RESEARCH BRIEF

Case Fatality Rate of Cancer Patients with COVID-19 in a New York Hospital System

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ABSTRACT

Patients with cancer are presumed to be at increased risk from COVID-19 infection–related fatality due to underlying malignancy, treatment-related immunosuppression, or increased comorbidities. A total of 218 COVID-19–positive patients from March 18, 2020, to April 8, 2020, with a malignant diagnosis were identified. A total of 61 (28%) patients with cancer died from COVID-19 with a case fatality rate (CFR) of 37% (20/54) for hematologic malignancies and 25% (41/164) for solid malignancies. Six of 11 (55%) patients with lung cancer died from COVID-19 disease. Increased mortality was significantly associated with older age, multiple comorbidities, need for ICU support, and elevated levels of D-dimer, lactate dehydrogenase, and lactate in multivariate analysis. Age-adjusted CFRs in patients with cancer compared with noncancer patients at our institution and New York City reported a significant increase in case fatality for patients with cancer. These data suggest the need for proactive strategies to reduce likelihood of infection and improve early identification in this vulnerable patient population.

SIGNIFICANCE: COVID-19 in patients with cancer is associated with a significantly increased risk of case fatality, suggesting the need for proactive strategies to reduce likelihood of infection and improve early identification in this vulnerable patient population.

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INTRODUCTION

The novel coronavirus COVID-19, or severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), has spread rapidly throughout the world since its emergence in December 2019 (1). The virus has infected approximately 2.9 million people in more than 200 countries with more than 200,000 deaths at the time of writing (2). Most recently, the United States has become the epicenter of this pandemic, reporting an estimated 956,000 cases of COVID-19 infection, with the largest concentration in New York City (NYC) and its surrounding areas (approximately >203,000 cases or 35% of all U.S. infections; ref. 3).

Early data suggests that 14% to 19% of infected patients will develop significant sequelae with acute respiratory distress syndrome, septic shock, and/or multiorgan failure (1, 4, 5), and approximately 1% to 4% will die from the disease (2). Recent meta-analyses have demonstrated an almost 6-fold increase in the odds of mortality for patients with chronic obstructive pulmonary disease (COPD) and a 2.5-fold increase for those with diabetes, possibly due to the underlying pulmonary and immune dysfunction (6, 7). Given these findings, patients with cancer would ostensibly be at a higher risk of developing and succumbing to COVID-19 due to immunosuppression, increased coexisting medical conditions, and, in cases of lung malignancy, underlying pulmonary compromise. Patients with hematologic cancer, or those who are receiving active chemotherapy or immunotherapy, may be particularly susceptible because of increased immunosuppression and/or dysfunction.

According the NCI, there were approximately 15.5 million cancer survivors and an estimated 1,762,450 new cases of cancer diagnosed in the United States in 2019 (8). Early case series from China and Italy have suggested that patients with malignancy are more susceptible to severe infection and mortality from COVID-19 (9–12), a phenomenon that has been noted in other pandemics (13). Many of these descriptive studies have included small patient cohorts and have lacked cancer site–specific mortality data or information regarding active cancer treatment. As New York has emerged as the current epicenter of the pandemic, we sought to investigate the risk posed by COVID-19 to our cancer population with more granular data regarding cancer type and active treatment, and identify factors that placed patients with cancer at highest risk of fatality from COVID-19.

RESULTS

Outcomes of 218 Cancer Patients with COVID-19 Show High Overall Mortality with Tumor-Specific Patterns

A total of 218 patients with cancer and COVID-19 were treated in Montefiore Health System (New York, NY) from March 18, 2020, to April 8, 2020. These included 164 (75%) patients with solid tumors and 54 (25%) with hematologic malignancies. This cohort included 127 (58%) males and 91 (42%) females. The cohort was predominantly composed of adult patients (215/218, 98.6%) with a median age of 69 years (range 10–92 years).

