COVID-19 in Immunocompromised Cancer Patients: A Case Series and Review of the Literature

Raj H. Patel, MBA[1] ⓘ, Rachana Vanaparthy, MBBS[2], and John N. Greene, MD, FACP[3]

Abstract

The global pandemic of the novel coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has presented newfound challenges to the oncology community regarding management of disease progression in immunocompromised and cancer patients. Further, the large influx of COVID-19 patients has overwhelmed healthcare facilities, limited access to intensive care unit beds and ventilators, and canceled elective surgeries causing disruptions to the cancer care continuum and re-organization of oncological care. While it is known that the potential threat of infection is greatest in elderly patients (>60 years of age) and patients with underlying comorbidities, there is still insufficient data to determine the risk of COVID-19 in cancer patients. Given the immunosuppressive status in cancer patients arising from chemotherapy and other comorbidities, management of COVID-19 in this patient population carries a unique set of challenges. We report three cases of COVID-19 in immunocompromised cancer patients and discuss the challenges in preventing, diagnosing, and treating this vulnerable group.

Keywords

cancer, COVID-19, SARS-CoV-2, immunocompromised, comorbidities

Introduction

The outbreak of the novel coronavirus disease 2019 (COVID-19) originating from Wuhan, the capital city of Hubei Province of China, has quickly transformed into a worldwide pandemic.[1] The etiological agent responsible for COVID-19 has been identified as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which is rapidly spread through human-to-human transmission via direct contact with infected patients, surfaces, objects, and droplet transmission.[2-4] Clinical symptoms primarily include fever, cough, fatigue, dyspnea, and myalgia. COVID-19 presents an unprecedented challenge in oncology care given the risks of transmission and heightened mortality in immunocompromised hosts.[5-7] Cancer patients routinely visit hospitals to receive treatment and monitoring and are thus at an increased risk of exposure to infection. These challenges have called for changes in oncological care which have in turn has led to delays and cancellations of routine therapy, diagnostic tests, and treatment procedures.[8,9]

Although it is known that older patients with comorbidities present with a more severe course of illness and have higher rates of mortality, there is a paucity of adequate information to determine the risk of COVID-19 on cancer patients.[5] Early evidence from China suggests that cancer patients may be at a greater risk of experiencing more severe sequelae of COVID-19 symptoms requiring intensive care unit (ICU) admission or invasive mechanical ventilation.[10,11] However, there are various potential confounding factors and limitations that exist

[1]Edward Via College of Osteopathic Medicine, Monroe, LA, USA
[2]Oregon Health and Science University, Portland, OR, USA
[3]Infectious Diseases and Hospital Epidemiology, Moffitt Cancer Center and Research Institute, Tampa, FL, USA

Corresponding Author:
John N. Greene, Infectious Diseases and Hospital Epidemiology, Moffitt Cancer Center and Research Institute, 12902 Magnolia Drive, Tampa, FL 33612, USA.
Email: john.greene@moffitt.org

within these studies as the limited number of patients reported also have immunocompromised states, advanced age, poor functional status, and noncancer comorbidities which could also have affected their prognosis. Data from countries that were affected early by the COVID-19 pandemic have provided little evidence to understand the risks of cancer in the setting of SARS-CoV-2 infection.[12] The effect of anti-cancer therapies on the virulence and severity of COVID-19 in cancer patients also remains unclear. In this case series, we describe our single-center experience with three immunocompromised cancer patients who developed SARS-CoV-2 infection and discuss the clinical characteristics and outcomes of COVID-19 in cancer patients.

Case 1

A 65-year-old female with stage III squamous cell carcinoma of the right lung, grade 3 pneumonitis, and pseudomonas pneumonia presented with symptoms of fever, shortness of breath, and fatigue. Past medical history is also significant for radiation esophagitis and anemia. She was on intravenous piperacillin/tazobactam for her grade 3 pneumonitis. For treatment of her stage III squamous cell carcinoma, she was undergoing chemotherapy with carboplatin/paclitaxel with concurrent ipilimumab. Most recently, she began immunotherapy with pembrolizumab. On admission, blood pressure was 147/77 mmHg, pulse 88 beats per minute, respiratory rate 20 breaths per minute, and body temperature 97.4 F, and maximum body temperature 103.2 F. Computed tomography (CT) of the thorax revealed cavitary lesions in the right lobe with draining fistula and multifocal ground-glass opacities suggestive of nonspecific pneumonia (Figure 1). Upon admission, antimicrobial therapy was escalated to intravenous meropenem. Empiric micafungin and 60 mg of intravenous methylprednisolone daily were added. After 2 days, her dyspnea and fever began to slowly improve.

