Diagnostic reliability of chest CT qualitative and quantitative assessment to predict survival and morbidity in oncology patients with COVID-19 infection

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Abstract

Background To estimate the diagnostic utility of chest CT qualitative assessment and chest CT total severity score (TSS) to predict mortality in oncology patients with COVID-19 infection.

Methods This retrospective study included 151 oncology patients with COVID-19 infection. 67, 84 were male and female, respectively. Their mean age (years) ± SD was 49.7 ± 14.9. Two radiologists individually reviewed the chest CT and scored the pulmonary abnormalities using TSS. Inter-observer agreement was determined using the Bland–Altman plot. Correlation between TSS and COVID-19 severity, complication, mortality, cancer status and effect in anti-cancer therapy plan was done.

Results There was a statistically significant excellent agreement between the independent observers in quantitative pulmonary assessment using TSS with interclass correlation (ICC) > 0.9 ($P < 0.001$). ROC curve analysis revealed that TSS was statistically significantly higher in non-survivors using an optimum cut-off value of 5 to predict in-hospital mortality. Univariate analysis showed that age, pulmonary predominant pattern, pleural effusion, tree-in-bud, ECOG PS, tumour stage 4 and post-COVID cancer status were a statistically significant predictor of mortality. Multivariate analysis reported that consolidation versus ground-glass opacity (GGO), crazy paving pattern versus GGO and progressive versus remittent cancer diseases were statistically significant independent predictors of mortality among those patients.

Conclusions TSS demonstrated excellent inter-observer agreement to assess COVID-19 in oncology patients with low cut-off value to predict in-hospital mortality, thus raising the attention to rapid proper care in this setting. There was a statistically significant positive correlation between TSS and delayed chemotherapeutic schedule.

Keywords COVID-19, Chest CT, Oncology patients, Cancer status

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Key points

- TSS revealed an excellent inter-observer agreement to assess in-hospital mortality in oncology patients with COVID-19 infection.
- TSS revealed a lower cut-off to predict in-hospital mortality in oncology patients compared to the general population. There was a statistically significant

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positive correlation between TSS and delay time to resume chemotherapy as well as post-COVID-19 cancer status.

- Predominant pulmonary pattern of consolidation or crazy paving pattern versus GGO and progressive diseases versus remittent diseases were statistically significant independent predictors of mortality among oncology patients with COVID-19 infection.

Background

Coronavirus disease 2019 (COVID-19) first appeared in Wuhan, China, in December 2019, then rapidly spread causing an outbreak [1]. The immunocompromised status of oncology patients (due to the disease itself or the treatment) raises their risk of infection [2]. Oncology patients deteriorate more rapidly with higher mortality than the general population with COVID-19 infection [3]. COVID-19 infection must be excluded preceding admission of oncology patients for anticancer therapies, also postponing those therapies should be considered according to patient performance status [4].

Clinical presentation of COVID-19 ranges from mild symptoms to severe disease such as acute respiratory distress syndrome necessitating mechanical ventilation and multi-organ failure [5]. Oncology patients had a higher mortality rate and intensive care unit (ICU) admissions as compared to non-cancer patients; therefore, early detection of COVID-19 can improve their management [6]. Also, oncology patients may experience long-term COVID-19 sequelae [7].

The reverse transcription–polymerase chain reaction assay (RT-PCR) assesses viral load and is considered the standard diagnostic means of COVID-19 infection [8]. Chest CT is a critical component in the diagnostic algorithm for patients with suspected COVID-19 infection [9]. Even few studies considered that chest CT is a more rapid, sensitive and effective tool than RT-PCR [10, 11]. The National Health Commission of the People's Republic of China has promoted diagnosis based on clinical and chest CT findings alone due to the shortage of PCR kits in extreme situations and the possibility of false negative RT-PCR results [12]. Previous studies reported low sensitivity of RT-PCR in the early presentation, while chest CT has established a higher sensitivity in detecting COVID-19 (37–71% and 56–98%, respectively) [13].

The CT findings of COVID-19 infection most frequently comprise multiple peripheral, ground-glass opacities (GGO) which may be accompanied by consolidation [14], also comprising a crazy paving pattern, and bronchial wall thickening [15]. CT is also particularly critical in oncology patients for the differential diagnosis of drug-induced pneumonitis and cancer progression [16].

Variable chest CT grading systems have been suggested to evaluate the severity of pulmonary involvement in COVID-19 infection [9, 17, 18]. A recent comparative study investigated the diagnostic performance of different CT scoring systems and concluded that the CT total severity score (TSS) had the highest specificity and the least time consumption [19]. Also, a recent study focused on selected high-risk groups with renal impairment considered high TSS as a substantial predictor of mortality [20].

To the best of our knowledge, the studies on quantitative chest CT evaluation of COVID-19 infection in oncology patients are limited, till now no available studies discussed the performance of TSS.

