



Determinants of the outcomes of patients with cancer infected with SARS-CoV-2: results from the Gustave Roussy cohort

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Patients with cancer are presumed to be at increased risk of severe COVID-19 outcomes due to underlying malignancy and treatment-induced immunosuppression. Of the first 178 patients managed for COVID-19 at the Gustave Roussy Cancer Centre, 125 (70.2%) were hospitalized, 47 (26.4%) developed clinical worsening and 31 (17.4%) died. An age of over 70 years, smoking status, metastatic disease, cytotoxic chemotherapy and an Eastern Cooperative Oncology Group score of ≥ 2 at the last visit were the strongest determinants of increased risk of death. In multivariable analysis, the Eastern Cooperative Oncology Group score remained the only predictor of death. In contrast, immunotherapy, hormone therapy and targeted therapy did not increase clinical worsening or death risk. Biomarker studies found that C-reactive protein and lactate dehydrogenase levels were significantly associated with an increased risk of clinical worsening, while C-reactive protein and D-dimer levels were associated with an increased risk of death. COVID-19 management impacted the oncological treatment strategy, inducing a median 20 d delay in 41% of patients and adaptation of the therapeutic strategy in 30% of patients.

By early March 2020, the spread of the coronavirus disease 2019 (COVID-19) outbreak had reached the Paris area, France. Since then, all medical resources have been reorganized to handle the pandemic. As a tertiary cancer center, Gustave Roussy has followed two objectives: define processes to safely sustain cancer care in a secured environment and reorganize internally to adapt its capacities to hospitalize patients with cancer and COVID-19 illness.

Patients with cancer have been considered at increased risk of COVID-19, on the rationale of the increased systemic immunosuppressive state caused by the underlying malignancy and anti-cancer treatments. The first report from a retrospective cohort in China suggested that patients with cancer were observed to have a higher risk of severe events (for example, a composite endpoint of intensive care unit (ICU) admission, invasive ventilation or death) compared with patients without cancer (seven (39%) of 18 patients versus 124 (8%) of 1,572 patients; $P=0.0003$) and that patients with cancer deteriorated more rapidly than those without cancer¹. While general determinants of COVID-19 severity have emerged from large cohorts from China and Italy^{2,3}, limited data are available on the specificity of patients with cancer to help the oncology

community to identify patients at risk of severe COVID-19. Furthermore, the impact of COVID-19 infection on ongoing cancer care is unexplored.

This study investigated the determinants of clinical worsening and death, as well as the impact on cancer care, for the first patients sequentially managed for COVID-19 and cancer in an academic tertiary cancer center.

Results

Patient population. From 24 March 2020 until 29 April 2020, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was detected in 196 (12%) of 1,633 tests performed internally at the Gustave Roussy Cancer Centre. Overall, 209 patients were identified (including a few identified by PCR with reverse transcription (RT-PCR) performed at another facility and some diagnosed by computed tomography scan alone) and the final study population included 178 adult patients. The following were reasons for exclusion: pediatric population (six patients); non-cancer patients (19 patients); and COVID-19 ultimately ruled out (six patients). Baseline demographics, comorbidities and underlying cancer characteristics for

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Table 1 | Patient characteristics

Characteristic	n (out of 178)	Percentage
Gender		
Male	76	42.7%
Female	102	57.3%
Age (years)		
Median (Q1–Q3)	61.0 (52.0–71.0)	
Mean (s.d.)	60.6 (14.8)	
≥70 years old	50	28.1%
Smoking		
Never	89	50.6%
Former	43	24.4%
Current	20	11.4%
Unknown	24	13.6%
Comorbidities		
Hypertension	65	36.5%
Diabetes	35	19.7%
Dyslipidemia	16	9.0%
Cardiac disease (ischemic/other)	9/21	5.1%/11.8%
Chronic kidney disease	10	5.6%
Autoimmune disease	9	5.1%
BMI		
Median (Q1–Q3)	25.0 (22.0–28.0)	
Mean (s.d.)	25.0 (4.9)	
<18.5	12	7.4%
18.5–25	64	39.3%
25–30	62	38.0%
≥30	25	15.3%
History of cancer		
Solid tumors	156 ^a	
Breast	32	20.5%
Gynecological	23	14.7%
Head and neck	22	14.1%
Gastrointestinal	21	13.5%
Genitourinary	20	12.8%
Thoracic	17	10.9%
Dermatology	11	7.1%
Others (endocrine, CNS, ACUP)	10	6.4%
Hematological malignancies	30 ^a	
Mature B cell neoplasm/myeloma	15	50.0%
Acute myeloid leukemia	8	26.7%
Hodgkin lymphoma	4	13.3%
Others	3	10.0%
Disease status		
Remission/curative intent	70	39.3%
Active/advanced disease	108	60.7%
PS at last oncological visit		
0/1	129	72.9%
≥2	48	27.1%

Continued

Table 1 | Patient characteristics (Continued)

Characteristic	n (out of 178)	Percentage
Systemic treatments in the past 3 months		
Yes	117	66.9%
Cytotoxic chemotherapy	66	37.1%
Target therapy	30	16.9%
Hormone therapy	16	10.3%
Immune checkpoint inhibitor	19	10.7%

^aTwo patients with a solid tumor had a history of hematological malignancy and six patients with a hematological malignancy had a history of solid tumor. ACUP, adenocarcinoma of unknown primary; CNS, central nervous system; PS, performance status; Q1, first quartile; Q3, third quartile.

the population are shown in Table 1. The study population included 102 (57.3%) female patients with a median age of 61 years old and a median body mass index (BMI) of 25. Among 156 patients with a history of solid tumor, the most frequent were breast cancer (20.5%), gynecological cancer (14.7%), head and neck tumors (14.1%), gastrointestinal cancer (13.5%) and genitourinary malignancies (12.8%). The most common hematological malignancy was mature B cell neoplasm, in 15 patients. The disease status at the last oncological or hematological follow-up was remission or localized tumor with ongoing curative treatment in 70 patients (39.3%) and locally advanced or metastatic disease in 108 patients (60.7%). The Eastern Cooperative Oncology Group (ECOG) performance status at the last follow-up was 0–1 in 73% of patients. Systemic anticancer treatment had been administered in the past 3 months in 117 (66.9%) patients.

Diagnosis. The vast majority of patients ($n=138$; 79.8%) presented with COVID-19 symptoms before any test or imaging. COVID-19 was suspected following symptoms prompting RT-PCR testing in 134 patients (75.7%) and following incidental findings on a computed tomography scan in 16 patients (9%), and was related to systematic screening (before surgery or another treatment modality) in 27 patients (15.3%). The most common symptoms reported are presented in Table 2. COVID-19 diagnosis was established by SARS-CoV-2-positive nasal RT-PCR in 166 patients (93.8%) and by computed tomography scan alone (confirmed by observation of the typical appearance of COVID-19 as defined by the American College of Radiology criteria for patients with a negative RT-PCR test⁴) in 11 patients (6.2%). Overall, 125 (70.2%) patients were hospitalized for COVID-19 illness. The median time between the first COVID-19 symptoms and admission was 4 d (Q1–Q3 = 2–8). The median duration of hospital stay was 10 d (range = 1–40 d).

COVID-19 systemic treatment. Based on the available data, systemic treatment for COVID-19 included a combination of hydroxychloroquine and azithromycin in 45 patients (25.4%), a combination of lopinavir and ritonavir in five patients (2.9%), an immunomodulatory interleukin-6 inhibitor (tocilizumab) in ten patients (5.6%) and steroids in 21 patients (11.9%), mostly administered intravenously with either dexamethasone (20 mg on days 1–3 and 10 mg on days 4–6) or >1 mg kg⁻¹ equivalent prednisone (Supplementary Table 1). Overall, 91 patients (51.4%) received anticoagulation. Among these 91 patients, anticoagulation was administered with thromboprophylaxis intent (low or intermediate risk: 62%; high risk: 13%) or with curative intent (25%). Among hospitalized patients, 11 patients (8.8%) experienced a documented bacterial infection, ten (8.1%) presented neurological or psychiatric symptoms and three (2.4%) developed a thromboembolic event.

