



## Chest CT severity score: assessment of COVID-19 severity and short-term prognosis in hospitalized Iranian patients

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### Summary

**Background** The aim of this study was to evaluate the value of chest computed tomography (CT) severity score in the assessment of coronavirus disease 2019 (COVID-19) severity and short-term prognosis.

**Methods** In this cross-sectional study, we evaluated all patients who were referred to our university hospital, from 21 May 2020 to 22 June 2020 with positive severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) reverse transcription-polymerase chain reaction (RT-PCR) test. The patients suspected of having other respiratory diseases including influenza, according to an infectious disease specialist, and those without chest CT scan were excluded. A chest CT was obtained for all patients between days 4 and 7 days after symptom onset. Chest CT severity score was also calculated based on the degree of involvement of the lung lobes as 0%, (0 points), 1–25% (1 point), 26–50% (2 points), 51–75% (3 points), and 76–100% (4 points). The CT severity score was quantified by summing the 5 lobe indices (range 0–20). The ROC curve analysis was performed for the clinical value of CT scores in

distinguishing the patients based on the severity of disease (mild/moderate group versus severe group), ICU admission, intubation requirement, and mortality.

**Results** Of the 148 patients included, 93 patients recovered, while 55 patients died (mortality rate 37%). The area under the curve of CT score for discriminating of recovered patients from deceased individuals was 0.726, and the optimal CT score threshold was 15.5 with 61.8% sensitivity and 76.3% specificity. The best CT score cut-off for discriminating of patients based on the severity of disease was 12.5 with 68.3% sensitivity and 72.7% specificity. In addition, with CT score cut-off of 15.5, sensitivities of 70.8% and 51.6% and specificities of 78% and 72.6% were observed for intubation and ICU admission, respectively.

**Conclusion** CT scan and semiquantitative scoring method could be beneficial and applicable in predicting the patient's condition.

**Keywords** Coronavirus disease 2019 · Computed tomography scan · Computed tomography severity score · Mortality · Severity

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### Background

On 31 December 2019, the World Health Organization reported the outbreak of coronavirus disease (COVID-19) in Wuhan, China [1]. The clinical spectrum of COVID-19 is broad, ranging from subclinical infections to severe pneumonia [2, 3]. Leukopenia, lymphocytopenia, high levels of C-reactive protein (CRP), and erythrocyte sedimentation rate (ESR) are the most frequent laboratory findings [4]. The most common findings in chest computed tomography (CT) of COVID-19 are multifocal bilateral ground glass opacities (GGO) with or without diffuse consolidations, predominantly in subpleural regions, inferior

lobes, and posterior segments of the lung [5, 6]. The gold standard diagnostic tool for a COVID-19 diagnosis is a positive severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) reverse transcription-polymerase chain reaction (RT-PCR) test of respiratory tract specimens. However, due to the shortages of the RT-PCR test and high sensitivity of CT for diagnosis of COVID-19, chest CT could help in screening of disease and accelerate early diagnosis of COVID-19 [7–9].

The severity of COVID-19 is unpredictable, ranging from asymptomatic patients to acute respiratory distress syndrome (ARDS) and multiorgan failure. The utility of CT imaging findings to predict the severity in the early stage of the disease is valuable for effective management of the disease spread [10]. Assessment of disease severity plays a key role in mortality rate. As there is no definite treatment for COVID-19, prediction of severity and short-term prognosis can play a great role in patient management. Recent studies support the role of chest CT scan in prioritizing COVID-19 patients in hospital triage [11]. The aim of this study was to evaluate the value of chest CT severity score in assessment of COVID-19 severity and short-term prognosis.

## Methods

### Study population

Our retrospective cross-sectional study was approved by the Review Board and Ethics Committee of Iran University of Medical Sciences. The requirement to obtain patient consent was waived.

We evaluated all patients who were referred to our university hospital, Rasoul Akram Hospital, Tehran, Iran from 21 May 2020 to 22 June 2020 and were definite cases of COVID-19 considering positive SARS-CoV-2 RT-PCR test, clinical, laboratory, and imaging findings. The patients suspected of having other respiratory diseases including influenza, according to an infectious disease specialist, and those who without chest CT scan were excluded.

A chest CT was available for all patients between day 4 and 7 after symptom onset. In situations of having more than one CT, only the first study was evaluated. CT, clinical, and laboratory findings were registered on the same day.

### Laboratory findings

Laboratory parameters included leukocyte, red blood cell, platelet, neutrophil, and lymphocyte counts, C-reactive protein (CRP), erythrocyte sedimentation rate (ESR), blood urea, serum creatinine, liver enzymes, lactate dehydrogenase (LDH), D-dimer, ferritin, creatine phosphokinase (CPK), albumin, procalcitonin, troponin, interleukin-6, prothrombin time

(PT), partial thromboplastin time (PTT), and international normalized ratio (INR).