Therefore, we aimed to investigate the diagnostic utility and inter-reader agreement of the TSS for predicting the survival, morbidity and effect on treatment plans among oncology patients after COVID-19 infection.

Methods

Study population

This is a retrospective single-centre study conducted on oncology patients with COVID-19 infection who underwent chest CT from June 2020 to May 2022. The study was approved by the Institutional Review Board of our university (Approval No: R.22.06.1738) and a waiver of the consent of medical record review was received. One hundred seventy patients were initially enrolled in this study. Then, 19 patients were excluded: two patients with negative findings at chest CT, eight patients with unavailable CT images upon admission and nine patients with incomplete clinical data. Lastly, 151 consecutive patients were included, the flowchart is demonstrated in Additional file 1: Fig. S1. 67, 84 were male and female, respectively. Their mean age (years) ± SD was 49.7 ± 14.9 ranging from 19 to 82 years.

Clinical data

Clinical data involved the duration of symptoms of COVID-19 infection, type of malignancy and its stage, type of anticancer therapy, Eastern Cooperative Oncology Group (ECOG) performance status, duration between the last chemotherapy and COVID-19 diagnosis and duration to resume chemotherapy. Laboratory data mainly included PCR results, arterial blood gases, serum creatinine and liver function tests. The need for oxygen supply, steroids, mechanical ventilation and ICU admission was reported.

Chest CT acquisition

All patients underwent chest CT imaging on a 16-detector CT scanner (Bright speed; GE Healthcare). Images were attained during a single inspiratory breath-hold.

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CT scan parameters were as follows: X-ray tube parameters, 120 KVp, 350mAs; rotation time, 0.5 s; pitch, 1.0; section thickness, 5 mm; intersection space, 5 mm; additional reconstruction with a slice thickness of 1.5 mm. Scans were reviewed at a window width and level of 1000 to 2000 HU and −700 to −500 HU, respectively, to assess the lung parenchyma.

Qualitative CT image analysis

All chest CT images obtained at the time of hospital admission were analysed. The main findings were described as the following: GGO, consolidation and crazy paving pattern based on the standard lexicon for thoracic imaging reported by the Fleischner Society and similar previous studies [21]. The predominant pattern, presence of pleural effusion, pulmonary nodules, tree-in-bud pattern, bronchial dilatation and mediastinal lymphadenopathy were reported.

Quantitative CT image analysis

The severity of pulmonary parenchymal involvement was quantified by the TSS. TSS is a quantitative score considering the pulmonary abnormalities in each of the five lobes of both lungs, involving the existence of GGOs, consolidation or mixed GGO [22]. All CT images were independently analysed by two radiologists (13 and 10 years of experience in the interpretation of chest CT scans). Both radiologists were blinded to clinical data. According to the extent of pulmonary involvement, each lobe could be scored from 0 to 4 points as the following: 0, no involvement; 1, from 1 to 25% involvement;2, from 26 to 50% involvement; 3, from 51 to75% involvement; and 4, more than 75% involvement. The sum of each lobar score resulted in the TSS which ranged from 0 to 20.

Statistical analysis

Data were entered and analysed using IBM SPSS Statistics for Windows (version 26). IBM Corp. Released 2019., Armonk, NY. Qualitative data were expressed as frequency (N) and percentage (%). The intraclass correlation coefficient (ICC) was used to determine inter-observer reliability (both consistency and absolute agreement). The Bland–Altman plot was used to compare TSS measurements by plotting the differences against the averages of the two observers. Spearman's correlation was used to assess the relationship between TSS score and cancer status. The Kruskal–Wallis test was performed to compare TSS with a predominant pulmonary pattern. ROC curves were used to determine the best threshold or "cutoff" value for distinguishing between two categories. The Kaplan–Meier method was used to estimate the probability of survival. The survival distributions of two or more groups of a between-subjects factor were compared for equality using the log-rank test. Cox regression was used to investigate the effect of several variables on survival. For any of the used tests, results were considered statistically significant if p value ≤ 0.050.

Results

Patients' characteristics

A total of 151 oncology patients with PCR-confirmed COVID-19 infection were included. The mortality rate was higher in patients older than 50 years. According to in-hospital mortality, 151 patients were classified into the non-survivor group ($n=77$) and the survivor group ($n=74$). The patients' characteristics and risk factors for in-hospital mortality are illustrated in Table 1. Only 24 patients developed post-COVID-19 complications, including acute liver insult, acute renal failure, neurological complication (encephalopathy and coma), persistent thrombocytopenia and pulmonary complication (fungal infection and lung fibrosis). Regarding ECOG Performance status, pairwise comparisons showed a statistically significant difference between score 3 versus score 1 ($\chi^2 = 10.561$, $p = 0.001$), and score 2 versus score 1 ($\chi^2 = 10.635$, $p = 0.001$), but not between score 2 versus score 3. There was a statistically significant higher mortality in patients who required steroid use, mechanical ventilation and ICU admission. The median survival time (95% CI) was 60 (18–120) days (Additional file 1: Fig. S2).