Outcome. At data cutoff on 6 May 2020, the median follow-up of the study population from COVID-19 diagnosis was 23 d (Q1–Q3 = 13–33 d). Among the 178 patients, 47 developed clinical

Table 2 | COVID-19 diagnosis characteristics

Characteristics	n (out of 178)	Percentage
Symptoms before test		
Yes	138	79.8%
No	35	20.2%
Symptoms reported		
Fever	82	46.1%
Dry cough	70	39.3%
Fatigue	52	29.2%
Dyspnea	55	30.9%
Diarrhea	17	9.6%
Anosmia	17	9.6%
Ageusia	14	7.9%
Reported contact with patient with COVID-19		
Yes	31	18.6%
No	62	37.1%
NA	74	44.3%
COVID-19 diagnosis		
RT-PCR SARS-CoV-2	166	93.8%
CT scan alone	11	6.2%
Extent of disease at first CT		
None/minimal (<10%)	68	52.7%
Moderate/mild (10–24%)	32	24.8%
Extensive (25–49%)	18	14.0%
Severe/critical (≥50%)	11	8.5%
NA	4	
No CT scan performed	45	

CT, computed tomography; NA, not available.

worsening or died (Table 3), corresponding to a clinical worsening-free survival rate of 73.7% (95% confidence interval (CI)=66.2–79.9%) 21 d after COVID-19 diagnosis. Sixteen patients (9%) had been admitted to the ICU. The median time from the first COVID-19 symptoms to clinical worsening was 7 d (minimum=1 d; maximum=19 d). Overall, 31 patients died, corresponding to an overall survival rate of 82% (95% CI=74.9–87.4%) 21 d after COVID-19 diagnosis. Among them, the primary cause of death was related to COVID-19 in 20 patients (64.5%) and to cancer in 11 patients (35.5%).

Cancer-related determinants of clinical worsening-free and overall survival in patients with cancer and COVID-19. Univariable and multivariable analyses of both clinical worsening-free and overall survival are presented in Table 4. In univariable analysis, an ECOG score of ≥2 at the last follow-up visit, smoking status (current and former) and the use of cytotoxic chemotherapy in the past 3 months were significantly associated with clinical worsening-free survival. A similar trend was observed according to the type of cancer (hematological malignancy). Determinants of increased risk of death, in univariable analysis, were age ≥70 years, smoking status (current and former), an ECOG score of ≥2 at the last follow-up, onco-hematological status (metastatic disease) and the use of cytotoxic chemotherapy in the past 3 months (Figs. 1 and 2). Among patients treated with cytotoxic chemotherapy in the past 3 months and presenting clinical worsening ($n=26$), four out of five (80%) patients in remission or with localized disease were admitted to the ICU versus five out of 21 patients (24%) with locally advanced or

Table 3 | Clinical outcome and impact on oncological treatment

Outcome	n (out of 178)	Percentage
Hospital admission	125	70.2%
Clinical worsening	47	26.4%
Admission to ICU	16	9.0%
At data cutoff		
Death	31	17.4%
Primary cause of death: COVID-19	20	
Primary cause of death: cancer	11	
Never hospitalized	51	28.7%
Still hospitalized	16	9.0%
Discharged	80	44.9%
Impact of COVID-19 on cancer treatment		
No change in strategy		
No delay in ongoing treatment	51	28.8%
Delay in ongoing treatment	73	41.2%
Change in strategy		
Dose modification	2	1.1%
Change of treatment modality	6	3.4%
Change of systemic therapy	7	4.0%
End of treatment (surveillance)	7	4.0%
End of treatment (palliative care or death)	31	17.5%
NA	1	

Data cutoff was 6 May 2020. The median follow-up was 23 d.

metastatic disease ($P=0.035$). Conversely, hormone therapy, targeted therapies and immune checkpoint inhibitors had no impact on the COVID-19 outcomes. Only 11 patients (6%) were receiving radiation therapy at the time of COVID diagnosis. Three patients presented with clinical deterioration (two with a gynecological cancer and one with a renal cell carcinoma metastatic to the bone). Among them, one patient eventually died from COVID-19. In multivariable analysis, an ECOG score of ≥2 at the last follow-up was the strongest determinant associated with both clinical worsening and death.

Baseline biological determinants of clinical worsening-free and overall survival in patients with cancer and COVID-19. Several biological factors, markers of infection, inflammatory status and underlying conditions have been investigated for their association with either the risk of clinical worsening or the risk of death and are presented in Table 5. Among these, C-reactive protein (CRP)>50 mg ml⁻¹, procalcitonin>0.5 µg l⁻¹, lymphopenia≤500 cells per µl, monocyteopenia≤200 cells per µl, ferritin>1,000 ng ml⁻¹, lactate dehydrogenase (LDH)>250 IU l⁻¹, albumin≤30 g l⁻¹ and troponin>upper limit of normal (ULN) were associated with a significantly increased risk of both clinical worsening and death in univariable analysis. In multivariable analysis, CRP and LDH were significantly associated with an increased risk of clinical worsening, and CRP and D-dimer>3 µg l⁻¹ were associated with an increased risk of death.

Impact of COVID-19 on oncological strategy. The results of a post-COVID-19 first-month assessment were available for 146 patients: 75% reported persistent symptoms of asthenia, 42% reported exertion dyspnea and 30% reported a cough. Among 141 patients with available information, 87 (62%) had cancer-specific treatment already restarted or planned. The overall impact of

Table 4 | Determinants for clinical worsening and overall survival

	Clinical worsening						Overall survival		
	Univariable analysis			Multivariable analysis			Univariable analysis		
	No. out of 178 (%)	n _{events} /n _{patients}	HR (95% CI)	P value (Wald)	HR (95% CI)	P value (Wald)	n _{events} /n _{patients}	HR (95% CI)	P value (Wald)
Gender									
Female	102 (57%)	23/102	0.19				14/102	1	
Male	76 (43%)	24/76	1.47 (0.83–2.61)	0.50			17/76	1.64 (0.81–3.32)	0.04
Age at diagnosis									
<70 years	128 (72%)	32/128	1				18/128	1	
≥70 years	50 (28%)	15/50	1.24 (0.67–2.28)	0.39			13/50	2.13 (1.04–4.36)	0.52
BMI									
<18.5	12 (7%)	5/12	1.63 (0.60–4.43)				4/12	2.34 (0.73–7.45)	
18.5–25	64 (39%)	17/64	1				10/64	1	
25–30	62 (38%)	12/62	0.76 (0.36–1.60)				9/62	1.05 (0.43–2.59)	
≥30	25 (15%)	8/25	1.43 (0.61–3.33)				4/25	1.16 (0.36–3.69)	
Smoking (n=152 with informative data)									
Never	89 (59%)	17/89	1				10/89	1	
Current/former	63 (41%)	22/63	2.03 (1.07–3.82)				17/63	2.78 (1.27–6.08)	
ECOG at last follow-up									
0–1	129 (73%)	22/129	1	<0.00001	1		9/129	1	
≥2	48 (27%)	25/48	3.61 (2.03–6.42)		3.25 (1.81–5.85)		22/48	7.49 (3.45–16.3)	
Type of cancer									
Solid tumor	150 (84%)	36/150	1		0.09	0.33			
Hematological malignancy	28 (16%)	11/28	1.80 (0.91–3.55)		1.42 (0.70–2.88)		4/28	0.67 (0.23–1.90)	
Onco-hematological status									
Remission/ localized	70 (39%)	13/70	1		0.13		4/70	1	
Active/metastatic	108 (61%)	34/108	1.64 (0.86–3.11)		0.20		27/108	4.23 (1.48–12.1)	
Treatment in the past 3 months									
No	58 (33%)	11/58	1				6/58	1	
Yes	117 (67%)	35/117	1.55 (0.79–3.06)		0.008		24/117	1.87 (0.77–4.59)	
Cytotoxic chemotherapy in the past 3 months									
No	112 (63%)	21/112	1		1		13/112	1	
Yes	66 (37%)	26/66	2.18 (1.22–3.87)		1.69 (0.92–3.10)		18/66	2.20 (1.08–4.49)	
Targeted therapy in the past 3 months									
No	148 (83%)	40/148	1				29/148	1	
Yes	30 (17%)	7/30	0.83 (0.37–1.86)		0.66		2/30	0.29 (0.07–1.24)	