On the third day of admission, it was discovered that she had been in contact with her husband who recently tested positive for COVID-19. The patient was then moved to strict isolation and the SARS-CoV-2 RT-PCR test was performed which was positive. Blood cultures were negative. Empiric micafungin and intravenous meropenem were discontinued as patient showed signs of improvement and also no microbiologic evidence of fungal pneumonia. For the remainder of the hospital course, she remained on room air with blood oxygen saturation levels (SpO$_2$) greater than 90%. As her symptoms steadily improved, she was switched from intravenous methylprednisolone to oral prednisone at 50 mg which was gradually lowered by 10 mg every 4 days. After 72 hours with no new fevers, nausea, significant pain, and baseline respiratory symptoms, she was discharged with intravenous piperacillin/tazobactam at 12.5 g every 24 hours for 6 weeks and oral prednisone. She was also advised to self-isolate and implement measures to limit contact with others, as her husband who was also recently discharged after being
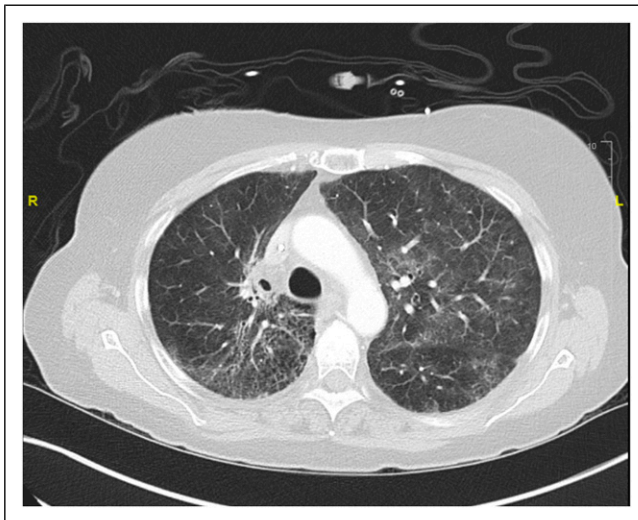

Figure 1. Computed tomography of the thorax demonstrating pulmonary nodules with multifocal ground-glass opacification suggestive of nonspecific pneumonia in patient 1.

admitted for COVID-19. During a follow-up visit three weeks later, she reported doing well with no recurrence of fever or dyspnea and resumed her chemotherapy regimen for squamous cell carcinoma of the right lung.