### Computed tomography protocol

A low-dose lung CT without contrast was performed using 16-slice CT-scanner (Toshiba Aquilion; Toshiba Medical System, Japan). Image acquisition parameters were as follows: a tube voltage of 120 KVp, a tube current of 60 mAs, and a slice thickness of 5 mm at a 5-mm slice interval. Adaptive Iterative Dose Reduction Algorithm was used to reconstruct the images. The mean CT dose index volume was 3.8 mGy (range 2.5–6.5 mGy). All CT images were interpreted in both pulmonary (width: 1600 HU, level: –550 HU) and mediastinal (width: 300 HU, level: 45 HU) windows by 2 different expert radiologists separately. In cases with conflict in interpretations, the opinion of the senior attending radiologist applied.

### Computed tomography features of lung involvement

GGO alone, GGO with consolidation, consolidation alone, reticular opacities, air space nodules, crazy paving pattern, reverse halo sign, atelectasis, tree-in-bud opacities, and pleural effusion cyst were all sought and precisely registered. The definition of all the mentioned features was based on the latest guidelines [12, 13].

Chest CT severity scores were also calculated based on the degree of involvement of the lung lobes as 0%, (0 points), 1–25% (1 point), 26–50% (2 points), 51–75% (3 points), and 76–100% (4 points). The CT severity score was quantified by summing the 5 lobe indices (range 0–20) [14].

### Location of the pulmonary involvement

The distribution of the lung engagement was defined as lobar (upper, middle, or lower lobes) as well as the laterality (right or left).

The pattern of pulmonary engagement was classified as the segmental and lobar, and the laterality of involvement was defined as bilateral, right-sided, and left-sided. The central lung portion was considered as the inner two-thirds of the pulmonary parenchyma, while the peripheral part was defined as the outer one-third of the lung.

### Severity of COVID-19

Severity was defined as the following major groups [15, 16]:

- Mild/Moderate: Patients without pulmonary infiltration and  $O_{2\text{ sat}} > 93\%$  with ambient air/patients with pulmonary infiltration and  $O_{2\text{ sat}} > 93\%$  with ambient air.
- Severe: Patients with respiratory rate 30 or more breaths per minute.  $O_{2\text{ sat}} \leq 93\%$  with ambient air

or pulmonary infiltration of more than 50% of both lungs, who are not in a critical state.

- Critical: Patients admitted to the intensive care unit; patients needing high flow oxygen with a nasal cannula, noninvasive ventilation, patients with acute respiratory syndrome distress or shock.

### Statistical analysis

The statistical analyses were performed with SPSS Software (Version 25, IBM, Chicago, IL, USA) and STATA 11 (StataCorp, College Station, TX, USA).  $P$  value < 0.05 was considered statistically significant. Categorical variables were described as frequency and percentages, and quantitative variables were described using mean (standard deviation [SD]) or median (interquartile range [IQR]) values. The  $\chi^2$  test and Fisher exact test were used for categorical variables. The continuous variables or ordinal variables were compared by t-test or Mann–Whitney U test.

The diagnostic performance of CT severity score was assessed by creating receiver operating characteristic (ROC) curves and measuring the area under the curve (AUC) and their 95% confidence intervals (CIs). Cut-offs were estimated at various sensitivities and specificities and at the maximum Youden's index (YI) [17].

**Table 1** Demographic characteristics, clinical finding and treatment profile of the patients

Variable	All patients (N= 148)	(%)
Sex (male)	99	66.9
Mechanical ventilation	48	32.4
Intubation requirement	44	29.7
ICU admission	64	43.2
<b>Signs and symptoms</b>		
Cough	120	81.1
Dyspnea	102	68.9
Fever	99	66.9
Myalgia	41	27.7
Vomiting	24	16.2
Weakness	23	15.5
Headache	19	12.8
Diarrhea	13	8.8
Tachypnea	12	8.1
Chest pain	9	6.1
Abdominal pain	8	5.4
Sore throat	4	2.7
Hemoptysis	6	4.1
Gastrointestinal bleeding	2	1.4
<b>Comorbidities</b>		
Hypertension	26	17.6
Diabetes	35	23.6
Others	47	31.8
ICU intensive care unit		