Continued

Table 4 | Determinants for clinical worsening and overall survival (Continued)

	Overall survival						P value (Wald)	
	Univariable analysis			Multivariable analysis				
	No. out of 178 (%)	n _{events} /n _{patients}	HR (95% CI)	P value (Wald)	HR (95% CI)	P value (Wald)		
Immune checkpoint inhibitors in the past 3 months								
No	159 (89%)	44/159	1		28/159	1	0.94	
Yes	19 (11%)	3/19	0.60 (0.19-1.93)		3/19	1.05 (0.32-3.45)	0.89	
Hormone therapy in the past 3 months (patient with a solid tumor only)								
No	140 (90%)	33/140	1		24/140	1	24/140	
Yes	16 (10%)	4/16	1.11 (0.39-3.13)		3/16	1.09 (0.33-3.61)	3/16	

The hazard ratio corresponds to the effect size of the covariate studied on the risk of clinical worsening or death. Statistical significance was determined by Cox models using the Wald test. Due to the exploratory nature of the analyses, no formal adjustment for multiplicity was done. All tests were two sided and significance was accepted at the 5% level.

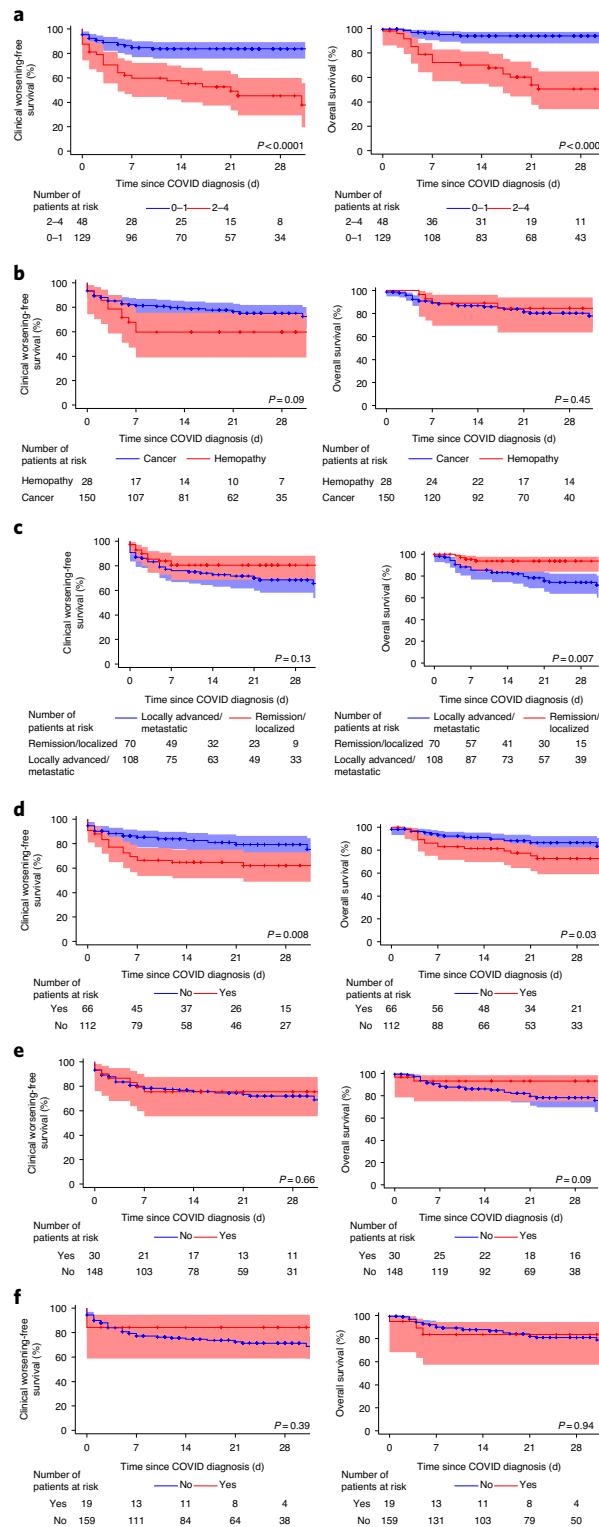


Fig. 1 | Determinants for clinical worsening and overall survival. **a-f**, Kaplan-Meier plots ($n=178$ patients) of clinical worsening-free survival (left) and overall survival (right), stratified according to ECOG score at the last onco-hematological consultation ($n=177$) (**a**), type of cancer ($n=178$) (**b**), onco-hematological status ($n=178$) (**c**), administration of cytotoxic chemotherapy inhibitors in the past 3 months ($n=178$) (**d**), administration of targeted therapy inhibitors in the past 3 months ($n=178$) (**e**) and administration of immune checkpoint inhibitors in the past 3 months ($n=178$) (**f**). Pointwise 95% confidence limits are reported (shaded intervals). Plus symbols indicate censored observations. Statistical significance was determined by Wald test of the univariable Cox models.

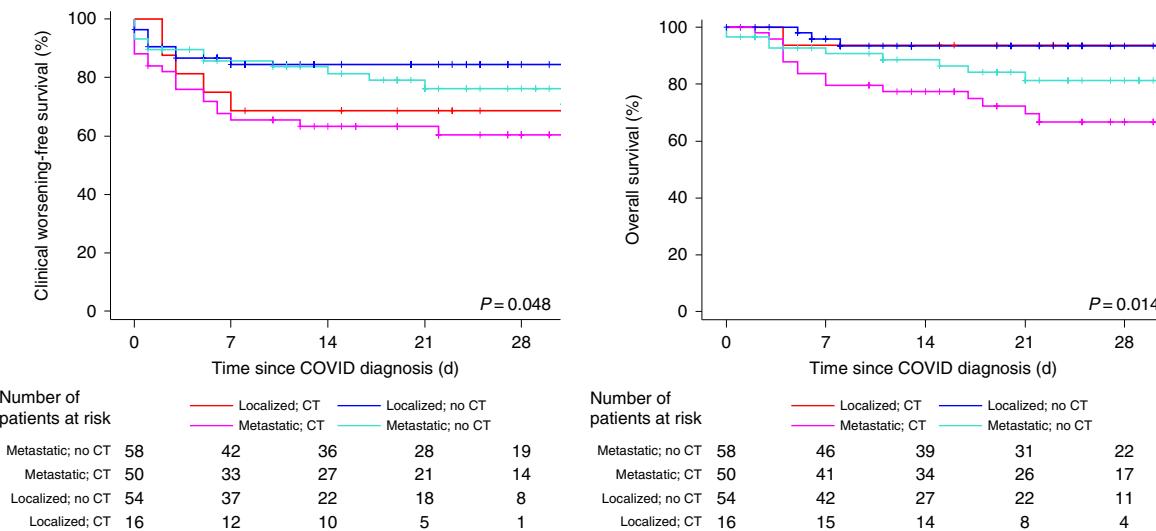


Fig. 2 | Impact of cytotoxic chemotherapy according to cancer status. Kaplan-Meier plots of clinical worsening-free survival (left) and overall survival (right), stratified according to cytotoxic chemotherapy in the past 3 months and onco-hematological status. Plus signs indicate censored observations. For all comparisons, $n=178$ patients. Statistical significance was determined by Wald test of the univariable Cox models. CT, chemotherapy.