Case 2

A 72-year-old male with relapsed diffuse large B-cell lymphoma with CNS involvement and neurosarcoidosis was previously admitted to the hospital for bacteremia, neutropenic fever, post-obstructive pneumonia, and COVID-19. Past medical history is also significant for benign prostatic hypertrophy, sarcoidosis, and pulmonary embolism. He was undergoing therapy with R-ICE (rituximab, ifosfamide, carboplatin, and etoposide phosphate) for diffuse large B-cell lymphoma with his last dose received 2 weeks prior to infection with SARS-CoV-2. He was discharged with vancomycin and cefepime for treatment of the bacteremia; hydroxychloroquine and azithromycin for treatment of COVID-19 after a positive SARS-CoV-2 RT-PCR result. Two days later, he presented to an urgent care clinic with acute on chronic hypoxic respiratory failure, weakness, and increased oxygen requirements from 2L nasal cannula (NC) to 5L NC on home oxygen therapy. He denied any symptoms of cough, secretions, nasal congestion, fever, or chills. On admission, blood pressure was 91/62 mmHg, pulse 81 beats per minute, body temperature was 36.6°C, and respiratory rate at 11 breaths/minute. Labs were significant for an elevated ferritin level of 533 ng/mL and C-reactive protein of 7.54 mg/dL. He had dyspnea and hypoxia along with increased secretions and cough resulted in mucosal plugging. Lab results were significant for a high white blood cell count of 1.944 k/uL. Computed tomography of the thorax revealed significant obstruction from endobronchial lesions in the left upper and
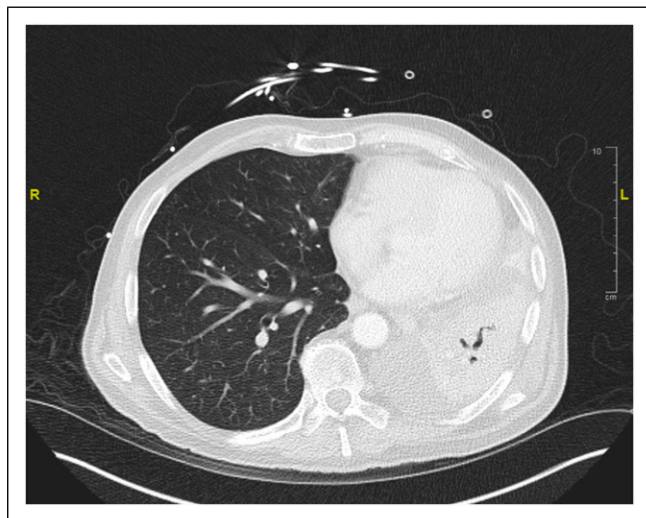
Figure 2. Computed tomography of the thorax demonstrating significant obstruction in the left upper lobe and left lower lobes of the left lung in case 2.

lower lobe of the left lung (Figure 2) which caused his symptoms of hypoxia. He was given hydroxychloroquine (200 mg) and azithromycin (250 mg) therapy as well as supplemental oxygen therapy to maintain SpO_2 at 92%. Intravenous vancomycin was also continued for treatment of *Staphylococcus epidermidis* bacteremia. After a week of therapy, he gradually improved and was discharged with instructions to self-isolate.

Case 3

A 33-year-old male with a history of salvage treatment for relapsed acute myeloid leukemia who recently was admitted with influenza pneumonia and complicated UTI presented with a fever. He was undergoing chemotherapy with high-dose cytarabine for AML with last dose received one month prior to infection. A SARS-CoV-2 RT-PCR test was administered which returned a positive result. The patient was subsequently admitted. Upon admission, blood pressure was 129/81 mmHg, heart rate 94 beats per minute, respiratory rate 17 breaths per minute, body temperature 37.2°C, pulse 94 beats per minute. Labs included an elevated ferritin of 6753 ng/mL and D dimer of 53 420 ng/mL. After three days of hospitalization, clinical symptoms improved and he was discharged home with instructions on oxygen saturation monitoring.

One week later, the patient returned with persistent fatigue, fever, and intermittent shortness of breath since he was discharged. He has had a productive cough of clear sputum and central chest discomfort. He denies any abdominal pain, diarrhea, blood in the stool or urine, and experiences no burning during urination. During this time, body temperature was 38.1°C, blood pressure 110/69 mmHg, heart rate 103 beats per minute, pulse 103 beats per minute, and oxygen saturation at 94%. Imaging revealed worsening left basilar consolidation

Figure 3. Chest X-ray revealing worsening left basilar consolidation suspicious for pneumonia in case 3.

suspicious for pneumonia (Figure 3 and 4). He was administered 10 mg of intravenous dexamethasone, 2000 mg of intravenous cefepime, 250 mg of oral azithromycin every 24 hours, and 800 mg–160 mg oral sulfamethoxazole/trimethoprim. The following day, the patient reported feeling better with resolving symptoms of fatigue and shortness of breath. He still however had intermittent episodes of dyspnea. After a 10 day hospital course, his symptoms gradually improved and he was asymptomatic for >72 hours. He was then discharged with instructions on self-isolation.

