



Infectious medicine, virology

# COVID-19 in persons with haematological cancers

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## Abstract

Infection with SARS-CoV-2, the cause of coronavirus infectious disease–19 (COVID-19), has caused a pandemic with >850,000 cases worldwide and increasing. Several studies report outcomes of COVID-19 in predominately well persons. There are also some data on COVID-19 in persons with predominately solid cancer but controversy whether these persons have the same outcomes. We conducted a cohort study at two centres in Wuhan, China, of 128 hospitalised subjects with haematological cancers, 13 (10%) of whom developed COVID-19. We also studied 226 health care providers, 16 of whom developed COVID-19 and 11 of whom were hospitalised. Co-variables were compared with the 115 subjects with haematological cancers without COVID-19 and with 11 hospitalised health care providers with COVID-19. There were no significant differences in baseline co-variables between subjects with haematological cancers developing or not developing COVID-19. Case rates for COVID-19 in hospitalised subjects with haematological cancers was 10% (95% Confidence Interval [CI], 6, 17%) compared with 7% (4, 12%;  $P = 0.322$ ) in health care providers. However, the 13 subjects with haematological cancers had more severe COVID-19 and more deaths compared with hospitalised health care providers with COVID-19. Case fatality rates were 62% (32, 85%) and 0 (0, 32%;  $P = 0.002$ ). Hospitalised persons with haematological cancers have a similar case rate of COVID-19 compared with normal health care providers but have more severe disease and a higher case fatality rate. Because we were unable to identify specific risk factors for COVID-19 in hospitalised persons with haematological cancers, we suggest increased surveillance and possible protective isolation.

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## Introduction

There have been several epidemic and clinical studies of community-acquired SARS-CoV-2-infection and coronavirus infectious disease–19 (COVID-19) [1–13]. There are also several studies of COVID-19 in persons with solid cancers, including those who are hospitalised for reasons other than COVID-19; whether these persons have a higher risk of developing COVID-19 after SARS-CoV-2-infection

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is controversial as is whether they have a worse prognosis [14–18].

There are few data on risk of developing COVID-19 in hospitalised persons with haematological cancers. Many, if not most persons with haematological cancers receive anti-cancer drugs with suppress bone marrow function or have cancers of the immune system and are at substantial risk of community- and hospital-acquired infections [19–21].

We analysed data of 128 hospitalised subjects with haematological cancers in Wuhan, China, 13 of whom developed COVID-19. Data were compared with 115 hospitalised subjects with haematological cancers without COVID-19 and with 11 health care providers with COVID-19. We show hospitalised subjects with haematological cancers who develop COVID-19 have more severe disease, and a substantially higher risk of death compared with health care providers with COVID-19. Hospitalised persons with haematological cancers at great risk to develop COVID-19 cannot be accurately prospectively identified. As such, these persons should receive heighten surveillance and protective isolation should be considered.

## Methods

### Study design

Beginning 23 January 2020, when Wuhan was locked down at the onset of the outbreak, people without COVID-19 were not admitted to our hospitals to avoid person-to-person transmission. We analysed data as of 14 February 2020. Centres included all hospitalised persons at two main haematology centres in Wuhan (Union Hospital and Wuhan Central Hospital, Tongji Medical College, Huazhong University of Science and Technology). Haematological cancers were classified according to the 2016 WHO classification.

In Wuhan, quantitative real-time polymerase chain reaction (qRT-PCR) testing for the diagnosis of SARS-CoV-2-infection was not available at our hospitals before 27 January 27 2020 and not used for routine screening before mid-February. Consequently, diagnosis of COVID-19 was based initially on lung computed tomography (CT) scans. [12, 22]. All hospitalised persons with haematological cancers and health care providers regardless of whether the symptoms consistent with COVID-19 had a screening lung CT scan. If the screening lung CT was normal it was repeated when/if the person developed signs or symptoms consistent with COVID-19. All cases of COVID-19 by lung CT had a diagnostic assay for SARS-CoV-2-infection by qRT-PCR of nasal and oropharyngeal swab specimens (Shanghai Bio-Germ Medical Technology Co Ltd) according to the WHO interim guidance [23] and the Novel

Coronavirus Pneumonia Diagnosis and Treatment Program of the National Health Commission of China [22].

