDS = myelodysplastic syndromes, SCCHN = squamous cell carcinoma of the head and neck, RCC = renal cell carcinoma, Heme = hematological malignancy, Solid = solid tumor, ICI = immune checkpoint inhibitor.
Figure 4: COVID-19 attributable hospitalizations, ICU admissions, and respiratory support among cancer patients.

COVID-19 attributable hospitalizations, ICU admissions, and respiratory support defined as the difference in the percent of COVID-19 positive patients experiencing each outcome minus the percent of COVID-19 negative patients experiencing each outcome are shown. Panel A shows overall data and data stratified by age, race, ethnicity, smoking, bmi, Charlson score, comorbidity, and region. Panel B shows data stratified by cancer type, cancer group, treatment time, and treatment type. 95% confidence intervals are shown. The dashed line shows the COVID-19 attributable contribution in the overall cohort, and the dotted line marks 0, the point where there is no COVID-19 attributable contribution. ICU = intensive care unit, BMI = body mass index, AMI = acute myocardial infarction, CHF = congestive heart failure, PVD = peripheral vascular disease, COPD = chronic obstructive pulmonary disease, MLD = mild liver disease, DIAB = diabetes without complications, DIABWC = diabetes with complications, REND = renal disease, MSLD = moderate or severe liver disease, HCC = hepatocellular carcinoma, CSCC = cutaneous squamous-cell carcinoma, MDS = myelodysplastic syndromes, SCCHN = squamous cell carcinoma of the head and neck, RCC = renal cell carcinoma, Heme = hematological malignancy, Solid = solid tumor, ICI = immune checkpoint inhibitor.
Figure 2

The figure illustrates the percent experiencing outcome in Covid-19 positive patients and Covid-19 negative patients across different groups:

- **Hospitalization**: 43.8% for positive, 31.5% for negative.
- **ICU**: 19.7% for positive, 11.8% for negative.
- **Respiratory Support**: 7.0% for positive, 6.6% for negative.
- **Death**: 14.0% for positive, 10.9% for negative.

The difference in percent experiencing outcome is also shown for each group.
Figure 4

A

Figure 4--FINAL

Downloaded from https://academic.oup.com/jnci/advance-article/doi/10.1093/jnci/djaa159/5919590 by guest on 25 November 2020