Discussion

Our three cases, reported early in the pandemic between the months of March to June 2020, describe the novel challenges in clinical decision-making that exist when managing SARS-CoV-2 infection in immunocompromised cancer patients. In the first case, the patient's complicated admission consisting of fever and respiratory symptoms was initially consistent with the diagnosis of bacterial pneumonia based on the initial CT scan. By the time she was diagnosed with COVID-19 during hospitalization, symptoms were gradually improving which was largely attributed to intravenous methylprednisolone. She was not given antiviral therapy due to favorable improvement on steroid therapy alone. In the second case, the patient had acute hypoxic respiratory failure arising from a combination of airway obstruction, post-obstructive pneumonia, and SARS-CoV-2 which complicated management. The patient's hypoxia was thought to be related to the endobronchial lesions
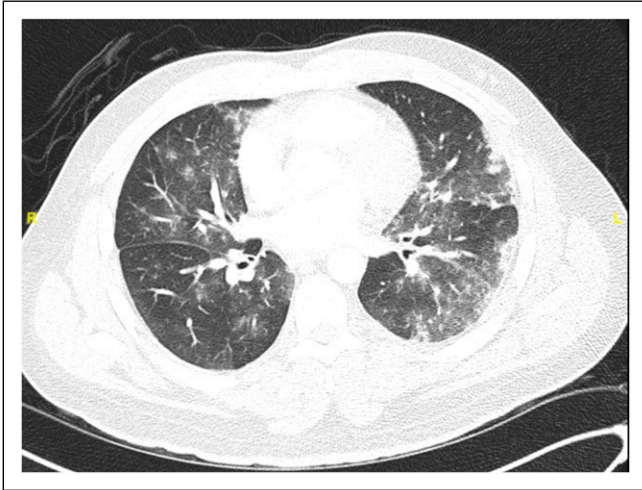
Figure 4. Computed tomography findings in case 3.

obstructing the left upper lobe and left lower lobe of the lungs. His worsening respiratory status was also found to be attributed to post-obstructive pneumonia from a mass in the left hilar region as opposed to COVID-19. These first two cases occurred earlier in the pandemic when remdesivir and dexamethasone was unavailable and not known to be helpful. Our third case occurred most recently and was treated with convalescent plasma. Although our patients suffered severe respiratory symptoms arising from COVID-19 and co-morbidities, none required prolonged invasive ventilation or admission to the ICU.

Evidence from the spread of SARS-CoV-2 infection in cancer patients from an epidemiologic standpoint is urgently needed. While it is known that cancer patients have a higher risk of developing infections due to their immunocompromised state and anti-cancer therapy, previous reports of COVID-19 cases in cancer patients have provided little knowledge regarding the associations between cancer and SARS-CoV-2 infection in patients due to limitations in long-term follow-up.[10-13] Some of these reports contain numerous limitations including limited clinical information, and small sample sizes which make it difficult to interpret the prevalence of COVID-19 in cancer patients.[13] It is also important to account for the influence of geographic factors as different countries have variances in healthcare service access, social factors, and cancer care. These factors can impact the generalizability of the reported findings of clinical characteristics, vulnerability, and prognosis. Interestingly, the Netherlands saw fewer cancer diagnoses in the period between February 24, 2020 and April 12, 2020 based on pathological cancer notifications in comparison to the period before the COVID-19 outbreak. This was most pronounced for skin cancers and seen among all age groups and geographical regions. This notable decrease may be answered by public health shifts or a nationwide prioritization of COVID-19 patients in hospitals.[14] However, it could also point to the widespread cancellations of screening procedures in February and March and prioritization of the management and prevention of COVID-19.

In a nationwide analysis from China conducted by Liang et al, 18 cancer patients were identified to have COVID-19 from a pool of 1590 COVID-19 cases spanning from 595 hospitals, with lung cancer being the most common type.[10] Within these 18 cancer patients those that received recent treatment in the forms of chemotherapy or surgery were found to have a severe sequalae of events than those without cancer (7 of 18 patients vs 124 of 1572 patients; $P = .0003$). It is important to note that 12 of these 18 patients did not have active cancer and were long-term cancer survivors. Another analysis of 28 cancer patients in Wuhan, China by Zhang et al, notes that 53.6% of these patients developed severe clinical symptoms (requiring ICU admission, mechanical ventilation, or death).[11] Both studies also found that lung cancer patients had the greatest risk of poor prognosis and rapid progression of COVID-19 symptoms. Computed tomography features of patchy consolidation in cancer patients upon admission for COVID-19 related symptoms or recent surgery were also identified as a risk factor prior to onset of severe symptoms.