Anticancer therapy

The most common malignancies were leukaemia 51 (33.7%) and breast cancer 31 (20.5%). The median duration between the last chemotherapy cycle and COVID-19 diagnosis was 10 days with the higher mortality rate in patients who received chemotherapy within 10 days before COVID-19 infection. There were no statistically significant differences in mortality regarding tumour type, anticancer therapy type, duration between last chemotherapy and COVID diagnosis if a patient was on active chemotherapy or not at the time of infection and post-COVID complication.

Cancer status and oncologic outcomes

Out of 85 patients who received chemotherapy before COVID-19 infection, 39 resumed chemotherapy after the resolution of COVID-19, while the other 46 patients died early. Other 18 newly diagnosed cancer patients started chemotherapy after the resolution of COVID-19. Post-COVID cancer status was accurately assessed in 130 patients, while 21 patients experienced rapid in-hospital mortality limiting their status assessment. Sixty-eight patients had tumour progression post-COVID-19 infection, 46 patients had tumour regression, and 16 patients

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Table 1 Patients' characteristics and risk factors for In-hospital mortality

Risk factor	N	Mortality N (%)	Median (95% CI)	Logrank test	
				χ^2	P value
Sex				2.1219	0.1452
Male	67	39 (58.2%)	24 (8–90)		
Female	84	38 (45.2%)	NA (NA–NA)		
Age (years)				6.0657	**0.0138**
≤ 50	70	29 (41.4%)	NA (NA–NA)		
> 50	81	48 (59.3%)	15 (8–72)		
ECOG Performance status				16.1641	**0.0003**
Score 1	97	39 (40.2%)	NA (NA–NA)		
Score 2	38	26 (68.4%)	8 (6–33)		
Score 3	16	12 (75%)	7 (5–34)		
Oxygenation required				41.5704	**< 0.001**
No	59	10 (17%)	NA (NA–NA)		
Yes	92	67 (72.8%)	11 (7–18)		
Steroid use				9.1494	**0.0025**
No	62	22 (35.5%)	NA (NA–NA)		
Yes	89	55 (61.8%)	15 (8–72)		
Mechanical ventilation				45.5922	**< 0.001**
No	117	44 (37.6%)	NA (NA–NA)		
Yes	34	33 (97.1%)	7 (5–13)		
Cancer status				28.957	**< 0.001**
In remission	16	2 (12.5%)	NA (NA–NA)		
Regressive/stable	46	14 (30.4%)	NA (NA–NA)		
Progressive	68	50 (73.5%)	12 (0–26.9)		
Tumour Stage 4				9.1387	**0.0025**
No	122	55 (45.1%)	NA (NA–NA)		
Yes	29	22 (75.9%)	12 (6–30)		
Type of Therapy				3.5043	0.4772
No, on follow up	51	28 (54.9%)	34 (7–72)		
Chemotherapy	85	44 (51.2%)	54 (13–120)		
Target	3	1 (33.3%)	NA (NA–NA)		
Both	2	0 (0%)	NA (NA–NA)		
Hormonal	5	4 (80%)	12 (6–15)		
On active chemotherapy				0.1201	0.729
No	60	32 (53.3%)	34 (12–72)		
Yes	91	45 (49.5%)	120 (15–120)		
Type of chemotherapy				0.021	0.8848
Non-cytotoxic	63	33 (52.4%)	60 (13–72)		
Cytotoxic	88	44 (50%)	90 (15–120)		
Type of tumour				0.1348	0.7135
Haematological	100	52 (52%)	47 (13–90)		
Solid	51	25 (49%)	120 (13–120)		
Occurrence of complications				0.7715	0.3797
Uncomplicated	127	66 (52%)	54 (15–90)		
Complicated	24	11 (45.8%)	NA (NA–NA)		

Bold represents significant *P* value that is less than 0.05

ECOG Eastern Cooperative Oncology Group performance status

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were still in remission. There was a statistically significant higher mortality among patients with tumour stage 4 and patients with progressive disease ($P < 0.001$). Pairwise comparisons showed a statistically significant difference between progressive disease versus regressive disease ($x^2 = 18.239$, $P < 0.001$) and remittent disease ($x^2 = 14.618$, $p < 0.001$), but not between regressive versus remittent disease.