COVID-19 on cancer treatment was assessed in the entire cohort (Table 3), leading to no change in oncological care management in 51 patients (29%). These included 28 patients who were under surveillance before COVID-19 and remained under surveillance, as well as 22 patients with ongoing oncological or hematological treatment for whom COVID-19 did not impact the ongoing care. In 73 patients (41%), COVID-19 diagnosis induced a delay but no change in the strategy, with a median delay of 20 d (interquartile range (IQR): 12–30 d) for systemic therapy and 28 d (IQR: 22–44 d) for surgery or ablative techniques. A change in oncological care management (such as surgery anticipation or switch to radiotherapy) was reported in 4% of patients, and a change in systemic therapy was reported in 4% of patients. The COVID-19 illness led to a discontinuation of cancer treatment in 4% of patients for the surveillance-only strategy. Among patients with any impact (delay, change or end of treatment), 78% of these changes were related to COVID-19, 18% were related to underlying cancer progression and 4% were related to cancer treatment toxicity. Among 11 patients who were diagnosed with COVID-19 while undergoing ongoing radiation therapy, four had an interruption in the radiation plan, and among eight patients with planned radiation therapy at the time of COVID-19 diagnosis, three had the start of radiation treatment delayed by >7 d.

Discussion

The outcomes of COVID-19 illness have been analyzed in previous datasets^{3,5,6} but data on predictors of disease severity specifically in patients with cancer are limited and the impact on cancer treatment is unknown. In this study, we report on COVID-19 management at a tertiary cancer center and investigate determinants of clinical worsening and death, as well as the impact on cancer care.

This study identified that 12% of the tested population were positive for COVID-19. COVID-19 led to a death rate of 17.4%, similar to the concomitant mortality of admitted patients with COVID-19 in the Paris area (<https://www.gouvernement.fr/info-coronavirus/carte-et-donnees>). Conflicting results have been reported recently on a potential increased risk of severe COVID-19 outcome in patients with cancer. A cohort of 5,688 patients, including 334 patients with cancer, did not identify any increased risk of death in patients with cancer (HR = 1.15 (95% CI = 0.84–1.57))⁷, while an analysis of 105 patients with cancer and 536 age-matched patients without cancer suggested that patients with cancer have higher risks

for all severe outcomes related to COVID-19 and an excess odds ratio of 2.17 ($P=0.06$) for death⁸. More recently, the OpenSAFELY study suggested there is increased COVID-19 mortality in patients with a recent diagnosis of solid tumors⁶.

Recently, two large retrospective international cohorts have been reported on, including all patients with cancer in the COVID-19 and Cancer Consortium (CCC19) study⁹ and all patients with thoracic cancer in the Thoracic Cancers International COVID-19 Collaboration (TERAVOLT) study¹⁰. Using a similar design, these two studies investigated factors associated with COVID-19 mortality. The design and results of these two studies, along with the current study and two others, are presented in Table 6, which summarizes the specificity of each cohort.

In our cohort, we observed a trend towards severe COVID-19 in patients with hematological malignancies (crude hazard ratio (HR) = 1.80 (95% CI = 0.91–3.55); $P=0.09$), as reported in other datasets^{6,11}. However, in our experience, this factor was not associated with a significant increased risk of death, potentially related to both a more intensive care strategy and the limited number of hematological patients in our cohort. The granularity of our dataset has enabled the investigation of several determinants including the impact of cancer status (remission or localized versus metastatic or advanced), the impact of the systemic anticancer treatment used and the ECOG performance status at the last oncological follow-up before COVID-19 diagnosis. Our analysis suggests that cancer status may not impact the risk of clinical worsening but seems to be associated with an increased risk of death (univariable analysis). With regard to systemic anticancer therapy, we did not identify a detrimental effect of the use of immune checkpoint inhibitors, hormone therapy or targeted therapy on the risk of clinical worsening or death. While some initial reports suggested a potential increased severity of COVID-19 with immune checkpoint inhibitors⁸, a more recent dataset including two cohorts of patients with lung cancer similarly concluded that programmed cell death protein 1 blockade exposure is not associated with an increased risk of severity of COVID-19 (refs. ^{10,12}). Conversely, the use of cytotoxic chemotherapy was associated with an increased risk of clinical worsening and death in univariable analysis and showed a trend for a higher risk of death after adjustment of ECOG performance status and cancer status in multivariable analysis. This may be partially explained by more intensive care solicitation in patients receiving

Table 5 | Biological determinants for clinical worsening and overall survival

	Clinical worsening						Overall survival					
	Univariable analysis			Multivariable analysis			Univariable analysis			Multivariable analysis		
	Frequency (%)	n _{events} /n _{patients}	HR (95% CI)	P value (Wald)	HR (95% CI)	P value (Wald)	n _{events} /n _{patients}	HR (95% CI)	P value (Wald)	HR (95% CI)	P value (Wald)	P value (Wald)
CRP	152	<0.0001	0.012	0.002	0.048							
≤50 mg l ⁻¹	84 (55%)	12/84	1	1								
>50 mg l ⁻¹	68 (45%)	33/68	4.17 (2.15–8.09)	2.62 (1.24–5.56)								
Procalcitonin	143	<0.0001										
≤0.50 µg l ⁻¹	110 (77%)	21/110	1									
>0.5 µg l ⁻¹	33 (23%)	23/33	5.71 (3.15–10.35)									
Hemoglobin	157	0.003										
<10 g dL ⁻¹	47 (30%)	22/47	2.43 (1.35–4.36)									
≥10 g dL ⁻¹	110 (70%)	23/110	1									
Leukocytes	157	0.09										
<4,000	46 (29%)	11/46	0.97 (0.47–2.0)									
4–10,000	87 (56%)	22/87	1									
>10,000	24 (15%)	12/24	2.07 (1.02–4.18)									
Lymphocytes	155	0.009										
≤500	34 (22%)	16/34	2.28 (1.23–4.23)									
>500	121 (78%)	28/121	1									
Neutrophil/lymphocyte ratio	155	0.011										
<7	103 (67%)	21/103	1									
≥7	52 (33%)	23/52	2.16 (1.19–3.92)									
Monocytes	155	0.0003										
≤200	24 (15%)	13/24	3.42 (1.77–6.59)	1.50 (0.70–3.21)	0.30							
>200	131 (85%)	31/131	1	1								
Fibrinogen	151	0.007										
≤5 g l ⁻¹	83 (55%)	17/83	1									
>5 g l ⁻¹	68 (45%)	28/68	2.29 (1.25–4.18)									
Ferritin	129	0.002										
≤1,000 ng mL ⁻¹	90 (69.8%)	20/90	1									
>1,000 ng mL ⁻¹	39 (30.2%)	20/39	2.66 (1.43–4.94)									

Continued

Table 5 | Biological determinants for clinical worsening and overall survival (Continued)