A large cohort study by Dai et al from Wuhan, China, identified 105 COVID-19 patients with cancer. This study found that patients with hematologic cancer, lung cancer, or with metastatic cancer (stage IV) had the highest frequency of severe events.[15] The study also reported that patients with non-metastatic cancer and those who underwent recent radiotherapy experienced similar frequencies of severe conditions as patients without cancer. Recent surgery was also described as a risk factor of developing severe events. Another study from Wuhan, China which reported 138 patients at a tertiary care hospital indicated the risk of hospital-acquired transmission as it accounted for 41.3% of the admitted patients.[16] The infection rate of SARS-CoV-2 in patients with cancer was found to be .79%, higher than the cumulative incidence of all diagnosed COVID-19 cases in the city of Wuhan during that period. This study highlighted the importance of enacting proper isolation protocols to mitigate the transmission of SARS-CoV-2 due to the high frequency of hospital visits by patients with cancer.[16] Other case studies have described similar outcomes and note that cancer patients with SARS-CoV-2 can rapidly become critical cases.[17,18] Another large cohort study analyzing outcomes of patients with cancer and COVID-19, all-cause mortality for 30 days was found to be high and associated with general risk factors unique to cancer patients. This study highlighted the importance of long-term follow-up in order to better understand the outcomes of COVID-19 on cancer and to make effective judgement in the continuity of cancer treatment.[19] Patients with hematological malignancies have been found to have worse outcomes than the general population with COVID-19, which highlights the need for aggressive infection prevention strategies.[20]

Some studies have also focused on outcomes in patients specific to certain types of cancer. A study by Montopoli

et al, found that although cancer patients have an increased risk of SARS-CoV-2 infection compared with noncancer patients, prostate cancer patients in particular that are receiving androgen-deprivation therapies may be partially protected from SARS-CoV-2 infection.[21] This may be explained by the fact that androgen receptors that regulate TMPRSS2 expression in non-prostatic tissues may increase susceptibility of males to severe SARS-CoV-2 infection. Androgen-deprivation therapies are known to decrease the levels of TMPRSS2 which both decreases susceptibility and severity of SARS-CoV-2 infection by modulating the immune response.[21] In another study identifying outcomes of COVID-19 and gynecologic cancer patients in New York City, case fatality rate among these patients was found to be 14%, wherein recent immunotherapy use was found as a significant factor associated with risk of mortality related to COVID-19. However, there were no associations found between cytotoxic chemotherapy and cancer-directed surgery with COVID-19 severity or death.[22] This study underscored the importance of continuing anti-cancer treatment during the pandemic. Patients with chronic lymphocytic leukemia were also found to be at a particularly high risk of infections and poor outcomes when infected with SARS-CoV-2 based on findings from a multicenter international experience.[23] Another study based in Paris analyzed 15 600 actively treated early or metastatic breast cancer patients. In this study, common clinical features mostly consisted of fever, cough, and ground-glass opacities as the most common radiologic sign on diagnosis. There was no association between prior radiation therapy fields or extent of radiation therapy sequelae and the extent of COVID-19 lung lesions. Most significantly, this study found that COVID-19 mortality rate in breast cancer patients depends more on comorbidities than prior radiation therapy or current anti-cancer treatment, highlighting the importance of comorbidities when estimating risk of severity in breast cancer patients.[24] Cancer patients with different tumor types have also been found to have differing susceptibility to SARS-CoV-2 infection and COVID-19 phenotypes. Patients with hematological malignancies who had recent chemotherapy were found to have an increased risk of death during COVID-19-associated hospital admission.[25]

Despite limitations, these studies provide initial insight into the difficulty of patient management during the COVID-19 pandemic. These studies also highlight the vulnerability of cancer patients to SARS-CoV-2 infection due to their immunosuppressive state and heightened exposure due to recurrent hospital visits for treatment. Patients with underlying cancer tend to show rapid progression of COVID-19 symptoms and also have poorer prognosis. The damages of chemotherapy to the bone marrow can also lead to thrombocytopenia and neutropenia, further lead to an increased risk of infection.[26] Patients also have the tendency of prolonged viral shedding which indicates the possibility of a prolonged contagious period.[26]