Onset time of COVID-19 in persons with haematological cancers was based on comprehensive analyses of signs and symptoms and/or a lung CT scan. Severity of COVID-19 was graded as follows [22]: (1) mild: mild clinical symptoms, no pneumonia on lung CT; (2) common: fever, cough and lung CT with pneumonia; (3) severe: respiratory distress (respiratory rate  $> 30 \text{ min}^{-1}$ , oxygen saturation ( $\text{O}_{2\text{Sat}}$ )  $\leq 93\%$  at rest and/or ratio of arterial oxygen partial pressure to fractional inspired oxygen  $\leq 300 \text{ mmHg}$  ( $\text{P}_{\text{aO}_2}/\text{F}_{\text{IO}_2}$ ); and (4) critical: aforementioned criteria of respiratory failure receiving mechanical ventilation, shock and/or organ failure other than lung and/or intensive care unit (ICU) hospitalisation. All the hospitalised subjects were transferred to isolation wards in the department of infectious disease when they were diagnosed with COVID-19. Hospitalised health care providers were used as a comparator cohort. The study was approved by the Ethics Committees of Wuhan Central Hospital (2020-007) and of Union Hospital (2020-0095). Written informed consent from subjects was waived by the Ethics Committees.

### Data collection

Epidemiological, clinical and laboratory data, radiology reports, therapy details and outcomes on patients were obtained by accessing standardised forms from electronic medical records. Data on non-hospitalised health care providers was obtained using standardised forms. Data collection forms were reviewed independently by two researchers; a third researcher adjudicated discordances.

### Outcomes

Outcomes were defined as follows: (1) death; (2) cure: two successive negative qRT-PCR tests  $> 24 \text{ h}$  apart and asymptomatic; (3) improved: improvement in signs and symptoms and laboratory parameters and no progression on lung CT; (4) progressing: increase in symptoms and/or progression of lung CT findings and (5) stable: improved nor progressing.

### Statistical analysis

Continuous variables were expressed as mean (SD) for normally distributed data or as the median (IQR) for abnormally distributed data. Categorical variables were frequency rates and percentages. Means were compared using independent group *t*-test and Mann–Whitney test for normally and abnormally distributed data. Proportions for categorical variables were compared by  $\chi^2$  tests. R version 3.5.2 was used for statistical analyses. For unadjusted

comparisons, a two-sided alpha of  $<0.05$  was considered significant. Analyses were not adjusted for multiple comparisons. Consequently, findings should be interpreted as exploratory and descriptive.

## Results

### Baseline characteristics of subjects with haematological cancer and COVID-19

We enrolled 224 health care providers and 128 hospitalised subjects with haematological cancers (Supplementary Tables 1 and 2). Most hospitalised subjects had acute myeloid leukaemia (AML;  $N=50$ ), acute lymphoblastic leukaemia (ALL;  $N=26$ ), non-Hodgkin lymphoma (NHL;  $N=18$ ), plasma cell myeloma (PCM;  $N=19$ ) or myelodysplastic syndrome (MDS;  $N=8$ ).