	Clinical worsening						Overall survival					
	Univariable analysis			Multivariable analysis			Univariable analysis			Multivariable analysis		
	Frequency (%)	n _{events} /n _{patients}	HR (95% CI)	Pvalue (Wald)	HR (95% CI)	Pvalue (Wald)	n _{events} /n _{patients}	HR (95% CI)	Pvalue (Wald)	HR (95% CI)	Pvalue (Wald)	P value (Wald)
D-dimer	117		0.15	0.43			14/87	1	0.025			0.02
≤3 µg l ⁻¹	87 (74%)	27/87	1		1		11/30	2.47 (1.12-5.46)				1
>3 µg l ⁻¹	30 (26%)	14/30	1.60 (0.84-3.05)	<0.0001	1.31 (0.67-2.52)	0.0285			0.009			2.63 (1.15-6.01)
LDH	151						7/78	1				0.61
≤250 IU l ⁻¹	78 (52%)	10/78	1		1		20/73	3.17 (1.34-7.51)				1
>250 IU l ⁻¹	73 (48%)	33/73	4.64 (2.28-9.45)		2.31 (1.09-4.88)							1.27 (0.51-3.16)
Albumin	150								0.002			
≤30 g l ⁻¹	36 (24%)	21/36	3.73 (2.05-6.79)				14/36	3.35 (1.57-7.12)				
>30 g l ⁻¹	114 (76%)	22/114	1				13/114	1				
Troponin	112			0.0001					0.01			
≤ULN	84 (75%)	19/84	1				11/84	1				
>ULN	28 (25%)	18/28	3.59 (1.88-6.88)				12/28	2.96 (1.29-6.79)				

The sample size varied between 157 and 112 patients, depending on the availability of samples for each laboratory test. The hazard ratio corresponds to the effect size of the covariate studied on the risk of clinical worsening or death. Statistical significance was determined by Cox models using the Wald test. Due to the exploratory nature of the analyses, no formal adjustment for multiplicity was done. All tests were two sided and significance was accepted at the 5% level.

cytotoxic chemotherapy in the setting of remission or localized disease. Similarly, the UK Coronavirus Cancer Monitoring Project did not identify evidence that patients with cancer who are on cytotoxic chemotherapy or another anticancer treatment are at an increased risk of mortality from COVID-19 disease compared with those not on active treatment¹³. In our experience, an ECOG score of ≥2 at the last oncological follow-up remains in multivariable analysis the strongest determinant of both increased risk of clinical worsening and increased risk of death.

Patient characteristics and prognostic models in our population highlight the fact that patients with cancer may not harbor the specific patterns of comorbidities reported in large COVID-19 series^{2,3,5}. Our dataset identified a trend towards worse outcomes in patient with a BMI >30, but the lack of a significant impact of BMI may be driven by underlying oncological disease and nutritional status in advanced oncological states, as captured in patients with a BMI <18.5 or albumin <30 g l⁻¹ in our cohort.

Several datasets have reported on the association of current smoking with favorable outcomes of COVID-19 (refs. ^{2,14}). Conversely, we report a detrimental effect of current or former smoking status on outcomes that may be driven by the underlying smoking-related malignancies in our population.

Furthermore, we investigated the role of several biological markers in disease outcome in patients with cancer. While levels of CRP and other inflammatory factors have been reported previously, we identified lymphopenia and moncytopenia as relevant markers associated with clinical worsening. Emerging data on a cohort of 142 patients in which blood markers (CRP, procalcitonin, interleukin-6, lymphocyte count and viral load (ORF1ab Ct)) were explored as predictors of survival in patients with COVID-19 have recently shown that lymphopenia is the strongest predictor for severity disease in patients with COVID-19 (ref. ¹⁵). Of note, lymphopenia has long been established as a prognostic factor for overall survival in patients with cancer¹⁶. We report on the potential role of moncytopenia as a predictor of clinical worsening. This finding is in line with recent immune cell profiling of patients with COVID-19 identifying that monocyte levels increased in patients in the early recovery stage of COVID-19 (ref. ¹⁷). Additionally, recent evidence suggests that pathological macrophages mostly derive from circulating monocytes that massively infiltrate the lungs¹⁸. Monocytes are considered to have the potential to differentiate into pro-inflammatory macrophages via activation of Janus kinase–signal transducer and activator of transcription (JAK–STAT) pathways and to contribute to hyper-inflammation associated with COVID-19 (ref. ¹⁹).

Our dataset explores the impact of COVID-19 on cancer management. Beyond the emerging data raising the concern of fewer cancer diagnoses during the COVID-19 pandemic²⁰, the impact on ongoing cancer care, including delays of treatment and halting of clinical trials, has been identified²¹. Our dataset identified a high incidence of delays, but the median time to anticancer systemic therapy or rescheduled surgery was <1 month. To ensure that patients continue to receive essential care while minimizing exposure to SARS-CoV-2 infection, cancer centers have organized their healthcare systems at an unprecedented scale and pace²². As such, we have amended our CAPRI telemedicine program, which was initially set up to monitor patients with cancer undergoing oral therapy, to face the ongoing COVID-19 crisis. The remote telemedicine monitoring strategy has been adapted to monitor outpatients positive for COVID-19 after they have provided informed consent²³.

Our study did not address the management of our pediatric patient population. At the institution level, it was decided that all pediatric patients should be tested routinely, and among 122 patients <18 years of age tested internally, 5% were found to be positive (minimum = 22 months; maximum = 13 years). Dedicated analysis is planned for the management of this specific population.

Table 6 | Study design and results for five studies investigating COVID-19 mortality in patients with cancer infected with SARS-CoV-2

Data	CCC19 (ref. ⁹)	UK Coronavirus Cancer Monitoring Project ¹³	Gustave Roussy cohort	TERAVOLT ¹⁰	Curie cohort ³⁴
Patients with cancer (<i>n</i>)	928	800	178	200	76
Cancer population	All cancers	All cancers	All cancers	Thoracic cancer	Breast cancer
Multicentric	Yes	Yes	No	Yes	No
Median follow-up	21 d	Not specified	23 d	15 d	Not specified
Primary endpoint	All-cause mortality within 30 d of diagnosis of COVID-19	All-cause mortality	All-cause mortality and clinical worsening-free survival	All-cause mortality	Death or ICU admission
Inclusion of biological findings	No	No	Yes	No	Yes
Inclusion of CT findings	No	No	Yes	No	Yes
Inclusion of type of cancer systemic treatment used (delay before COVID-19)	Yes (1 month)	Yes (1 month)	Yes (3 months)	Yes (not specified)	Yes (1 month)
Inclusion of COVID-19 systemic treatment used	Yes	No	Yes	No	Yes
Inclusion of impact on cancer treatment strategy after COVID-19 diagnosis	No	No	Yes	No	No
Prognostic factors of death studied in univariable analysis	Increased age (per 10 years), male sex, smoking status (former smoker versus never smoked), number of comorbidities (two versus none), type of malignancy (multiple cancers versus only solid tumor), active cancer (progressing versus remission), ECOG score ≥ 2 and azithromycin/hydroxychloroquine treatment	Age, male sex, hypertension, cardiovascular disease, COVID-19 severity score, ICU admission and shortness of breath	Age ≥ 70 years, smoking status (current and former), ECOG score ≥ 2 at last follow-up, onco-hematological status (metastatic disease), use of cytotoxic chemotherapy in past 3 months and levels of CRP, procalcitonin, lymphopenia, monocytopenia, ferritin, LDH, albumin and troponin	Age >65 years, smoking status (current versus former smoker), treatment with chemotherapy, presence of any comorbidities and dyspnea	Age (>70 years) and hypertension ^a
Prognostic factors of death studied in multivariate analysis	Increased age (OR = 1.84; 95% CI = 1.53–2.21), male sex (OR = 1.63; 95% CI = 1.07–2.48), smoking status (OR = 1.60; 95% CI = 1.03–2.47), number of comorbidities (2 versus 0) (OR = 4.50; 95% CI = 1.33–15.28), ECOG score ≥ 2 (OR = 3.89; 95% CI = 2.11–7.18), active cancer (progressing versus remission) (OR = 5.20; 95% CI = 2.77–9.77) and azithromycin/hydroxychloroquine treatment (OR = 2.93; 95% CI = 1.79–4.79)	None ^b	ECOG score at last follow-up ≥ 2 (HR = 5.83; 95% CI = 2.60–13.1), CRP levels (HR = 2.80; 95% CI = 1.01–7.78) and D-dimer levels (HR = 2.63; 95% CI = 1.15–6.01)	Smoking history (OR = 3.18; 95% CI = 1.11–9.06)	Not done

^aDeath or ICU admission. ^bMultivariable analysis was only done for cancer treatment. There was no significant effect on mortality for patients who received chemotherapy in the past 4 weeks, immunotherapy, hormonal therapy, targeted therapy, or radiotherapy in the past 4 weeks. CT, computed tomography; OR, odds ratio.