Chest CT findings

There was statistically significantly higher mortality among patients with consolidation, crazy paving pattern, pleural effusion and tree-in-bud pattern (Additional file 1: Fig. S3). All chest CT findings are illustrated in Table 2. The predominant pattern of abnormality upon hospital admission was pulmonary consolidation (71 patients) followed by GGO (68). Pairwise comparisons showed a statistically significant difference in mortality between GGO versus both consolidation ($x^2 = 74.062$,

$p < 0.001$), and crazy paving ($x^2 = 50.937$, $p < 0.001$), but not between consolidation and crazy paving.

TSS

The ROC curve analysis revealed that TSS was statistically significantly higher in non-survivors (AUC = 0.758, $p < 0.001$). The optimum cut-off value of TSS used to predict in-hospital mortality was 5, with a sensitivity of 79.2% and a specificity of 62.2% (Fig. 1). Demonstrative survivor and non-survivor cases were presented in (Figs. 2, 3).

Median TSS (Q1–Q3) = 11.5 (7.3–14), 7 (5–10) and 5 (4–8) in patients with crazy paving, consolidation and GGO, respectively, with a statistically significant difference, H [2] = 22.556, $P < 0.001$. TSS was statistically significantly lower in GGO versus consolidation and crazy paving pattern (adjusted $p = 0.001$ and $p < 0.001$, respectively), but there was no statistically significant difference between TSS in consolidation and crazy paving pattern (adjusted $p = 0.0156$) (Additional file 1: Fig. S4).

Table 2 Chest CT findings and risk factors for in-hospital mortality

Risk factor	N	Mortality N (%)	Median (95% CI)	Logrank test	
				x^2	P value
GGO				1.8855	0.1697
Absent	19	13 (68.4%)	30 (5–120)		
Present	132	64 (48.5%)	NA (NA–NA)		
Consolidation				29.999	**< 0.001**
Absent	57	13 (22.9%)	NA (NA–NA)		
Present	94	64 (68.1%)	13 (7–25)		
Crazy paving				7.8586	**0.005**
Absent	135	63 (46.7%)	NA (NA–NA)		
Present	16	14 (87.5%)	11 (6–16)		
Predominant pattern				78.788	**< 0.001**
GGO	68	8 (11.8%)	NA (NA–NA)		
Consolidation	71	58 (81.7%)	8 (6–13)		
Crazy paving	12	11 (91.7%)	11 (5–30)		
Pleural effusion				19.403	**< 0.001**
Absent	112	47 (42%)	NA (NA–NA)		
Present	39	30 (76.9%)	7 (5–12)		
Lymph nodes				0.4004	0.5269
Absent	124	62 (50%)	90 (22–120)		
Present	27	15 (55.6%)	24 (7–33)		
Bronchial dilation				0.6132	0.4336
Absent	141	70 (49.7%)	90 (18–120)		
Present	10	7 (70%)	22 (5–25)		
Tree-in-bud				8.9943	**0.003**
Absent	118	54 (45.8%)	NA (NA–NA)		
Present	33	23 (69.7%)	7 (6–15)		

Bold represents significant P value that is less than 0.05

GGO Ground-glass opacity

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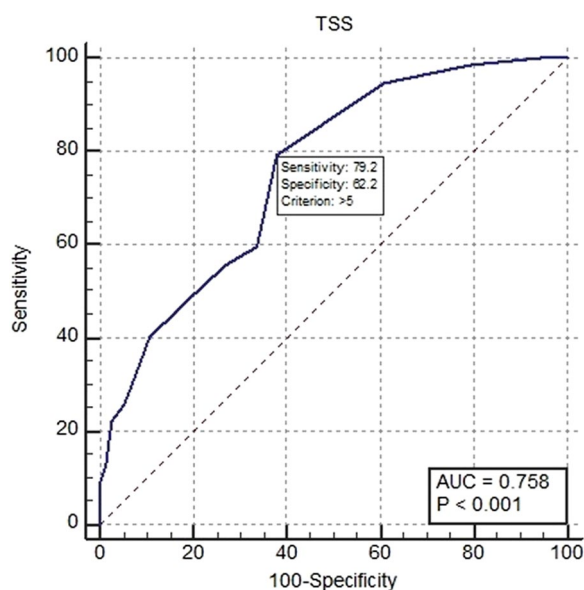
Fig. 1 ROC curve for diagnostic performance of TSS to predict mortality

There was no statistically significant difference in TSS among complicated and non-complicated cases ($p = 0.473$).

TSS correlation with treatment plan and cancer status

Median TSS (Q1–Q3) = 5 (4–7), 7.5 (5–10.3) and 5 (3–9.3) in patients who resumed, not resumed and started chemotherapy after COVID-19 treatment, respectively, with a statistically significant difference, H [2] = 11.53, $P = 0.003$). TSS was statistically significantly lower in patients who resumed versus who did not resume chemotherapy (adjusted $p = 0.005$), but there was no statistically significant difference between TSS in patients who resumed versus who started chemotherapy (adjusted $p = 1$). TSS was marginally significantly lower in patients who started versus those who did not resume chemotherapy (adjusted $p = 0.057$) (Additional file 1: Fig. S4).