Thirteen of the one hundred and twenty-eight hospitalised subjects with a haematological cancer (10%; 95% Confidence Interval (CI), 6, 17%) developed COVID-19 including four with AML, five with ALL, three with PCM and one with MDS (Table 1). There was no case of COVID-19 amongst 18 subjects with NHL. There was no correlation between type of haematological cancer and likelihood of developing COVID-19 when analysed by leukaemia versus lymphoma or myeloid versus lymphoid cancer. Seven subjects in the COVID-19 cohort were male versus 65 in the non-COVID-19 cohort ( $P>0.99$ ). Median age of subjects with and without COVID-19 was 35 year (range, 23–53 years) and 49 year (range, 33–59 years;  $P=0.082$ ). Cardio- and cerebrovascular diseases were the most common comorbidities with similar prevalence (24%). Overall, 122 of the 128 subjects with haematological cancers (95%) received prior anti-cancer treatment including chemotherapy ( $N=76$ ), molecular targeted therapy ( $N=9$ ), immune therapy ( $N=23$ ) or a proteasome inhibitor ( $N=9$ ) before ( $N=75$ ) or after ( $N=110$ ) hospitalisation. Median interval from the end of the last cycle of anti-cancer therapy to diagnosis of COVID-19 was 9 days (range, 7–19 days) in the six subjects who had previously received drugs damaging the bone marrow. Thirty-two (25%) received  $\geq 4$  cycles of anti-cancer therapy previously. There was no difference in numbers of prior anti-cancer cycles ( $P=0.783$ ) or disease state (remission or not) of haematological cancers ( $P=0.670$ ) between the COVID-19 and non-COVID-19 haematological cancer cohorts. Ten of thirteen subjects with COVID-19 and one hundred of one hundred and fifteen (87%) subjects without COVID-19 received anti-cancer treatment after admission and before the symptom onset of COVID-19.

Overall, 16 of 224 health care providers (7.1% [4, 12%]) developed COVID-19. This case rate is like the case rate in

hospitalised subjects with haematological cancers ( $P=0.322$ ). Three of the thirteen hospitalised haematological cancer subjects (subjects 6, 13 and 14) were initially diagnosed by a screening lung CT and 10 (subjects 1, 2, 4, 5 and 7–12) by a lung CT done after developing symptoms. One of sixteen health care providers (patient 16) was diagnosed by a screening lung CT and the remainder (subjects 17–31) by a lung CT done after developing symptoms. The distribution for the 11 hospitalised health care providers was 1 (subject 16) diagnosed by a screening lung CT and 10 (subjects 21–25 and 27–31) by a lung CT after symptoms.

### Clinical co-variates and outcomes of subjects with haematological cancer and COVID-19

The 11 hospitalised health care providers were used as a comparator cohort. Nine were female. Median age was 32 years (range, 29–36 years). Nine were nurses, one, a physician and one, a health care attendant. (Supplementary Tables 1, 3 and 6). The 13 hospitalised subjects with haematological cancer and COVID-19 and the 11 hospitalised health care providers with COVID-19 had similar sex and age distributions (Table 2). Twelve haematological cancer subjects became febrile compared with four health care providers ( $P=0.008$ ), cough, twelve compared with four ( $P=0.008$ ) and dyspnoea, ten compared with three ( $P=0.043$ ). Lung CT scans of subjects with COVID-19 showed typical changes including patchy shadows, ground-glass opacity, air space consolidation or complete opacity (whiteout) [16] but were similar between the cohorts (Fig. 1). At the start of the disease, subjects with haematological cancer and COVID-19 had significantly higher levels of C-reactive protein (CRP) and procalcitonin, lower haemoglobin, lymphocyte and platelet concentrations but similar levels of lactate dehydrogenase (LDH), aspartate aminotransferase (AST), alanine aminotransferase, bilirubin, creatinine and blood urea nitrogen, compared with the cohort without haematological cancer. Some or all of these differences may be related to therapy of the haematological cancers rather than COVID-19.

After symptom onset of COVID-19 subjects with haematological cancer had significantly decreased haemoglobin, lymphocyte, lymphocyte subset, platelet and concentrations and higher concentrations of D-dimer ( $P=0.001$ ), AST, LDH, CRP, procalcitonin and ferritin compared with health care providers with COVID-19 but not different concentrations of cytokines including interleukins-6, -2, -4 and -10, tumour necrosis factor-alpha and interferon-gamma (Supplementary Table 4). Subjects with haematological cancer and COVID-19 had more co-infections including bacteria ( $N=11$ ), fungi ( $N=9$ ) and other viruses ( $N=7$ ). Only three health care providers with COVID-19 had a bacterial co-infection. Subjects with haematological cancer and COVID-19 had more complications including six with