Sixty-one (28%) patients expired as a result of COVID-19 disease at the time of analysis (Table 1). The mortality was 25% among all patients with solid tumors and was seen to occur at higher rates in patients with lung cancers (55%), gastrointestinal (GI) cancers [colorectal (38%), pancreatic (67%), upper GI (38%)], and gynecologic malignancies (38%). Genitourinary (15%) and breast (14%) cancers were associated with relatively lower mortality with COVID-19 infection.

Hematologic malignancies were associated with higher rate of mortality with COVID-19 (37%). Myeloid malignancies [myelodysplastic syndromes (MDS)/acute myeloid leukemia (AML)/myeloproliferative neoplasm (MPN)] showed a trend for higher mortality compared with lymphoid neoplasms [non-Hodgkin lymphoma (NHL)/chronic lymphoid leukemia (CLL)/acute lymphoblastic leukemia (ALL)/multiple myeloma (MM)/Hodgkin lymphoma; Table 1]. Rates of ICU admission and ventilator use were slightly higher for hematologic malignancies than solid tumors (26% vs. 19% and 11% vs. 10%, respectively), but this did not achieve statistical significance.

Disease Characteristics of Cancer Patients with COVID-19 Demonstrate the Effect of Age, Comorbidities, and Laboratory Biomarkers on Mortality

Analysis of patient characteristics with mortality did not show any gender bias (Table 2). Older age was significantly associated with increased mortality, with median age of deceased cohort at 76 years when compared with 66 years for the nondeceased group ($P = 0.0006$; Cochran-Armitage test). No significant associations between race and mortality were seen.

COVID-19 disease severity, as evident from patients who needed ICU care and ventilator support, was significantly associated with increased mortality. Interestingly, active disease (<1 year) and advanced metastatic disease showed a trend for increased mortality, but the association did not achieve statistical significance ($P = 0.09$ and 0.06, respectively). Active chemotherapy and radiotherapy treatment were not associated with increased case fatality. Very few patients in this cohort were on immunotherapy, and this did not show any associations with mortality.

Analysis of comorbidities demonstrated increased risk of dying from COVID-19 in patients with cancer with concomitant heart disease [hypertension (HTN), coronary artery disease (CAD), and congestive heart failure (CHF)] and chronic lung disease (Table 2). Diabetes and chronic kidney disease were not associated with increased mortality in univariate analysis (Table 2).

We also analyzed laboratory values obtained prior to diagnosis of COVID-19 and during the time of nadir after COVID-19 positivity in our cancer cohort. Relative anemia pre–COVID-19 was associated with increased mortality, whereas pre-COVID platelet and lymphocyte counts were not (Table 3). Post–COVID-19 infection, lower hemoglobin levels, higher total white blood cell (WBC) counts, and higher absolute neutrophil counts were associated with increased mortality (Table 3). Analysis of other serologic biomarkers demonstrated that elevated D-dimer, lactate, and lactate dehydrogenase (LDH) in patients were significantly correlated with dying (Table 3).

Next, we conducted multivariate analyses and used variables that showed a significant association with mortality in univariate

Table 1. Outcomes in patients with cancer and COVID-19

	Alive	Deceased
Total	157 (72%)	61 (28%)
Solid tumors	123 (75%)	41 (25%)
Genitourinary	39 (85%)	7 (15%)
Breast	24 (86%)	4 (14%)
Colorectal	13 (62%)	8 (38%)
Gynecologic	8 (62%)	5 (38%)
Lung	5 (45%)	6 (55%)
Head and neck	7 (88%)	1 (13%)
Neurologic	7 (88%)	1 (13%)
Upper GI	5 (63%)	3 (38%)
Hepatobiliary	5 (71%)	2 (29%)
Bone/soft tissue	4 (80%)	1 (20%)
Neuroendocrine	3 (100%)	0 (0%)
Pancreas	1 (33%)	2 (67%)
Skin	2 (67%)	1 (33%)
Hematologic malignancies	34 (63%)	20 (37%)
NHL	10 (67%)	5 (33%)
MDS	2 (40%)	3 (60%)
MPN	5 (71%)	2 (29%)
ALL	4 (100%)	0 (0%)
AML	1 (100%)	0 (0%)
MM	8 (62%)	5 (38%)
CML	0 (0%)	1 (100%)
Hodgkin lymphoma	2 (40%)	3 (60%)
CLL	2 (67%)	1 (33%)
Myeloid malignancy	8 (57%)	6 (43%)
Lymphoid malignancy	26 (65%)	14 (35%)