## Results

### Demographic, clinical, and laboratory findings

Our study involved 148 patients with positive SARS-CoV-2 RT-PCR tests who met the inclusion criteria. The mean age of the patients was  $59.27 \pm 16.80$  years (range 20–98 years); there were 99 men (66.9%) and 49 women (33.1%). Ninety-three patients recovered, while 55 patients died (mortality rate 37%). The mean duration of hospitalization for recovered and deceased patients was  $8.06 \pm 4.5$  days and  $8.07 \pm 5.47$  days, respectively. All data were assessed, based on mortality and severity. Of the 148 patients included in this study, 22 were in the moderate group (14.9%), 54 in the severe group (36.5%), and 72 in the critical group (48.6%), with respective mean ages of 50.13, 56.14, and 64.40 years ( $P$  value < 0.001). The median length of hospital stay in the moderate group was 4 days (IQR 3–8), in the severe group 7 days (IQR 4.75–9), and in the critical group 10 days (IQR 6–13). All demographic data, clinical findings and the treatment profiles of the patients are summarized in Table 1. Hydroxychloroquine, levofloxacin, and lopinavir/ritonavir were the most frequent medications. A total of 44 patients were intubated, and of the 148 cases, 64 patients were admitted to the ICU (29.7% and 43.2%, respectively).

In our study, 40 patients had no comorbidities (27%). The most common comorbidities were diabetes mellitus (23.6%) and hypertension (17.6%). The most common symptom in all groups was cough (81.1%), followed by respiratory distress (70.3%), dyspnea (68.9%), and fever (66.9%). The other signs and symptoms were myalgia (27.7%), vomiting (16.2%), weakness (15.5%), headache (12.9%), diarrhea (8.8%), tachypnea (8.1%), chest pain (6.1%), abdominal pain (5.4%), hemoptysis (4.1%), sore throat (2.7%), and gastrointestinal bleeding (1.4%).

The analysis showed that the mortality rate was significantly higher in patients with comorbidities including diabetes mellitus and hypertension ( $P$  value = 0.003).

Table 2 shows laboratory findings of the patients, based on the mortality and severity of COVID-19. The lymphocyte counts were significantly decreased in patients who had died. The levels of white blood cell count (WBC), neutrophil counts, lactate dehydrogenase, urea, CRP, and PT were significantly higher in individuals who died compare to patients who recovered. Elevated levels of troponin and D-dimer were seen in cases with critical stage of COVID-19.

### CT imaging findings

The chest x-ray of 60 patients was negative at admission time (40.5%). However, the CT imaging findings were analyzed for all patients and of the 148 cases (Tab. 3), 147 CT images showed involvement (99.3%).