The risks of transmission and heightened rates of morbidity and mortality in immunocompromised hosts with COVID-19 has presented a set of unique challenges regarding delivery of cancer care. This has led to delays and cancellations of elective surgery and other cancer treatment procedures which can negatively alter the prognosis of this fragile population.[27] Disruption to the full spectrum of medical cancer care services is predicted to have a significant impact on cancer-related mortality, as much as 5–10% decrease in survival in high-income countries.[28] Questions regarding which cancer patients are at a greater risk of developing COVID-19, the effect of anti-cancer therapies on the virulence and severity of infection, whether the risks of delaying cancer diagnosis/treatment outweigh the risks of potential COVID-19 exposure, or the effect of the pandemic on future cancer mortality rates are also yet to be answered.[29-32] Further, it is important to consider the high risk of developing COVID-19 from nosocomial infections during the pandemic, especially in cancer centers.[33] The importance of balancing pandemic control and providing continued cancer care is a difficult decision that must be made in consideration with individual circumstances in a multidisciplinary approach.[34,35] Continuing anti-cancer therapy and follow-up visits in a large tertiary care hospital was found to be feasible and safe after the implementation of strict-population wide and institutional safety measures in conjunction with routine SARS-CoV-2 testing of patients.[36]

A recent 2021 update of the AGIHO guideline on evidence-based management of COVID-19 patients with cancer discusses the preventive, diagnostic, and therapeutic options for these patients. This article also notably suggests the use of remdesivir, especially in the early phase of SARS-CoV-2 acute viral replication.[37] However, patients with cancer may be at risk of prolonged periods of active viral replication. Currently, the WHO does not recommend the use of remdesivir in the treatment of COVID-19 within the general population. The article also mentioned the potential benefits of JAK inhibitors in reducing the time to recovery, especially in those patients receiving high-flow oxygen or non-invasive ventilation.[37] Another recent retrospective analysis of COVID-19 cancer patients from New York City, in which prostate and breast cancer were the most common, found that rapid clinical deterioration was seen in patients aged 60 and above.[38] Higher mortality rates were particularly seen with those patients that had hypertension and elevated lactate dehydrogenase and C-reactive protein.[38] Age and sex were also seen to be higher risk factors for poorer prognosis in a recent larger meta-analysis of studies reporting fatalities in COVID-19 patients with cancer.[39]

During this unprecedented time, it becomes increasingly important to evaluate hospital infection control protocol and screening measures as these practices are crucial in preventing the spread of infection. Oncologists should proactively communicate practice modifications, provide more intensive

surveillance in cancer patients infected with SARS-CoV-2, and identify novel strategies to provide remote cancer care and allow for isolation.

Conclusion

Independent and multidisciplinary decisions must be made for effective management of cancer patients suffering from COVID-19 depending on the severity of illness and clinical course. Our three case reports describe the novel challenges associated with clinical decision-making in patients with cancer who are infected with SARS-CoV-2. Cancer centers should identify strategies to minimize the disruption to the cancer care continuum and work to provide optimal care for cancer patients in the setting of COVID-19.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

ORCID iD

Raj H. Patel https://orcid.org/0000-0003-1896-1961

References

1. Yang K, Sheng Y, Huang C, et al. Clinical characteristics, outcomes, and risk factors for mortality in patients with cancer and COVID-19 in Hubei, China: A multicentre, retrospective, cohort study. *Lancet Oncol.* 2020;21(7):904-913.

2. Gandhi M, Yokoe DS, Havlir DV. Asymptomatic transmission, the achilles' heel of current strategies to control Covid-19. *N Engl J Med.* 2020;382(22):2158-2160.

3. Ong SWX, Tan YK, Chia PY, et al. Air, surface environmental, and personal protective equipment contamination by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) From a symptomatic patient. *J Am Med Assoc.* 2020;323(16): 1610-1612. doi:10.1001/jama.2020.3227.