The retrospective nature of this work from a single institution and the heterogeneity of our cancer center population are inherent limitations to our study. Due to the small sample size and relatively low number of events, multivariable models were only adjusted on the main prognostic factors. Some analyses may have failed to

identify other determinants of clinical deterioration and overall survival by lack of power. As a result of the testing strategy (mainly in symptomatic patients who were likely to have more severe infection), our results may not apply to asymptomatic and paucisymptomatic patients with cancer. However, this highlights the challenges that

cancer centers have faced when handling the COVID-19 pandemic: the need for daily fine-tuned patient management and the need to inform the community on strategies to ensure our patients with cancer have access to essential care in an adjusted environment.

In summary, cancer centers had to face the COVID-19 outbreak with the concomitant objective to secure patients' care while protecting them from the infection. Globally, these objectives have been reached, with COVID-19 outcomes comparable to those of the general population and cancer care minimally delayed and already safely restarted.

Methods

Statistics and reproducibility. *Study design.* We performed a retrospective observational study to describe the management of adult patients with cancer (solid tumors or hematological malignancies) managed at the Gustave Roussy Cancer Centre after a diagnosis of SARS-CoV-2 infection (COVID-19) between 14 March 2020 and 29 April 2020. The modalities of COVID-19 diagnosis, clinical presentation, treatments administered for COVID-19 and patient outcomes, including impacts on cancer management, are reported. The aim of the study was to identify clinical and biological prognostic factors of clinical worsening and/or death. No statistical method was used to predetermine sample size. A total of 31 observations were excluded from the final analysis: six pediatric patients; 19 patients who did not have cancer; and six patients in whom COVID-19 was ultimately ruled out. Due to the retrospective nature of this study, there was neither randomization nor blinding.

Measures. Prognostic factors included demography (age and gender), comorbidities, solid tumor or hematological malignancies (tumor site and type, disease status and treatment received) and biological factors from laboratory tests at COVID-19 diagnosis. All of the measurements were performed independently in each patient (no repeated measurements were done). Biological factors were categorized using pre-defined threshold values based on normal value cutoffs or recently published cutoffs for the study of COVID-19. Chest computed tomography imaging characteristics, including the extent of lung involvement at diagnosis, were recorded.

Outcomes. The outcomes studied were clinical worsening-free survival and overall survival. Clinical worsening-free survival was defined as the time from COVID-19 diagnosis to clinical worsening (oxygen needs $\geq 61\text{ min}^{-1}$ or admission to the ICU) or death. Overall survival was defined as the time from COVID-19 diagnosis to death from any cause. These outcomes were chosen because they are objective, reliably recorded and reflect the increasing severity of COVID-19, as recommended by the World Health Organization for the assessment of patients in clinical studies²⁴.

Statistical analysis. Descriptive statistics (numbers, percentages, medians, IQRs and ranges) were used to describe population characteristics. The χ^2 test (or Fisher's test) and Student's *t*-test (or Wilcoxon test) were performed for intergroup comparisons, as appropriate. Time-to-event endpoints (clinical worsening-free survival and overall survival) were reported using the Kaplan-Meier method with Rothman's CIs. For the study of clinical and biological prognostic factors, Cox's proportional hazard models were used to provide *P*values and HRs with associated 95% CIs in both univariable and multivariable analyses. The choice of variables to include in the multivariable analyses was driven by the number of events available (three to four variables were included for 47 clinical worsenings/deaths and 31 deaths), the strength of the association in the univariable analyses and the absence of collinearity between variables included in the model (assessed by χ^2 test and Fisher's test for qualitative variables or Spearman's correlation coefficient for quantitative variables). The assumption of proportional hazards was checked by testing the existence of an interaction between each variable and log[time] in each model. Due to the exploratory nature of the analyses, no formal adjustment for multiplicity was done. All tests were two sided and significance was accepted at the 5% level. The analyses were performed using SAS 9.4 software (SAS institute).

Database and ethical approval. Study data were collected and managed using REDCap 9.8.4 tools hosted at the Gustave Roussy Cancer Centre^{25,26}. In accordance with the French regulations, there was no requirement for ethical approval to be sought for this observational study, based on medical files. Conforming to the General Data Protection Regulation and French law about clinical retrospective studies, the patients included in our study all received an information notice (non-oppositional information) introducing the study, following information included in Article 14 of the General Data Protection Regulation, and describing their rights in relation to their data. This study was also declared to the Gustave Roussy Cancer Centre's data protection officer and registered on the website of the French Healthcare Data Institute (declaration number: MR4911200520).

COVID-19 screening strategy. Due to testing resources, the screening strategy for SARS-CoV-2 infection evolved over the course of the reported study. Initially,

PCR testing was performed for symptomatic patients. Subsequently, there was systematic screening of non-symptomatic patients scheduled for surgery and/or radiation therapy, as well as in the pediatric population. Ultimately, testing was offered to any patients with a solid tumor or hematological malignancies as part of the ongoing ONCOVID clinical trial (Epidemiology of SARS-CoV-2 and Mortality to COVID-19 Disease in French Cancer Patients; NCT04341207).

COVID-19 PCR testing. SARS-CoV-2 diagnostic testing of clinical samples by RT-PCR was conducted from 14 March to 23 March at an outside facility (263 patients were tested, of whom 35 were found to be positive) using the Charité protocol²⁷. From 23 March, testing was performed internally at the Gustave Roussy Cancer Centre.

Nasopharyngeal swab samples were collected using flocked swabs (Sigma Virocult) and placed in viral transport media. SARS-CoV-2 RNA was detected using a multiplex real-time RT-PCR diagnostic kit (the Applied Biosystems TaqPath COVID-19 CE-IVD RT-PCR Kit) targeting three regions (ORF1ab, nucleocapsid and spike genes) with the following modifications. Nucleic acids were extracted from specimens using automated Maxwell instruments following the manufacturer's instructions (Maxwell RSC simplyRNA Blood Kit; AS1380; Promega). Real-time RT-PCR was performed on the QuantiStudio 5 Dx Real-Time PCR System (Thermo Fisher Scientific) in a final reaction volume of 20 μl , including 5 μl of extracted nucleic acids. Samples were reported as positive if at least two targets were detected.

COVID-19 and oncological treatment strategies. COVID-19 therapeutic management has been defined through institutional guidelines (Extended Data Fig. 1). These institutional guidelines were adjusted over time, depending on emerging data from the pandemic^{28,29}, clinical experience^{30–33} and onsite activation of clinical trials (NCT04331808, NCT04341207 and NCT04333914). The oncological treatment strategy was adapted based on international and national guidelines, as previously summarized³².

Reporting Summary. Further information on research design is available in the Nature Research Reporting Summary linked to this article.

Data availability

The data underlying the findings of this study cannot be made freely available because of ethical and legal restrictions. This is because the present study includes an important number of variables that, together, could be used to re-identify the patients based on a few key characteristics. However, data from this study can be requested by filling out the data request form for Gustave Roussy clinical studies at <https://redcap.gustaveroussy.fr/redcap/surveys/?s=DYDTLPE4AM>. The process is similar for every study sponsored by Gustave Roussy. The study steering committee and the sponsor will review the requests on a case-by-case basis. In case of approval, a specific agreement between the sponsor and the researcher may be required for data transfer.