**Table 1** Baseline co-variates of subjects with haematological cancer and COVID-19.

	Total, <i>n</i> = 128	COVID-19 <sup>a</sup> , <i>N</i> = 13	Non-COVID-19 <sup>a</sup> , <i>N</i> = 115	<i>P</i> value
Age, median (IQR), years	49 (31, 59)	35 (23, 53)	49 (33, 59)	0.082
Male sex	72 (56%)	7	65 (57%)	>0.999
Co-morbidities				
ASCVD	31 (24%)	3 (23)	28 (24%)	>0.999
Diabetes	8	0	8	0.706
Digestive system disease	7	0	7	0.830
Hepatitis B	7	0	7	0.830
Other cancer	2	0	2	>0.999
Exposure				
Huanan Seafood Wholesale Market exposure	1	0	1	<0.001
Contact with suspected persons	0	0	0	
Contact with clinically diagnosed persons	2	2	0	
Contact with confirmed persons	1	1	0	
Cancer				
Acute myeloid leukaemia	50 (39%)	4	46 (40%)	0.729
Acute lymphoblastic leukaemia	26 (20%)	5	21 (18%)	0.176
Plasma cell myeloma	19 (15%)	3	16 (14%)	0.639
Myelodysplastic syndromes	8	1	7	>0.999
Non-Hodgkin lymphoma	18 (14%)	0	18 (16%)	0.264
Therapy				
Chemotherapy	76 (59%)	6	70 (61%)	0.468
Allotransplant	10	3	7	0.106
Targeted drug	9	1	8	>0.999
Immune suppression	23 (18%)	2	21 (18%)	>0.999
Proteasome inhibitor	9	2	7	0.502
Prior anti-cancer therapy (cycles)				
0	50 (39%)	7	43 (38%)	
1	19 (15%)	1	18 (16%)	0.783
2	7	1	6	
3	17 (13%)	1	16 (14%)	
≥4	32 (25%)	3	29 (25%)	
Anti-cancer treatment after admission	110 (86%)	10	100 (87%)	0.572
Disease state				
Newly diagnosed	14	1	13	0.668
Unevaluated	28 (22%)	3	25 (22%)	
CR	35 (27%)	3	32 (28%)	
Non-CR	32 (25%)	3	29 (25%)	
Progression	7	0	7	
Relapse	12	3	9	

Data are *N* (%) unless specified otherwise.

ASCVD cardio- and cerebro-vascular disease, CR complete remission.

<sup>a</sup>Haematological cancer subjects with and without COVID-19 (COVID-19/non-COVID-19).

**Table 2** Clinical and laboratory co-variates, therapy and outcomes of subjects with haematological cancer and COVID-19.