There was a statistically significant positive correlation of large strength between the delay time to resume chemotherapy after COVID-19 resolution and TSS ($n = 39$), as TSS increased the time to resume chemotherapy is longer ($r_s = 0.511$, $p = 0.001$). Also, there was a statistically significant positive correlation of low strength between the post-COVID-19 cancer status and TSS, as patients with progressive disease revealed higher TSS ($r_s = 0.183$, $p = 0.037$).

Inter-observer reliability

Three hundred-two observations were depicted for the TSS. There was statistically significant reliability (absolute agreement) between the two independent observers in quantitative pulmonary assessment using TSS with ICC > 0.9 ($P < 0.001$) (Table 3 and Fig. 4).

Risk factors for mortality

The Cox regression analysis was performed to predict the risk factors for mortality. Univariate analysis revealed that age, pulmonary predominant pattern, pleural effusion, tree-in-bud, ECOG PS, tumour stage 4 and post-COVID cancer status were a statistically significant predictor of mortality. So, all these seven predictor variables were entered in a multivariate logistic regression model. The model was statistically significant (χ^2 [7] = 75.79, p value < 0.001) with an AUC (95% CI) of 0.923 (0.863–0.963). Of the seven predictor variables, only consolidation versus GGO, crazy paving pattern versus GGO and progressive diseases versus remittent diseases were statistically significant independent predictors of mortality among oncology patients with COVID-19 infection. The tree-in-bud pattern was a marginally independent risk factor for mortality (Table 4).

Discussion

To the best of our knowledge, this is the first study to investigate the diagnostic reliability of TSS to predict mortality and its effect on treatment plans in oncology patients with COVID-19 infection. Our results revealed a statistically significant inter-observer agreement for the evaluation of pulmonary abnormalities with a statistically significantly higher TSS among non-survivors versus survivors. That was in line with a retrospective study limited to patients with solid malignancy concluded that patients who presented with high baseline CT scores and required ICU care had a higher mortality [23]. Unlike our study, there was no correlation between TSS and the implication of COVID-19 infection on the cancer status and management plan.

In concordance with our results, a recently published study discussed the severity of COVID-19 in oncology patients using chest radiographs only without performing chest CT and concluded that the baseline radiological severity of COVID-19 diagnosis is associated with poor outcomes [24].

Multivariate regression analysis revealed that post-COVID progressive cancer diseases versus remittent diseases were statistically significant independent predictors of mortality. Similar higher mortality in progressive disease was approved in a retrospective study on patients with solid malignancy, unlike our study there was no

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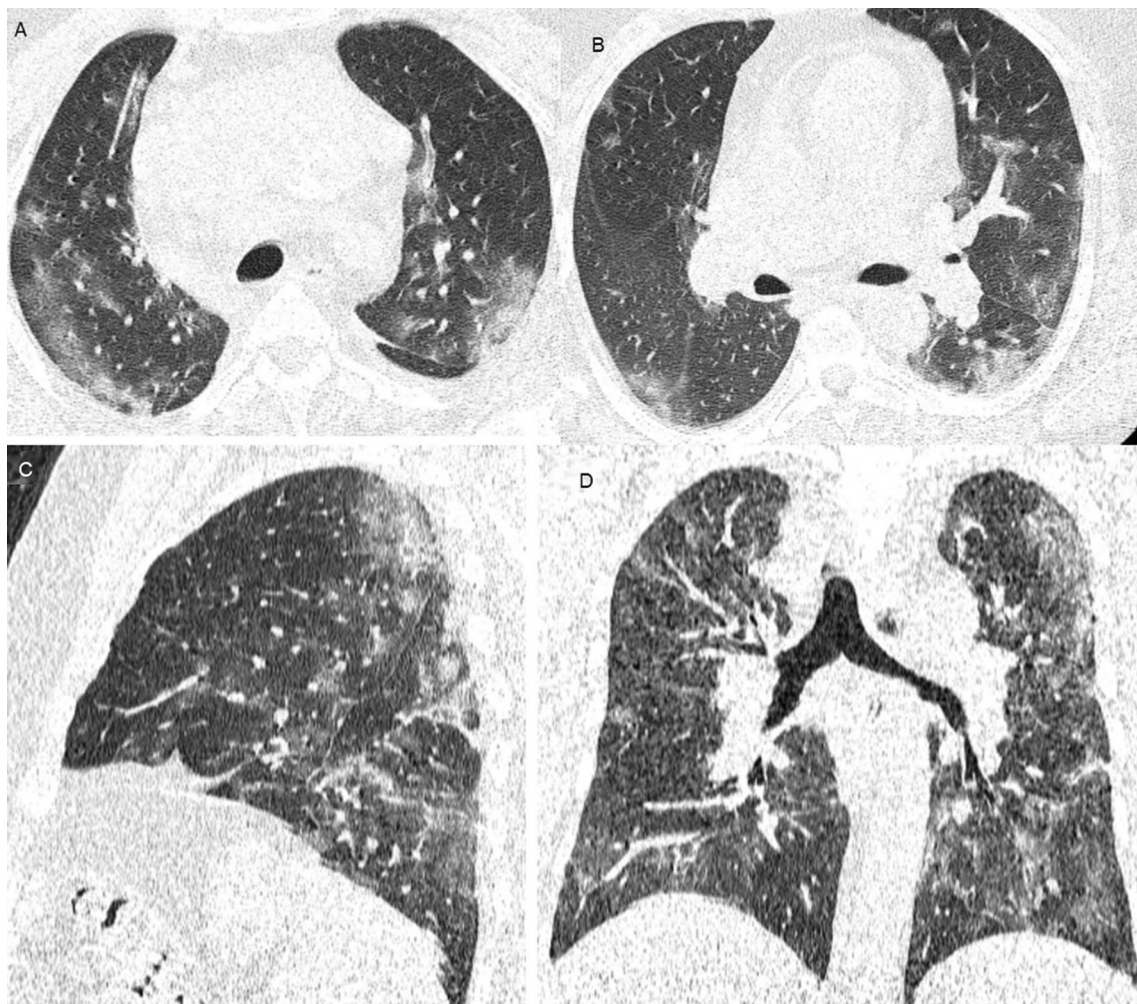
Fig. 2 A 37-year-old male with acute leukaemia. Non-contrast chest CT was axial (**a**, **b**), sagittal (**c**) and coronal (**d**) reconstructed images show bilateral small ground-glass opacities of predominant peripheral subpleural location. The TSS is 4