Abbreviation: CML, chronic myeloid leukemia.

analysis ($P < 0.05$ in univariate was seen with age, ICU admission, hypertension, chronic lung disease, CAD, CHF, baseline hemoglobin, nadir hemoglobin, WBC counts, D-dimer, lactate, and LDH). Gender was forced in the model and we used a composite score of comorbidities from the sum of indicators for diabetes mellitus (DM), HTN, chronic lung disease, chronic kidney disease, CAD, and CHF capped at a maximum of 3. In the multivariate model (Supplementary Table S1), we observed that older age [age < 65; OR, 0.23; 95% confidence interval (CI), 0.07–0.6], higher composite comorbidity score (OR, 1.52; 95% CI, 1.02–2.33), ICU admission (OR, 4.83; 95% CI, 1.46–17.15), and elevated inflammatory markers (D-dimer, lactate, and LDH) were significantly associated with mortality after multivariate comparison in patients with cancer and COVID-19.

Interaction with the Healthcare Environment was a Prominent Source of Exposure for Patients with Cancer

A detailed analysis of deceased patients ($N = 61$; Supplementary Table S2) demonstrated that many were either nursing-home or shelter ($n = 22$) residents, and/or admitted as an inpatient or presented to the emergency room within the 30 days prior to their COVID-19 positive test (21/61). Altogether, 37/61 (61%) of the deceased cohort were exposed to the healthcare environment at the outset of the COVID-19 epidemic. Few of the patients in the cohort were on active oncologic therapy. The vast majority had a poor Eastern Cooperative Oncology Group performance status (ECOG PS; 51/61 with an ECOG PS of 2 or higher) and carried multiple comorbidities.

Patients with Cancer Demonstrate a Markedly Increased COVID-19 Mortality Rate Compared with Noncancer and All NYC COVID-19 Patients

An age- and sex-matched cohort of 1,090 patients at a 5:1 ratio of noncancer to cancer COVID-19 patients from the same time period and from the same hospital system was also obtained after propensity matching and used as control to estimate the increased risk posed to our cancer population (Table 4). We observed case fatality rates (CFR) were elevated in all age cohorts in patients with cancer and achieved statistical significance in the age groups 45–64 and in patients older than 75 years of age.

To also compare our CFRs with a larger dataset from the greater NYC region, we obtained official case numbers from New York State (current up to April 12, 2020; ref. 3). In all cohorts, the percentage of deceased patients was found to rise sharply with increasing age (Table 4). Strikingly, CFRs in

Table 2. Disease characteristics of patients with cancer with COVID-19 and association with mortality