	Haematological cancer, <i>N</i> = 13	Health care providers <sup>a</sup> , <i>N</i> = 11	<i>P</i> value
Age, median (IQR), years	35 (23, 53)	32 (28, 36)	0.794
Male sex			0.227
Male	7	2	
Signs and symptoms at onset			
Fever	12	4	0.008
Cough	12	4	0.008
Dyspnoea	10	3	0.043
Muscle ache	1	0	>0.999
Headache	1	0	>0.999
Diarrhoea	3	2	>0.999
Fever, cough and shortness of breath	8	3	0.205
Lung CT scan ( <i>N</i> = 11) <sup>b</sup>			
Patchy shadows	2	2	>0.999
Ground-glass opacity	8	9	
Air space consolidation/complete opacity	1	0	
Laboratory findings (normal range), median (IQR) <sup>c</sup>			
WBC × 10E + 9/L (3.5–9.5)	3.9 (1.0, 9.4)	6.1 (5.3,.6)	0.470
Neutrophils, ×10E + 9/L (1.8–6.3)	1.9 (0.4, 7.3)	4.1 (2.9,.5)	0.337
Lymphocytes × 10E + 9/L (1.1–3.2)	0.5 (0.3, 0.9)	1.5 (1.2,.1))	0.012
Platelets, ×10E + 9/L (125–350)	67 (24, 80)	247 (210, 274)	<0.001
Haemoglobin, g/L (male, 130–175; female, 115–150)	69 (62, 89)	132 (125,134)	<0.001
Prothrombin time, s (11–16)	16 (14, 17)	13 (12, 13)	0.105
Activated partial thromboplastin time, s (28.0–43.5)	41.8 (34.2, 47.4)	28.8 (26.9, 30.6)	0.0148
D-dimer, mg/L (<0.5)	0.8 (0.6, 1.3)	0.5 (0.4, 0.7)	0.476
Alanine aminotransferase, U/L (9–52)	17 (12, 27)	21 (17, 26)	0.799
Aspartate aminotransferase, U/L (14–36)	23 (21, 32)	20 (19, 21)	0.496
Total bilirubin, μmol/L (3–22)	11.1 (7.2,16.1)	9.4 (9.4, 9.4)	0.444
Blood urea nitrogen, mmol/L (2.5–6.1)	4.7 (3.0, 6.5)	3.5 (3.3, 3.6)	0.476
Serum creatinine, μmol/L (46.0–92.0)	47.4 (42.5, 69.8)	58.1 (54.7, 61.6)	0.800
Lactate dehydrogenase, U/L (114–240)	246 (182, 313)	168 161, 175.5)	0.264
Procalcitonin, ng/mL (<0.5)	1.5 (0.4, 3.7)	0.04 (0.03, 0.04)	0.022
C-reactive protein, mg/L (<8.00)	68 (37, 126.0)	3.6 (2.5, 4.6)	0.001
Staging			
Mild	0	3	0.001
Common	4	8	
Severe	4	0	
Critical	5	0	
Co-infection			
Other viruses	7	0	0.006
Bacteria	11	3	0.011
Fungus	9	0	<0.001
Complications			
ARDS	6	0	0.016
Acute renal failure	1	0	>0.999
Sepsis	2	0	0.482

**Table 2** (continued)

	Haematological cancer, <i>N</i> = 13	Health care providers <sup>a</sup> , <i>N</i> = 11	<i>P</i> value
Treatment			
Umifenovir	8	7	>0.999
Interferon	6	10	0.458
Antibiotics	13	2	0.037
Corticosteroids	4	2	0.649
Oxygen	10	3	0.043
Non-invasive ventilation	2	0	0.482
Mechanical ventilation	1	0	>0.999
Outcomes <sup>d</sup>			
Cured	5	8	0.001
Improved	0	3	
Stable	0	0	
Progressing	0	0	
Dead	8	0	

Data are *N* (%) unless specified.

<sup>a</sup>Health care providers with COVID-19.

<sup>b</sup>Lung CT scan data of subjects 1 and 5 were unavailable.

<sup>c</sup>Subjects with haematological cancers and abnormal laboratory parameters were censored if seemed likely the abnormality was caused by anti-cancer therapies.

<sup>d</sup>Follow-up date was 29 February, 2020.

acute respiratory distress syndrome (ARDS), one with acute renal dysfunction and two with sepsis. No health care provider had these complications.

Persons with COVID-19 infection were treated as described [13, 24]. There were no differences between the cohorts in use of anti-virus therapy, including umifenovir and interferon, antibiotics or corticosteroids (Table 2). Subjects with haematological cancer and COVID-19 received supplemental oxygen (*N* = 10), non-invasive ventilation support (*N* = 2) and invasive ventilation (*N* = 1) compared with three controls who received supplemental oxygen.

To analyse the effect of haematological disorders on the severity and outcomes of COVID-19, we analysed data from 29 subjects with COVID-19 including the 13 subjects with haematological cancer and 11 hospitalised health care providers (Supplementary Tables 5 and 6). Four cases were mild, sixteen, common, four, severe, and five, critical (Supplementary Table 3). All nine severe or critical severity cases were subjects with haematological cancer (*P* = 0.001).