correlation between cancer status and TSS or even chest CT findings [23]. Our results revealed a statistically significant positive correlation between the post-COVID-19 cancer status and TSS. This is in concordance with the hypothesis that COVID-19 infection could be associated with proinflammatory markers which may activate premetastatic cancer cell dissemination [25, 26].

There were no statistically significant differences in mortality rate and TSS between complicated and non-complicated cases, thus assuming to be the small number of included complicated cases. Among the 24 complicated cases, 11 cases were died.

The management of patients in our centre was following multidisciplinary meeting decisions according to ESMO guidelines and treatment priorities in managing cancer patients during covid-19 pandemic [27, 28]. Regarding COVID-19 treatment, 89 patients received steroids with statistically higher mortality rates

($p = 0.0025$). A total of 111 patients did not receive antiviral drugs, while 10, 6, 3, 8, 7 and 5 patients received Acyclovir, Oseltamivir, Ribavirin, Favipiravir, Remdesivir and Avipravir, respectively.

There were no statistically significant differences regarding tumour type, anticancer therapy type and whether the patient was on active chemotherapy or not at the time of COVID-19 infection between survivors and non-survivors. This was in line with a previous study that discussed the determinants of COVID-19 severity in oncology patients [3]. Contrary to our results, studies in New York City cancer centre patients stated that patients with haematological tumours had a higher mortality rate than those with solid ones [29].

Our results revealed higher mortality in patients who received chemotherapy within 10 days before COVID-19 infection. In line with other studies concluded that anticancer therapy within 30 or 14 days before COVID-19