	Alive	Deceased	*P*
Total	157 (72%)	61 (28%)	
Males	91 (72%)	36 (28%)	0.6
Females	66 (73%)	25 (27%)	0.6
Median age (range)	66 (10–92)	76 (10–92)	0.0006
Race			0.602
Caucasian	14 (64%)	8 (36%)	
Hispanic	58 (76%)	18 (24%)	
African American	67 (73%)	25 (27%)	
Asian	5 (71%)	2 (29%)	
Other	13 (62%)	8 (38%)	
	N/total alive (%)	*N*/total deceased (%)	
ICU admission	8 (5%)	15 (24%)	9.10E-05
Ventilator support	10 (6%)	35 (57%)	1.74E-15
Hemodialysis	10 (6%)	6 (10%)	0.37
Metastasis (solids only)	27 (22%)	15 (37%)	0.06
Active cancer (<1 yr)	60 (38%)	32 (52%)	0.09
Active chemotherapy	34 (22%)	8 (13%)	0.2
Immunotherapy	4 (3%)	1 (2%)	1
Radiotherapy	38 (24%)	11 (18%)	0.33
DM	53 (34%)	27 (44%)	0.116
HTN	100 (64%)	47 (77%)	0.047
Chronic lung disease	34 (22%)	28 (46%)	0.0003
Chronic kidney disease	33 (21%)	21 (34%)	0.052
Coronary artery disease	24 (15%)	19 (31%)	0.012
CHF	18 (11%)	15 (25%)	0.019

cancer patients with COVID-19 were significantly, many-fold higher in all age groups when compared with all NYC cases (Table 4).

DISCUSSION

To our knowledge, this is the first large report of COVID-19 CFRs among patients with cancer in the United States. The overall case fatality among COVID-19–infected patients with cancer in an academic center located within the current epicenter of the global pandemic exceeded 25%. In addition, striking tumor-specific discrepancies were seen, with marked increased susceptibility for those with hematologic malignancies and lung cancer. CFRs were 2 to 3 times the age-specific percentages seen in our noncancer population and the greater NYC area for all COVID-19 patients.

Our results seem to mirror the typical prognosis of the various cancer types. Among the most common malignancies within the U.S. population (lung, breast, prostate, and colorectal), there was 55% mortality among patients with lung cancer, 14% for breast cancer, 20% for prostate cancer, and 38% for colorectal cancer. This pattern reflects the overall known lethality of these cancers. The percent annual mortality (ratio of annual deaths/new diagnosis) is 59.3% for lung cancer, 15.2% for breast cancer, 17.4% for prostate cancer, and 36% for colorectal cancer (8). This suggests that COVID-19 infection amplifies the risk of death regardless of the cancer type.

Patients with hematologic malignancies demonstrate a higher mortality than those with solid tumors. These patients tend to be treated with more myelosuppressive therapy, and are often severely immunocompromised because of underlying disease. There is accumulating evidence that one major mechanism of injury may be a cytokine-storm syndrome secondary to hyperinflammation, which results in pulmonary damage. Patients with hematologic malignancy may potentially be more susceptible to cytokine-mediated inflammation due to perturbations in myeloid and lymphocyte cell compartments (14).

Many of the predictive risk factors for mortality in our cancer cohort were similar to published data among all COVID-19 patients. A recent meta-analysis highlighted the association of chronic diseases including hypertension (OR, 2.29), diabetes (OR, 2.47), COPD (OR, 5.97), cardiovascular disease (OR, 2.93), and cerebrovascular disease (OR, 3.89) with a risk for developing severe COVID-19 infection among all patients (15). In our cancer patient dataset, a large proportion of patients had at least one of these concurrent risk factors. In a univariate model, we observed significant associations of death from COVID-19 infection in patients with hypertension, chronic lung

Table 3. Laboratory values of cancer patients with COVID-19 and association with mortality

	Alive	Deceased	*P*
Total	157 (72%)	61 (28%)	
Pre-COVID-19 (means)			
Hemoglobin	11.99	11.22	0.048
Platelet count	225	256	0.16
WBC	7.33	7.55	0.12
ANC	4.9	5.8	0.18
Total lymphocyte count	1.6	1.7	0.5
Post-COVID-19 (means)			
Hemoglobin	10.7	9.9	0.047
Platelet count	177	171	0.7
WBC	5.8	8.8	0.01
ANC	4.4	6.6	0.017
Total lymphocyte count	0.7	0.6	0.6
Ferritin	1491	2136	0.21
D-dimer	4.1	8.8	0.002
Lactate	2	4	0.001
LDH	438	683	0.01

Abbreviation: ANC, absolute neutrophil count.

disease, coronary heart disease, and congestive heart failure. Serologic predictors in our dataset predictive for mortality included anemia at time of infection, and elevated LDH, D-dimer, and lactic acid, which correlate with available data from all COVID-19 patients.