4. Li Q, Guan X, Wu P, et al. Early transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia. *N Engl J Med.* 2020;382(13):1199-1207. doi:10.1056/NEJMoa2001316.

5. Gosain R, Abdou Y, Singh A, Rana N, Puzanov I, Ernstoff MS. COVID-19 and cancer: A comprehensive review. *Curr Oncol Rep.* 2020;22(5):53.

6. El-Shakankery KH, Kefas J, Crusz SM. Caring for our cancer patients in the wake of COVID-19. *Br J Canc.* 2020;123:3-4.

7. Sidaway P. COVID-19 and cancer: What we know so far. *Nat Rev Clin Oncol.* 2020;17(6):336.

8. Hanna TP, Evans GA, Booth CM. Cancer, COVID-19 and the precautionary principle: Prioritizing treatment during a global pandemic. *Nat Rev Clin Oncol.* 2020;17(5):268-270.

9. Shankar A, Saini D, Roy S, et al. Cancer care delivery challenges amidst coronavirus disease - 19 (COVID-19) outbreak: Specific precautions for cancer patients and cancer care providers to prevent spread. *Asian Pac J Cancer Prev.* 2020;21(3): 569-573.

10. 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.

11. Zhang L, Zhu F, Xie L, et al. Clinical characteristics of COVID-19-infected cancer patients: A retrospective case study in three hospitals within Wuhan, China. *Ann Oncol.* 2020;31:894-901.

12. Spicer J, Chamberlain C, Papa S. Provision of cancer care during the COVID-19 pandemic. *Nat Rev Clin Oncol.* 2020;17(6): 329-331.

13. Xia Y, Jin R, Zhao J, Li W, Shen H. Risk of COVID-19 for patients with cancer. *Lancet Oncol.* 2020;21(4):e180.

14. Dinmohamed AG, Visser O, Verhoeven RHA, et al. Fewer cancer diagnoses during the COVID-19 epidemic in the Netherlands. *Lancet Oncol.* 2020;21(6):750-751. Erratum in: Lancet Oncol. 2020 May 4. doi:10.1016/S1470-2045(20) 30265-5.

15. Dai M, Liu D, Liu M, et al. Patients with cancer appear more vulnerable to SARS-CoV-2: A multicenter study during the COVID-19 outbreak. *Canc Discov.* 2020;10(6):783-791.

16. Yu J, Ouyang W, Chua MLK, Xie C. SARS-CoV-2 transmission in patients with cancer at a tertiary care hospital in Wuhan, China. *JAMA Oncol.* 2020;6(7):1108-1110.

17. Ma J, Yin J, Qian Y, Wu Y. Clinical characteristics and prognosis in cancer patients with COVID-19: A single center's retrospective study. *J Infect.* 2020;81:318-356.

18. Chen J, Qi T, Liu L, et al. Clinical progression of patients with COVID-19 in Shanghai, China. *J Infect.* 2020;80(5):e1.

19. Kuderer NM, Choueiri TK, Shah DP, et al. Clinical impact of COVID-19 on patients with cancer (CCC19): A cohort study. *Lancet.* 2020;395(10241):1907-1918. doi:10.1016/S0140-6736(20) 31187-9. Erratum in: Lancet. 2020 Sep 12;396(10253):758.

20. Passamonti F, Cattaneo C, Arcaini L, et al. Clinical characteristics and risk factors associated with COVID-19 severity in patients with haematological malignancies in Italy: A retrospective, multicentre, cohort study. *Lancet Haematol.* 2020; 7(10):e737-e745. doi:10.1016/S2352-3026(20)30251-9.

21. Montopoli M, Zumerle S, Vettor R, et al. Androgen-deprivation therapies for prostate cancer and risk of infection by SARS-CoV-2: A population-based study (N = 4532). *Ann Oncol.* 2020; 31(8):1040-1045. doi:10.1016/j.annonc.2020.04.479.

22. Lara OD, O'Cearbhaill RE, Smith MJ, et al. COVID-19 outcomes of patients with gynecologic cancer in New York city. *Cancer.* 2020;126:4294-4303. doi:10.1002/cncr.33084.