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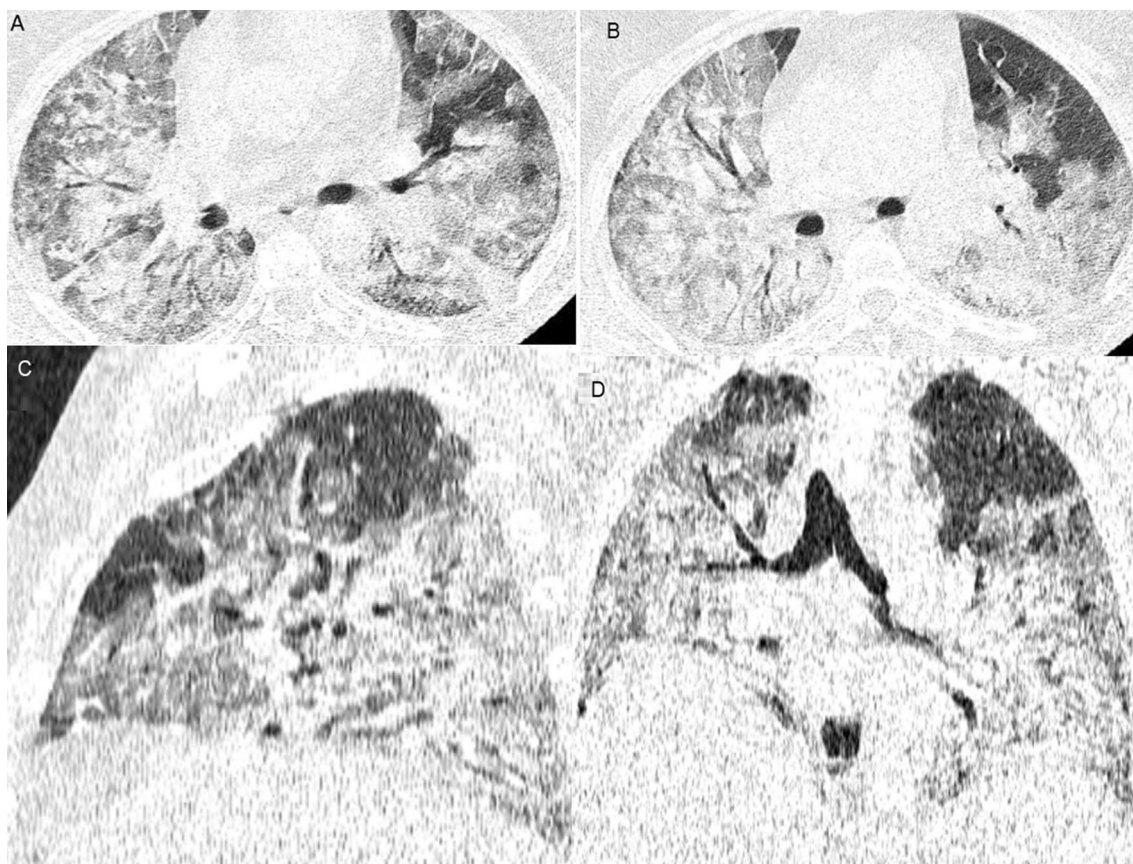
Fig. 3 A 45-year-old female with breast cancer. Non-contrast chest CT was axial (**a**, **b**), sagittal (**c**) and coronal (**d**) reconstructed images show bilateral large patchy ground-glass opacities mixed with consolidation and a predominant crazy paving pattern. The TSS is 18
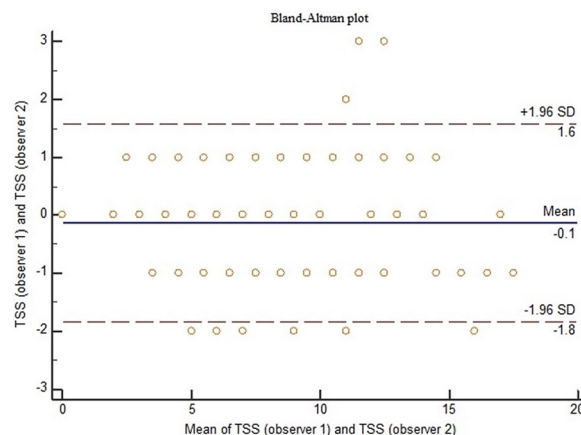
Table 3 Inter-observer agreement in the assessment of TSS

ICC definition	ICC	95% CI	*P* value
Consistency	0.971	0.961–0.979	**< 0.001**
Absolute agreement	0.971	0.960–0.979	**< 0.001**

Bold represents significant *P* value that is less than 0.05

ICC intraclass correlation coefficient. *CI* confidence interval

Fig. 4 Bland–Altman plots for inter-observer reliability of TSS measurements

diagnosis has a higher risk of developing severe events [6].

Multivariate regression analysis revealed that consolidation or crazy paving pattern versus GGO were statistically significant independent predictors of mortality. There was no statistically significant difference in patients with GGO among survivors and non-survivors, while patients with consolidation or crazy paving patterns had a statistically significant higher mortality. This prevalence was in line with several previous studies on non-cancer patients [19, 30]. In our study predominant pulmonary pattern upon hospital admission was pulmonary consolidation followed by GGO, this high prevalence of consolidation could be explained by their immunocompromised status and rapid deterioration compared to the general population.