Rapidly accumulating reports suggest that age and race may play a role in the severity of COVID-19 infection. In our cancer cohort, the median age of the patients succumbing to COVID-19 was 76 years, which was 10 years older than patients who have remained alive. The CDC has reported a disproportionate number of African Americans are affected by COVID-19 in the United States, accounting for 33% of all hospitalized patients while constituting only 13% of the U.S. population (15). However, the racial breakdown of our patients was proportional to the Bronx population as a whole, and race was not a significant predictor of mortality in our univariate or multivariate models. Our data might argue that the increased mortality noted in the larger NYC populations might also likely be driven by socioeconomic and health disparities in addition to underlying biological factors. Overall mortality with COVID-19 has been higher in the Bronx, which is a socioeconomically disadvantaged community with a mean per capita income of $19,721 (16, 17). Our patients with cancer were predominantly from the Bronx and potentially had increased mortality in part due to socioeconomic factors and comorbidities. Even after accounting for the increased mortality seen in COVID-19 in the Bronx, the many-fold magnitude increase in death rates within our

Table 4. Comparison of cancer and COVID-19 mortality with all NYC cases (official NYC numbers up to 5 p.m., April 12, 2020) and a control group from the same healthcare facility

Age groups	Cancer COVID-19 cases	Cancer COVID-19 deaths	%	Control group cases	Control group deaths	%	OR	*P*	NYC cases	NYC deaths	%	OR	*P*
Total	218	61	28%	1090	149	14%	2.45	8.46E-07	104185	6182	6%	6.160	< 2.2e-16
0–17	3	1	33%	5	0	0%	na	0.375	2025	3	0%	304.66	0.006
18–44	13	1	8%	75	2	3%	2.99	0.38466	39704	284	1%	11.56	0.088
45–64	64	10	16%	320	13	4%	4.35	0.00161	37851	1449	4%	4.65	0.0001
65–74	59	13	22%	282	41	15%	1.66	0.169939	13128	1511	12%	2.17	0.020
>75	79	36	46%	408	93	23%	2.83	7.34E-05	11477	2935	26%	2.44	0.0001

Note: The NYC cohort and the control group were compared independently with the cancer–COVID-19 cohort, and the *P* values and OR are shown.

cancer cohort can potentially be attributed to the vulnerability of oncology patients. This was evident in the comparison with a control group from the same hospital system that demonstrated a significant association of cancer with mortality in patients between 45 and 64 years of age and older than 75 years of age.

Interaction with the healthcare environment prior to widespread knowledge of the epidemic within NYC was a prominent source of exposure for our patients with cancer. Many of those who succumbed to COVID-19 infection were older and frail with significant impairment of pulmonary and/or immunologic function. These findings could be utilized to risk-stratify patients with cancer during this pandemic, or in future viral airborne outbreaks, and inform mitigation practices for high-risk individuals. These strategies could include early and aggressive social distancing, resource allocation toward more outpatient-based care and telemedicine, testing of asymptomatic high-risk patients, and institution of strict infection-control measures. Indeed, such strategies were implemented early in the pandemic at our center, possibly explaining the relatively low number of infected patients on active therapy.