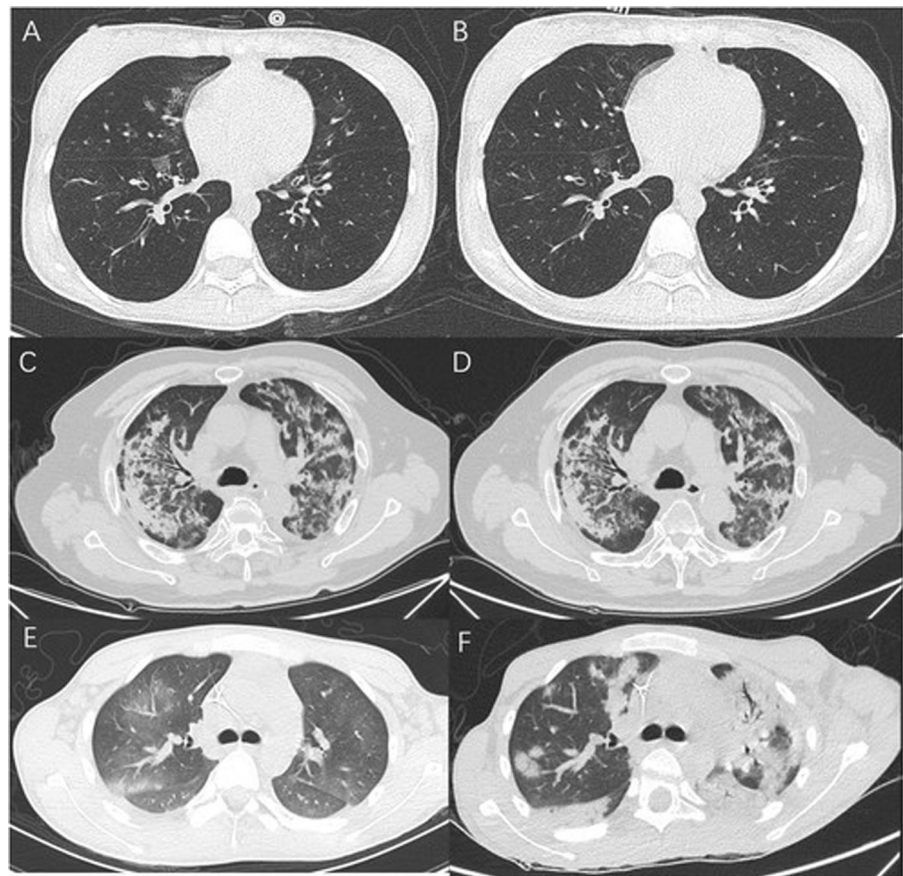
Eight subjects with haematological cancers and COVID-19 died compared with no controls (*P* = 0.001). Median survival of the eight subjects with haematological cancer and COVID-19 from symptom onset to death was 11 days (range, 6–29 days). Deaths were from ARDS (*N* = 6), septic shock (*N* = 1) and multiple organ failure (*N* = 1; Table 2; Supplementary Table 5). Subjects with haematological cancer and COVID-19 had a greater incidence of ARDS compared with non-COVID-19 controls (6/13 versus 0/11,

*P* = 0.016) (Table 2; Supplementary Tables 5 and 6). And a higher incidence of ARDS was detected in non-survivors than survivors with haematological cancers (6/8 versus 0/5: *P* = 0.039). Amongst subjects with haematological cancer and COVID-19 non-survivors had significantly higher (*P* = 0.03) onset baseline D-dimer levels than survivors (Table 3 and Supplementary Table 7).