23. Mato AR, Roeker LE, Lamanna N, et al. Outcomes of COVID-19 in patients with CLL: A multicenter international experience. *Blood.* 2020;136(10):1134-1143. doi:10.1182/blood.2020006965.

24. Vuagnat P, Frelaut M, Frelaut M, et al. COVID-19 in breast cancer patients: A cohort at the Institut Curie hospitals in the Paris area. *Breast Canc Res.* 2020;22(1):55. doi:10.1186/ s13058-020-01293-8.

25. Lee LYW, Cazier JB, Starkey T, et al. COVID-19 prevalence and mortality in patients with cancer and the effect of primary tumour subtype and patient demographics: A prospective cohort study. *Lancet Oncol*. 2020;21(10):1309-1316. doi:10.1016/S1470-2045(20)30442-3.

26. Yeoh CB, Lee KJ, Rieth EF, et al. COVID-19 in the cancer patient. *Anesth Analg*. 2020;131(1):16-23.

27. Rassy E, Khoury-Abboud RM, Ibrahim N, Kattan C, Assi T, Kattan J. What the oncologist needs to know about COVID-19 infection in cancer patients. *Future Oncol*. 2020;16(17):1153-1156.

28. The Lancet Oncology. Safeguarding cancer care in a post-COVID-19 world. *Lancet Oncol*. 2020;21(5):603. doi:10.1016/S1470-2045(20)30243-6.

29. Ueda M, Martins R, Hendrie PC, et al. Managing cancer care during the COVID-19 pandemic: Agility and collaboration toward a common goal. *J Natl Compr Canc Netw*. 2020;18:366-369. doi:10.6004/jnccn.2020.7560.

30. Sharpless NE. COVID-19 and cancer. *Science*. 2020;368(6497):1290. doi:10.1126/science.abd3377.

31. AlShamsi HO, Alhazzani W, Alhuraiji A, et al. A practical approach to the management of cancer patients during the novel coronavirus disease 2019 (COVID-19) pandemic: An international collaborative group. *Oncol*. 2020;25(6):e936-e945. doi:10.1634/theoncologist.2020-0213.

32. Kutikov A, Weinberg DS, Edelman MJ, Horwitz EM, Uzzo RG, Fisher RI. A war on two fronts: Cancer care in the time of COVID-19. *Ann Intern Med*. 2020;172(11):756-758.

33. Mei H, Dong X, Wang Y, Tang L, Hu Y. Managing patients with cancer during the COVID-19 pandemic: frontline experience from Wuhan. *Lancet Oncol*. 2020;21(5):634-636. doi:10.1016/S1470-2045(20)30238-2.

34. Burki TK. Cancer guidelines during the COVID-19 pandemic. *Lancet Oncol*. 2020;21(5):629-630. doi:10.1016/S1470-2045(20)30217-5.

35. Singh AP, Berman AT, Marmarelis ME, et al. Management of lung cancer during the COVID-19 pandemic. *JCO Oncol Pract*. 2020;16(9):579-586. doi:10.1200/OP.20.00286.

36. Berghoff AS, Gansterer M, Bathke AC, et al. SARS-CoV-2 testing in patients with cancer treated at a tertiary care hospital during the COVID-19 pandemic. *J Clin Oncol*. 2020;38:3554-3547. doi:10.1200/JCO.20.01442.

37. Giesen N, Sprute R, Rüthrich M, et al. 2021 update of the AGIHO guideline on evidence-based management of COVID-19 in patients with cancer regarding diagnostics, viral shedding, vaccination and therapy. *Eur J Canc*. 2021;147:154-160. doi:10.1016/j.ejca.2021.01.033.

38. Ramachandran P, Kathirvelu B, Chakraborti A, et al. COVID-19 in cancer patients from New York city: A comparative single center retrospective analysis. *Cancer Control*. 2020;27(1):107327482096045. doi:10.1177/1073274820960457.

39. Zhang H, Han H, He T, et al. Clinical characteristics and outcomes of COVID-19-infected cancer patients: A systematic review and meta-analysis. *J Natl Cancer Inst*. 2021;113(4):371-380. doi:10.1093/jnci/djaa168.