Code availability

SAS software version 9.4 was used for the analysis without customization. Statistical codes (SAS software) will be made available with the data if requested.

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Author contributions

L.A., S.F., A.B. and F.B. conceived of and designed the study. L.A., S.F., A.B., B.G., F.P., C.W., A.S., M.M., F.G., L.L., F.N., T.H., C.B., S.A., E.C., G.B., A.P., A.H., J.H., J.-M.M., N.C. and F.B. collected and assembled the data and provided the patients. L.A., S.F., A.B. and F.B. analyzed and interpreted the data. L.A., S.F., A.B., B.G., F.P., C.W., A.S., M.M., F.G., L.L., F.N., T.H., C.B., S.A., E.C., G.B., A.P., A.H., J.H., J.-M.M., N.C., V.S., M.H., J.-B.M., R.S., D.V.-C., F.A., F.S., B.B., J.-C.S. and F.B. wrote the manuscript. L.A., S.F., A.B., B.G., F.P., C.W., A.S., M.M., F.G., L.L., F.N., T.H., C.B., S.A., E.C., G.B., A.P., A.H., J.H., J.-M.M., N.C., V.S., M.H., J.-B.M., R.S., D.V.-C., F.A., F.S., B.B., J.-C.S. and F.B. gave final approval of the manuscript. L.A., S.F., A.B., B.G., F.P., C.W., A.S., M.M., F.G., L.L., F.N., T.H., C.B., S.A., E.C., G.B., A.P., A.H., J.H., J.-M.M., N.C., V.S., M.H., J.-B.M., R.S., D.V.-C., F.A., F.S., B.B., J.-C.S. and F.B. were accountable for all aspects of the work.

Competing interests

L.A. reports receiving consulting fees from Pfizer, Novartis, Bristol Myers Squibb, Ipsen, Roche, MSD, AstraZeneca, Merck, Amgen, Astellas, Exelixis, Corvus Pharmaceuticals and Peloton Therapeutics outside the submitted work. C.B. reports sponsorship for research from GE Healthcare and personal fees from Bracco. A.H. reports sponsorship for research at the Gustave Roussy Cancer Centre from AbbVie, Agios, Amgen, Astex, AstraZeneca, Bayer, BeiGene, Blueprint Medicines, Bristol Myers Squibb, Boehringer Ingelheim, Celgene, Chugai, Forma, Genentech, GlaxoSmithKline, H3 Biomedicine, Incyte, Innate Pharma, Janssen, Lilly, Loxo, MedImmune, MSD, Novartis, Oncopeptides, Roche, Sanofi, Taiho and Xencor outside the submitted work. J.-M.M. reports sponsorship for research at the Gustave Roussy Cancer Centre from AbbVie, Agios, Amgen, Astex, AstraZeneca, Bayer, BeiGene, Blueprint Medicines, Bristol Myers Squibb, Boehringer Ingelheim, Celgene, Chugai, Forma, Genentech, GlaxoSmithKline, H3 Biomedicine, Incyte, Innate Pharma, Janssen, Lilly, Loxo, MedImmune, MSD, Novartis, Oncopeptides, Roche, Sanofi, Taiho and Xencor outside the submitted work, as well as personal fees, travel grants or advisory board fees from Astex, iQone, Mundipharma and Bristol Myers Squibb outside the submitted work. J.-B.M. reports sponsorship for research at the Gustave Roussy Cancer Centre from H3 Biomedicine and personal fees, travel grants or advisory board fees from AbbVie, Novartis, Astellas and Jazz Pharmaceuticals outside the submitted work. R.S. reports grants from the ARC Foundation and Paris-Saclay University outside the submitted work. N.C. reports sponsorship for research at the Gustave Roussy Cancer Centre from the Bristol Myers Squibb Foundation, Sanofi, GlaxoSmithKline and Roche outside the submitted work, as well as personal fees, travel grants or advisory board fees from AstraZeneca, Bayer and Boehringer Ingelheim outside the submitted work. D.V.-C. reports receiving consulting fees from EUSA Pharma and sponsorship for research at the Gustave Roussy Cancer Centre from Orphelia outside the submitted work. F.A. reports receiving grants from Novartis, AstraZeneca, Pfizer, Lilly and Roche outside the submitted work. F.S. reports receiving personal fees from Helsinn, MSD, Roche, Amgen, Pierre Fabre Oncology, Pfizer, Mundipharma, Mylan and Leo Pharma outside the submitted work. B.B. reports sponsorship for research at the Gustave Roussy Cancer Centre from AbbVie, Amgen, AstraZeneca, BeiGene, Blueprint Medicines, Bristol Myers Squibb, Boehringer Ingelheim, Celgene, Cristal Therapeutics, Daiichi Sankyo, Eli Lilly, GlaxoSmithKline, Ignyta, IPSEN, Invata, Janssen, Merck, MSD, Nektar, Onxeo, OSE Immunotherapeutics, Pfizer, Pharma Mar, Roche–Genentech, Sanofi, Servier, Spectrum Pharmaceuticals, Takeda, Tiziana Pharma and Tolero Pharmaceuticals outside the submitted work. J.-C.S. reports receiving consultancy fees from AstraZeneca, Astex, Clovis, GlaxoSmithKline, GamaMabs, Lilly, MSD, Mission Therapeutics, Merus, Pfizer, Pharma Mar, Pierre Fabre, Roche–Genentech, Sanofi, Servier, Sympogen and Takeda; was a full-time employee for AstraZeneca between September 2017 and December 2019; and reports receiving other fees from the shareholder Gritstone during the conduct of the study. F.B. reports receiving personal fees from AstraZeneca, Bayer, Bristol Myers Squibb, Boehringer Ingelheim, Eli Lilly Oncology, F. Hoffmann-La Roche, Novartis, Merck, MSD, Pierre Fabre, Pfizer and Takeda outside the submitted work. S.F., A.B., B.G., F.P., C.W., A.S., M.M., F.G., L.L., F.N., T.H., S.A., E.C., G.B., A.P., J.H., V.S. and M.H. declare no competing interests.

Additional information

Extended data is available for this paper at <https://doi.org/10.1038/s43018-020-00120-5>.