### Presumed cluster transmission related to intensive care unit (ICU)

Amongst the 29 subjects with COVID-19, one had exposure to the Huanan Seafood Wholesale Market (the suspected origin site for SARS-CoV-2), seven had contact with clinically diagnosed persons with COVID-19 and one had contact with qRT-PCR-test confirmed person without COVID-19. The other 20 denied exposure to potential SARS-CoV-2 vectors. Sixteen subjects with COVID-19 were in ICUs before the COVID-19 pandemic began including eight subjects with haematological cancers and eight health care providers in the ICU as part of their work. These data compare with only 5 of 112 non-ICU subjects with haematological cancers (*P* < 0.001) and with only 13 of 289 non-ICU subjects (hospitalised subjects with haematological cancers and health care providers; *P* < 0.001). These data suggest more than one-half of COVID-19 cases we studied were ICU exposure related. In the case map an ICU nurse (patient 22) had the earliest onset time

**Fig. 1 Representative lung CT scans (transverse plane) of three subjects with COVID-19.** **a** Ground-glass opacity in both lungs; **b** absorption of bi-lateral ground-glass opacity after treatment (patient 2); **c** Multiple condensation shadows in both lungs, edges were blurred; **d** no significant changes on image findings after treatment (patient 8); **e** multiple ground-glass opacity in both lungs and patchy consolidation in the right lung; and **f** diffuse condensation shadows with blurred edges; bronchiolar-inflation sign is seen in the left lung tissue area of the lesion after treatment (patient 4).



(Supplementary Fig. 1). There were correlations between and amongst more than one-half of the COVID-19 subjects we studied. We detected no more cases of COVID-19 amongst persons with a haematological cancer after the last cases with symptom onset of COVID-19 on January 31 (patient 2) and February 12 (patients 13 and 14), in Union Hospital and Wuhan Central Hospital. These data are consistent with a cluster of transmission related to ICU exposure in Union Hospital (Supplementary Tables 1–3 and Fig. 1).

## Discussion

We found a 10% case rate of COVID-19 amongst 128 hospitalised persons with haematological cancer in Wuhan, much higher than reported for hospitalised persons with other cancers at another Wuhan hospital with an estimated <1% incidence [15] but similar to the case rate of health care providers. No pre-COVID-19 co-variate could accurately predict which persons with haematological cancers were at greatest risk to develop COVID-19. We also found hospitalised subjects with haematological cancers and with COVID-19 had more severe disease and a higher case fatality rate compared with hospitalised health care

providers with COVID-19. Most of our data suggest this is attributable to their haematological cancer and/or therapy thereof. One might expect persons with immune system cancers such as lymphomas and lymphoid leukaemias might be at increased risk to develop COVID-19 compared with myeloid cancer such as AML and MDS but we found no such association. The increased case fatality rate of hospitalised subjects with haematological cancers and COVID-19 seems related predominately to bacterial co-infections. This is consistent with a higher probability of decreased granulocyte concentrations because of their disease or therapy thereof.

Our study has important limitations including heterogeneous subject haematological diagnoses and disease states, confounding co-variables such as therapy of haematological cancers and interval to developing COVID-19. Our diagnosis of COVID-19 was based initially on results of a screening lung CT scan but most cases were confirmed by qRT-PCR. We did not analyse infection rates with SARS-CoV-2 because tests were unavailable so are conclusions are based solely on lung CT scan findings and symptom reporting which is unreliable in subjects with haematological cancers who may have other reasons for developing fever, cough etc., especially those receiving anti-cancer therapy. Also, our start time for COVID-19 was abnormal lung CT scan or onset of symptoms