There were several limitations to our study. Data regarding do not resuscitate or intubate orders were not included in the analysis and could have significantly affected the decision-making and mortality surrounding these patients. Although an attempt was made to control for those receiving active cancer treatment or with additional comorbidities, we could not fully account for the patients' preexisting health conditions prior to COVID-19 infection. Differential treatment paradigms for COVID-19 infection and sequelae were not controlled for in our analysis. Because of the limited follow-up, the full clinical course of these patients may not be included. Future comparative studies to noncancer patients will be needed to fully ascertain the risk posed to oncology patients. Finally, though our data does include those who were tested and discharged within our health system, we cannot fully account for those who were tested in nonaffiliated outpatient settings, which may potentially bias our study to more severe cases. We also acknowledge that the mortality rate is highly dependent on the breadth of testing, and therefore understand that more widespread detection of viral infection would likely alter the results.

Our data suggest significant risk posed to patients with cancer infected with COVID-19, with an observed significant increase in mortality. The highest susceptibility appears to be in hematologic or lung malignancies, suggesting that proactive strategies to reduce likelihood of infection and improve early identification of COVID-19 positivity in the cancer patient population are clearly warranted. Overall, we hope and expect that our data from the current epicenter of the COVID-19 epidemic will help inform other healthcare systems, patients with cancer, and the public about the particular vulnerability of patients with cancer to this disease.

METHODS

Study Design and Participants

Data regarding all patients who had tested positive for COVID-19 from March 18, 2020, until April 8, 2020, were extracted from the electronic medical records from a single, urban, academic medical center. These records were cross-referenced with an existing cancer database, and a retrospective review was done by senior authors to extract additional data on patients with a history of malignancy. Reverse transcriptase qPCR assay was utilized to determine SARS-CoV-2 status. Baseline characteristics, laboratory data, and clinical outcomes were tabulated, with data collection finalized on April 12, 2020. All patients who were tested were symptomatic for COVID-19 at the time of testing due to the unavailability of prophylactic testing for asymptomatic individuals early in the epidemic. Cases identified as having benign neoplasms were excluded. Information collected included demographic data, medical history including comorbidities, cancer diagnosis, chemotherapy and/or radiation in the last 30 days, curative versus palliative treatment, laboratory data pre-infection (when available) and post-infection (WBC, hemoglobin, platelet count, differential counts, ferritin, D-dimer, lactate, LDH), hospital course (admission, discharge, ICU, need for ventilator support and/or dialysis), and mortality. CFRs of patients with cancer with COVID-19 at our institution were compared with an age- and sex-matched control cohort within our hospital system, as well as publicly available NYC COVID-19 mortality data (ref. 16; https://www1.nyc.gov/assets/doh/downloads/pdf/imm/covid-19-deaths-confirmed-probable-daily-04142020.pdf). Our institutional ethics review board reviewed and approved the study and waived the need for informed consent.

Statistical Analysis

For categorical data, percentages of each variable were calculated after dichotomization based on mortality status. Medians with range were determined for age, and means were calculated and utilized for laboratory values. For continuous data, Wilcoxon rank sum test or Student *t* test were used to compare continuous data for patients in the alive or deceased cohorts. Fisher exact test was performed for the categorical variables. Multivariate analysis was done utilizing logistic regression with inclusion of variables significant in univariate testing ($P < 0.05$). The multivariate logistic model was built from a two-sided stepwise regression based on Akaike information criterion (AIC). Missing data points for some laboratory values were imputed with the R package using the MissForest-nonparametric missing value imputation for mixed-type data method. Propensity score–based case matching was then utilized to match noncancer COVID-19 patients as controls to COVID-19 patients with cancer based on age and sex at a 5:1 ratio. ORs for mortality were calculated via logistic regression comparing both cohorts in their entirety and broken down by age group. All statistical analyses were done using R (version 3.5.3, The R Foundation).

Disclosure of Potential Conflicts of Interest

N. Ohri is a consultant at Merck and AstraZeneca. R. Perez-Soler is a consultant at Merck, AstraZeneca, Stelexis, Roche/Genentech, Lilly, and Novartis and has ownership interest (including patents) in Stelexis. B. Halmos is a consultant at AstraZeneca, Merck, Amgen, BMS, Boehringer Ingelheim, Spectrum, Novartis, Pfizer, TPT, Guardant Health, and Foundation Medicine. A. Verma reports receiving commercial research grants from Celgene, BMS, Eli Lilly, Novartis, Medpacto, and Curis and has ownership interest (including patents) in Stelexis. No potential conflicts of interest were disclosed by the other authors.