Table 4 Cox regression analysis for predictors of mortality

Risk factor	Univariate		p value	Multivariate		P value
	HR	95% CI		HR	95% CI	
Age (years)			**0.017**			0.167
≤ 50	r(1)	r(1)		r(1)	r(1)	
> 50	1.8	1.1–2.8		1.4	0.84–2.6	
Predominant pattern						
GGO	r(1)	r(1)		r(1)	r(1)	
Consolidation	13.3	6.3–28.2	**< 0.001**	7.7	3.5–17.2	**< 0.001**
Crazy paving	13.4	5.3–33.8	**< 0.001**	10.2	3.8–27.2	**< 0.001**
Pleural effusion						0.183
Absent	r(1)	r(1)	**< 0.001**	r(1)	r(1)	
Present	2.6	1.6–4.2		1.5	0.81–2.9	
Tree-in-bud			**0.004**			0.052
Absent	r(1)	r(1)		r(1)	r(1)	
Present	2	1.2–3.3		1.8	0.9–3.3	
ECOG (PS)						
1	r(1)	r(1)		r(1)	r(1)	
2	2.2	1.3–3.6	**< 0.001**	1		0.997
3	2.7	1.4–5.3	**< 0.001**	0.6		0.367
Stage 4			**0.004**			0.707
Absent	r(1)	r(1)		r(1)	r(1)	
Present	2	1.2–3.4		1.1	0.6–2.1	
Disease status						
Remittent	r(1)	r(1)		r(1)	r(1)	
Regressive	2.7	0.62–12	0.184	3.2	0.7–15	0.123
Progressive	9.1	2.3–37.6	**0.002**	5.8	1.3–25.5	**0.019**

Bold represents significant *P* value that is less than 0.05

r(1) reference category, *HR* hazard ratio, *CI* confidence interval

The GGO is considered a marker of the early and active disease stage [30]. Consolidation indicates an increased inflammatory exudate of the alveolar space with subsequent increased mortality, while the crazy paving pattern affirms a mixture of alveolar oedema and interstitial inflammatory changes [31].

Our results revealed a statistically significantly higher TSS among non-survivors versus survivors using a cut-off value of 5 or above for detection of in-hospital mortality. Concordant results were reported by a retrospective study in non-cancer patients with a higher TSS threshold of 7.5, 12 and 8.5 showed a sensitivity of 82.6%, 77.3% and 86.7% with a specificity of 100%, 90.5% and 87.5%, respectively, for diagnosing severe-critical COVID-19 cases and in-hospital mortality [19, 20, 22]. This lower TSS cut-off value in our patients is assumed to be the immune-compromised state and the detected high prevalence of predominant consolidation pattern, rationalizing more attention to those vulnerable patients. TSS was statistically significantly higher in patients with consolidation and crazy paving patterns versus patients with GGO.

So, we recommend that hospitalization and precise follow-up may be beneficial for oncology patients with a baseline TSS of more than 5. This can help rapid assessment and selection of proper treatment plans in critical cases, especially where ICU resources are restricted.

The chemotherapy was delayed in 39 patients, and TSS was statistically significantly lower in patients who resumed versus those who did not resume chemotherapy after COVID-19 resolution. Concordant results were revealed by a previous study on acute myeloid leukaemia patients as the chemotherapeutic schedule was delayed in 68 patients, unlike our study there was no correlation with TSS and treatment plan [32].

The strength of our study is besides the reasonable diagnostic performance of TSS to expect mortality, our results firstly presented a statistically significant positive correlation between TSS and post-COVID cancer status and delay in chemotherapy schedule. Thus, TSS provides an applicable rapid quantitative radiological assessment to predict mortality, cancer status and modification of

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treatment plan, helping to provide special cases in such settings and improve the patient's outcome.

There are some limitations to the study. First, the single-centre retrospective study design is observed. Secondly, the number of complicated cases was small, further studies on post-COVID-19 complications are recommended. Lastly, future studies assessing the performance of machine-learning-based tools against radiologist-based scoring systems are recommended.

Conclusions

Predominant pulmonary patterns of consolidation or crazy paving pattern versus GGO and progressive diseases versus remittent diseases are statistically significant independent predictors of mortality in oncology patients. TSS assessed the severity of COVID-19 with excellent inter-observer agreement and revealed a positive correlation between delay time to resume chemotherapy and post-COVID cancer status. TSS is a rapidly applicable method to improve the decision-making about the treatment plan.

Abbreviations

COVID-19	Coronavirus disease 2019
CT	Computed tomography
ECOG PS	Eastern Cooperative Oncology Group performance status
GGO	Ground-glass opacity.
ICC	Interclass correlation
RT-PCR	Reverse transcription–polymerase chain reaction assay.
TSS	Total severity score

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s43055-024-01259-2.

Additional file 1: Fig. S1. Flowchart of the study. **Fig. S2**. Kaplan–Meier curve for survival time analysis. **Fig. S3**. Kaplan–Meier curves of risk factors for mortality (A–F). **Fig. S4**. Pairwise comparisons of TSS and predominant pulmonary pattern as well as chemotherapy after COVID-19 (A&B).

Declarations

Ethical approval and consent to participate
Institutional Review Board approval was obtained. (Approval No: R.22.06.1738), All procedures performed in the study were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments.

Consent of publication
Written informed consent was waived by the Institutional Review Board.

Competing interests
The authors of this manuscript declare no relationships with any companies, whose products or services may be related to the subject matter of the article.

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