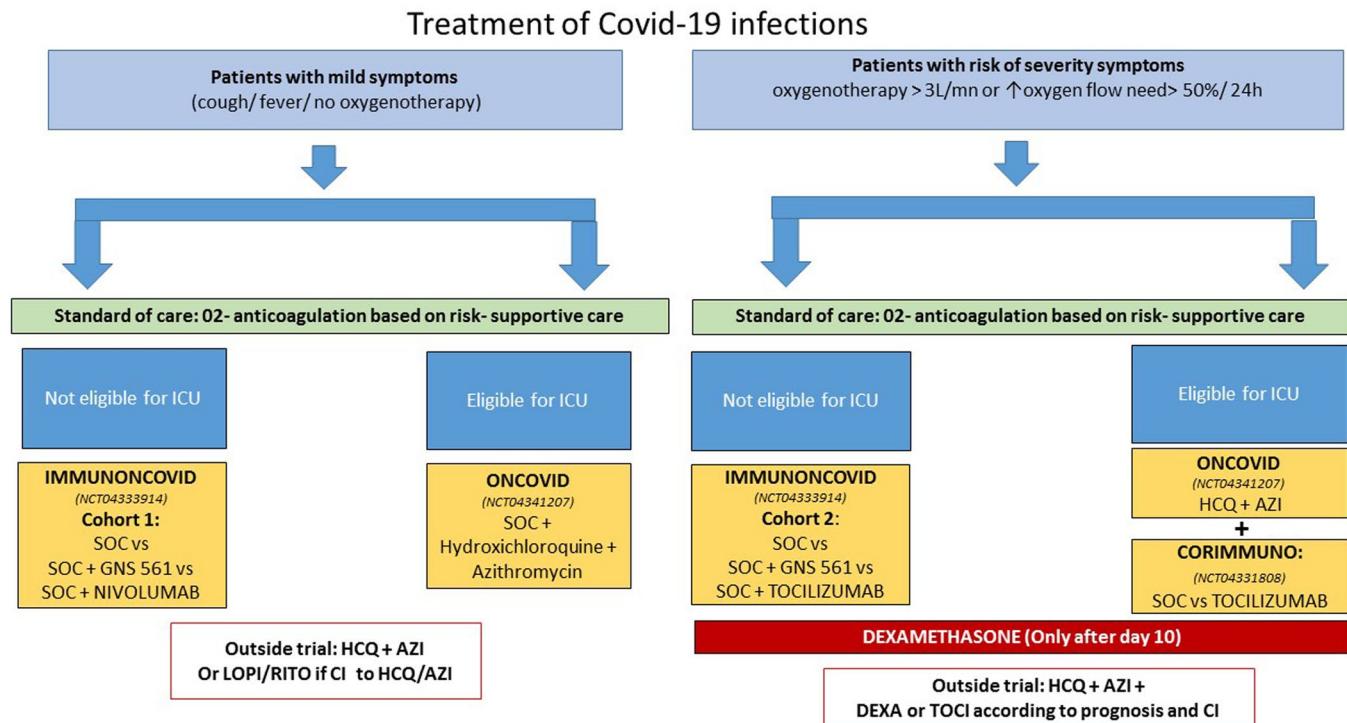
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SOC : standard of care ; ICU: intensive care unit; HCQ : hydroxychloroquine ; AZI : azithromycin ;
DEXA : dexamethasone ; TOCI : Tocilizumab ; LOPI : Lopinavir ; RITO : Ritonavir ; CI : contraindication

Extended Data Fig. 1 | Summary of COVID-19 treatments and symptom presentation. SOC, standard of care; ICU, intensive care unit HCQ, hydroxychloroquine; AZI, azithromycin; DEXA, dexamethasone; TOCI, tocilizumab; LOPI, Lopinavir; RITO, Ritonavir; CI, contraindication.

Reporting Summary

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Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

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- The exact sample size (n) for each experimental group/condition, given as a discrete number and unit of measurement
- A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
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- For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
- For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
- Estimates of effect sizes (e.g. Cohen's d , Pearson's r), indicating how they were calculated

Our web collection on [statistics for biologists](#) contains articles on many of the points above.

Software and code

Policy information about [availability of computer code](#)

Data collection

Study data were collected and managed using REDCap® 9.8.4 (Research Electronic Data Capture) tools hosted at Gustave Roussy

Data analysis

Descriptive statistics (number, percentages, median, interquartile range (IQR) and range) were used to describe population characteristics. The χ^2 test (or Fisher test) and student test (or Wilcoxon test) were performed for inter-group comparisons, as appropriate. Time-to-event endpoints (clinical worsening-free survival and overall survival) were reported using the Kaplan-Meier method with Rothman's 95% confidence intervals (CI). For the study of clinical and biological prognostic factors, Cox's proportional hazard models were used to provide p-values and Hazard Ratios (HR) with associated 95% CI in both univariable and multivariable analyses. The choice of variables to include in the multivariable analyses were driven by the number of events available (3-4 variables to include for 47 clinical worsenings/deaths and 31 deaths), the strength of the association in the univariable analyses and the absence of collinearity between variables included in the model (assessed by χ^2 test and Fisher test for qualitative variables or Spearman correlation coefficients for quantitative variables). The assumption of proportional hazards was checked by testing the existence of an interaction between each variable and log(time) in each model. Due to the exploratory nature of the analyses, no formal adjustment for multiplicity was done. All tests were two-sided, and significance was accepted at the 5% level. The analyses were performed using SAS 9.4 software (SAS institute, Cary NC).

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All manuscripts must include a [data availability statement](#). This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A list of figures that have associated raw data
- A description of any restrictions on data availability

The data underlying the findings cannot be made freely available because of ethical and legal restrictions. This is because the present study includes an important number of variables that, together, could be used to re-identify the patients based on a few key characteristics. However, data from this study can be requested by filling out the data request form for Gustave Roussy clinical studies at:
<https://redcap.gustaveroussy.fr/redcap/surveys/?s=DYDTLPE4AM>.
The process is similar for every study sponsored by Gustave Roussy. The study steering committee and the sponsor will review the requests on a case-by-case basis. In case of approval, a specific agreement between the sponsor and the researcher may be required for data transfer. Statistical codes (SAS software) will be made available with the data, if requested.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

Life sciences Behavioural & social sciences Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see nature.com/documents/nr-reporting-summary-flat.pdf

Life sciences study design

All studies must disclose on these points even when the disclosure is negative.

Sample size

In this retrospective study, no power analysis was done to calculate the sample size, and the aim was descriptive in nature. We used data from all the patients followed at Gustave Roussy and diagnosed COVID-19 between March 24th, 2020, until April 28th, 2020 corresponding to the peak of the epidemic in Paris area.

Data exclusions

209 patients were identified and the final study population included 178 adult patients, with the following exclusions: paediatric population (6) and non-cancer patients (19) or COVID-19 ultimately ruled out (6).

Replication

All the measurements were independently done in each patient (no repeated measurements).

Randomization

There was no randomization in this retrospective observational study.

Blinding

There was no blinding in this retrospective observational study.

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

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Clinical data

Policy information about [clinical studies](#)

All manuscripts should comply with the ICMJE [guidelines for publication of clinical research](#) and a completed [CONSORT checklist](#) must be included with all submissions.

Clinical trial registration

In accordance with the French regulations, there was no requirement for ethics approval to be sought for this observational study, based on medical files. Conforming to GDPR and French law about clinical retrospective studies, patients included in our study have all received an information notice (non-oppositional information) introducing study, following information included in article 14 of GDPR, and their rights about their data. This study was also declared to the Gustave Roussy's data protection officer on May 12th, 2020 then registered on the website of the Health Data French Institute, on May 20th, 2020 (declaration n° MR4911200520).

Study protocol

A synopsis of the study protocol has been posted on the website of the Health Data French Institute (<https://www.indssante.fr/fr/repertoire-public/etudes-sous-mr>)

Data collection

We performed a retrospective observational study to describe the management of adult patients with cancer (solid tumors or haematological malignancies) managed at Gustave Roussy after a diagnosis of SARS-CoV-2 (COVID-19) infection between March 14th, 2020 and April 29th, 2020. Study data were collected and managed using REDCap® 9.8.4 (Research Electronic Data Capture) tools hosted at Gustave Roussy

Outcomes

The aim of the study was to identify clinical and biological prognostic factors of clinical worsening and/or death.

Measures

Prognostic factors included demography (age, gender), comorbidities, solid tumor or haematological malignancies (tumour site, type, disease status, treatment received), and biological factors from lab tests at COVID-19 diagnosis. All the measurements were independently done in each patient (no repeated measurements). Biological factors were categorized using pre-defined threshold values based on normal value cut-offs or recently published cut-offs in COVID-19. Chest CT imaging characteristics including extent of lung involvement at diagnosis were collected.

Outcomes

The outcomes studied were the clinical worsening-free survival (CWFS) and the overall survival (OS). CWFS was defined as the time from COVID-19 diagnosis to clinical worsening (oxygen needs $\geq 6\text{L}/\text{min}$ or admission to intensive care unit) or death. OS was defined as the time from COVID-19 diagnosis to death from any cause.