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REFERENCES

1. Guan WJ, Ni ZY, Hu Y, Liang WH, Ou CQ, He JX, et al. Clinical characteristics of coronavirus disease 2019 in China. N Engl J Med 2020;382:1708–20.
2. WHO. Coronavirus disease 2019 (COVID-19) situation report-79. https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200408-sitrep-79-covid-19.pdf
3. CDC. Coronavirus 2019 (COVID-19) cases in U.S. https://www.cdc.gov/coronavirus/2019-ncov/cases-updates/cases-in-us.html
4. Wu Z, McGoogan JM. Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China: summary of a report of 72314 cases from the Chinese center for disease control and prevention. JAMA 2020 Feb 24 [Epub ahead of print].
5. Yang X, Yu Y, Xu J, Shu H, Xia J, Liu H, et al. Clinical course and outcomes of critically ill patients with SARS-CoV-2 pneumonia in Wuhan, China: a single-centered, retrospective, observational study. Lancet Respir Med 2020 Feb 24 [Epub ahead of print].
6. Wang B, Li R, Lu Z, Huang Y. Does comorbidity increase the risk of patients with COVID-19: evidence from meta-analysis. Aging 2020;12:6049–57.
7. Yang J, Zheng Y, Gou X, Pu K, Chen Z, Guo Q, et al. Prevalence of comorbidities in the novel Wuhan coronavirus (COVID-19) infection: a systematic review and meta-analysis. Int J Infect Dis 2020;94: 91–95.
8. National Cancer Insitute: Surveillance, Epidemiology and End Results Program. Cancer stat facts: cancer of any site. https://seer.cancer.gov/statfacts/html/all.html
9. Liang W, Guan W, Chen R, Wang W, Li J, Xu K, et al. Cancer patients in SARS-CoV-2 infection: a nationwide analysis in China. Lancet Oncol 2020;21:335–7.
10. Xia Y, Jin R, Zhao J, Li W, Shen H. Risk of COVID-19 for patients with cancer. Lancet Oncol 2020;21:e180.
11. Wang H, Zhang L. Risk of COVID-19 for patients with cancer. Lancet Oncol 2020;21:e181.
12. Onder G, Rezza G, Brusaferro S. Case-fatality rate and characteristics of patients dying in relation to COVID-19 in Italy JAMA. 2020 Mar 23 [Epub ahead of print].
13. Dignani MC, Costantini P, Salgueira C, Jordan R, Guerrini G, Valledor A, et al. Pandemic 2009 influenza A (H1N1) virus infection in cancer and hematopoietic stem cell transplant recipients; a multicenter observational study. F1000Res 2014;3:221.
14. Mehta P, McAuley DF, Brown M, Sanchez E, Tattersall RS, Manson JJ, et al. COVID-19: consider cytokine storm syndromes and immunosuppression. Lancet 2020;395:1033–4.
15. Garg S, Kim L, Whitaker M, O'Halloran A, Cummings C, Holstein R, et al. Hospitalization rates and characteristics of patients hospitalized with laboratory-confirmed coronavirus disease 2019 — COVID-NET, 14 states, March 1–30, 2020. MMWR Morb Mortal Wkly Rep 2020;69:458–64.
16. New York City Health Department. Confirmed and probable COVID-19 deaths daily report. https://www1.nyc.gov/site/doh/covid/covid-19-data.page
17. United States Census Bureau. Quick facts: Bronx county (Bronx borough), New York. https://www.census.gov/quickfacts/fact/table/bronxcountybronxboroughnewyork/SEX255218