**Table 3** Clinical and laboratory co-variables and therapy of subjects with haematological cancer and COVID-19.

	Survivors <i>N</i> = 5	Non-survivors <i>N</i> = 8	<i>P</i> value
Age, median (IQR), years	35 (26, 37)	39 (22, 54)	0.665
Male sex	2	5	0.826
Diagnosis			
Laboratory confirmed	5	8	>0.999
Clinically diagnosed	0	0	
Staging			
Mild	0	0	0.194
Common	3	1	
Severe	1	3	
Critical	1	4	
Lung CT scan			
Patchy shadows	1	1	0.487
Ground-glass opacity	2	6	
Air space consolidation/whiteout	1	0	
NA <sup>a</sup>	1	1	
Laboratory findings (normal range)			
WBC, median (IQR), ×10E + 9/L (3.5–9.5)	3.9 (2.6, 7.8)	2.6 (0.5, 11.6)	0.833
Neutrophils, median (IQR), ×10E + 9/L (1.8–6.3)	2.7 (1.1, 6.8)	0.7 (0.2, 6.5)	0.626
Lymphocytes, median (IQR), ×10E + 9/L (1.1–3.2)	0.7 (0.5, 0.9)	0.5 (0.2, 0.7)	0.329
Platelets, mean (SD), ×10E + 9/L (125–350)	107.2 ± 86.0	54.1 ± 45.1	0.168
Haemoglobin, mean (SD), g/L (male, 130–175; female, 115–150)	81.0 ± 19.3	71.9 ± 20.6	0.444
Prothrombin time, median (IQR), s (11.0–16.0)	16.2 (15.6, 16.5)	16.4 (13.7, 16.9)	>0.999
Activated partial thromboplastin time, mean (SD), s (28.0–43.5)	44.7 ± 10.9	37.5 ± 16.3	0.408
D-dimer, median (IQR), mg/L (<0.5)	0.6 (0.6, 0.6)	1.3 (0.8, 2.4)	0.030
Alanine aminotransferase, mean (SD), U/L (9–52)	18.7 ± 10.3	18.9 ± 10.6	0.0975
Aspartate aminotransferase, mean (SD), U/L (14–36)	26 ± 10	24 ± 14	0.766
Total bilirubin, median (IQR), μmol/L (3–22)	11.1 (9.6, 12.9)	11.7 (6.0, 17.2)	0.943
Blood urea nitrogen, mean (SD), mmol/L (2.5–6.1)	4.7 ± 2.2	5.5 ± 3.2	0.651
Serum creatinine, median (IQR), μmol/L (46–92)	44 (41, 70)	56 (43, 68)	0.622
Lactate dehydrogenase, median (IQR), U/L, (114–240)	275 (261, 296)	184.0 (155, 413)	0.268
Procalcitonin, mean (SD), ng/mL (<0.5)	1.2 ± 1.2	4.0 ± 4.2	0.234
C-reactive protein, median (IQR), mg/L (<8.00)	121 (37, 144)	68 (64, 115)	>0.999
Co-infections			
Other viruses	3	4	>0.999
Bacteria	3	8	0.248
Fungi	3	6	>0.999
Complications			
ARDS	0	6	0.039
Acute renal failure	0	1	>0.999
Sepsis	1	1	>0.999
Treatment			
Umifenovir	3	5	>0.999
Interferon	2	4	>0.999
Antibiotics	3	6	>0.999
Corticosteroids	1	3	0.962
Oxygen inhalation	3	7	0.420
Non-invasive ventilation	0	2	0.671
Mechanical ventilation	0	1	>0.999

<sup>a</sup>Lung CT scan data of subjects 1 and 5 were unavailable.

surveillance of which is subject to selection and recall biases. Our control cohort was health care providers rather than hospitalised persons with cancer other than haematological cancers and receiving comparably bone marrow suppressive

anti-cancer therapy. Also, our data are consistent with cluster transmission related to ICU exposure.

Because we could not accurately predict which hospitalised persons with haematological cancer were at increased



risk to develop COVID-19, we recommend special attention to SARS-CoV-2-infection and subsequent COVID-19 in hospitalised persons with haematological cancers, especially those receiving bone marrow suppressing drugs and those with advanced cancers. Protective isolation should be considered, especially in persons hospitalised in the ICU.

### Data availability

All data generated or analysed during this study are included in this published article and its Supplementary Information files.

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**Author contributions** QL, ZC and HW designed the study. QL, WH, LeC, LC, GY, YF, WC, DW, BL, XL, YM and LL collected the data. All authors had full access to the data, and were involved in data interpretation and vouch for the accuracy of the analyses. QL, WH, LeC and RPG prepared the typescript which all authors approved final approval and supported the decision to submit for publication.

### Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

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