**Table 2** Laboratory findings of the patients with COVID-19. The significant level is below 0.05

Variable	All patients (N= 148)	Patients who recovered (N= 93)	Patients who died (N= 55)	P value*	Moderate group (N= 22)	Severe group (N= 54)	Critical group (N= 72)	P value
Age (year)	58.5 (47.25–75)	51 (45–67)	69 (53–78)	0.001	47.5 (41.5–54.75)	56 (45.75–69)	66.5 (52–76)	<0.0001
White blood cell count ( $\times 10^9$ cells per L)	6.4 (4.7–9)	6 (4.6–7.3)	7.9 (4.9–10.8)	0.003	5.1 (4.6–6.4)	6.2 (4.5–7.4)	7 (5.7–9.6)	<0.0001
Red blood cell count ( $\times 10^9$ cells per L)	4.36 (3.95–4.8)	4.49 (4.1–4.9)	4.23 (3.6–4.8)	0.019	4.4 (3.95–4.7)	4.5 (4.1–5.1)	4.2 (3.8–4.6)	0.017
Hemoglobin (g/dL)	12.6 (11.6–14)	12.7 (11.45–14.2)	12.6 (11.6–13.5)	0.580	13.5 (11.4–14)	13.5 (11.8–15.2)	12.3 (11–13.4)	0.094
Platelet count ( $\times 10^9$ cells per L)	170 (133–223)	171 (140–218)	157 (108–238)	1.000	171 (138–211)	163 (134–231)	184 (113–236)	0.393
Neutrophil count ( $\times 10^9$ cells per L)	5.2 (3.5–7.7)	4.9 (3.3–5.5)	6.1 (4–8.6)	0.000	3.8 (2.9–5.2)	4.9 (3.3–6.2)	5.8 (4.7–8.5)	0.001
Lymphocyte count ( $\times 10^9$ cells per L)	0.9 (0.7–1.2)	1 (0.8–1.2)	0.8 (0.6–1.2)	0.001	1 (0.7–1.3)	1 (0.8–1.2)	0.8 (0.6–1.1)	0.024
Blood urea nitrogen (mg/dl)	15 (11–23)	14 (11–18)	19 (12–34)	0.000	15 (10.75–16.25)	14 (11–18.25)	18 (11–33.75)	0.007
Creatinine ( $\mu$ mol/L)	1.2 (1–1.6)	1.2 (1–1.4)	1.5 (1–1.8)	0.041	1.2 (1–1.4)	1.2 (1–1.4)	1.35 (1–1.75)	0.237
Creatine phosphokinase (U/L)	175 (120–372)	194 (119–367)	166 (120–541)	0.902	155 (115–377)	213 (131–367)	174 (120–433)	0.482
CK-MB (IU/L)	23.5 (17–30)	25 (14–28.25)	22 (18–30.5)	0.656	25.00	25 (16–25)	22 (17–30)	0.453
Lactate dehydrogenase (U/L)	763 (588–1003)	612 (541–830)	945 (745–1176)	0.005	529 (454.5–854.5)	612 (500–801)	913 (612–1148)	0.180
Albumin (g/dl)	3.5 (3.2–3.8)	3.6 (3.4–3.9)	3.2 (2.8–3.6)	0.058	4 (3.5–4.1)	83.6 (3.3–3.75)	3.3 (3.1–3.6)	0.06
Alanine aminotransferase (U/L)	41 (32–57.5)	22 (20–38)	44 (34.5–64)	0.151	34 (28–41)	43 (32–52)	44 (33–61.5)	0.055
Aspartate aminotransferase (U/L)	22 (19–34)	22 (20–38)	25 (18–32)	0.571	21 (18–23)	24.5 (21–37)	22 (17–35)	0.342
C-reactive protein (mg/L)	48 (24–48)	24 (24–48)	48	0.004	48 (24–48)	24 (24–48)	48 (24–48)	–
Erythrocyte sedimentation rate (mm/h)	58 (28–77)	40 (26.5–77)	65 (40–73)	0.072	34 (20–77)	52 (23–78)	64 (32.5–73)	0.091
Prothrombin time (s)	14.6 (13.7–15.6)	14 (13–15)	16 (14.3–17.6)	0.001	15.25 (13.25–15.6)	13.7 (13–15)	15 (14–17)	0.218
Partial thromboplastin time (s)	34.5 (32–42)	34 (30–37)	37 (32–50)	0.429	33 (28–37)	34 (31–37)	35 (32.5–50)	0.406
International normalized ratio	1.1 (1–1.3)	1.1 (1–1.2)	1.3 (1.1–1.5)	0.000	1.15 (1–1.3)	1.1 (1–1.2)	1.2 (1.1–1.4)	0.051
Procalcitonin (ng/ml)	0.2 (0.05–0.5)	0.05 (0.05–0.2)	0.2 (0.2–0.58)	0.057	–	0.13 (0.05–0.41)	0.21 (0.06–0.52)	1.000
Troponin (ng/ml)	7.4 (4.4–18.2)	5.4 (3.6–84.4)	8 (6.1–209.6)	0.656	–	5.4 (1.5–6.1)	16.8 (4.4–283)	0.033
IL-6 (pg/ml)	130 (7.1–320)	129 (6.6–264)	207 (86–320)	1.000	129	7.1 (6.2–207)	169 (86–320)	0.222
Ferritin (ng/mL)	315 (157–743)	315	743	0.100	–	315	743 (315–743)	0.329
D-dimer (pg/mL)	1231 (517–7981)	536 (511–1926)	10000	0.429	536	511	5963 (1926–10000)	0.018

CK-MB Creatine kinase-MB, IL-6 Interleukin-6

GGO were the most common findings (95.9%). The other typical manifestations were consolidation (105 of 147; 70.9%) and bilateral lung involvement (142 of 148, 95.9%). Moreover, CT images showing involvement of more than 2 lobes were found in 142 of 148 patients (96%). The main pattern of distribution was diffuse peripheral/central (106 of 148; 71.6%). Pleural effusion, pulmonary nodules, lymphadenopathy, atelectasis, fibrosis, and pericardial effusion were rare. The empyema was not seen in any of the CT scans. Right lung involvement was dominantly higher in findings than the left lung (88/148 and 44/148, respectively). There was no statistical relationship between severity of disease and sex. There were sig-

nificant differences between the severity of disease and RML and LUL involvement ( $P$  value: 0.046 and 0.027, respectively). There were significant differences between presence of pleural effusion in the moderate and severe/critical groups. Among CT imaging findings, there was a significant difference between pleural effusion and the severity of disease ( $P$  value=0.035). However, no significant difference between presence of pleural effusion and death was found ( $P$  value=0.38).

**Table 3** CT findings of the patients with COVID-19

Parameter		N= 148	%	P value
Ground glass opacities	–	142	95.9	0.843
Consolidation	–	105	70.9	0.628
Bilateral lung involvement	–	142	95.9	–
Atelectasis	–	47	31.8	0.103
Lymphadenopathy	–	43	29.1	0.294
Pleural effusion	–	32	21.6	0.384
Pulmonary nodules	–	7	4.7	0.055
Fibrosis	–	2	1.4	0.274
Pericardial effusion	–	12	8.1	0.347
Cardiomegaly	–	58	39.2	0.028
Opacity distribution	Central	2	1.4	0.083
	Peripheral/Central	106	71.6	
	Peripheral	40	27.0	

### ROC curve for CT severity score

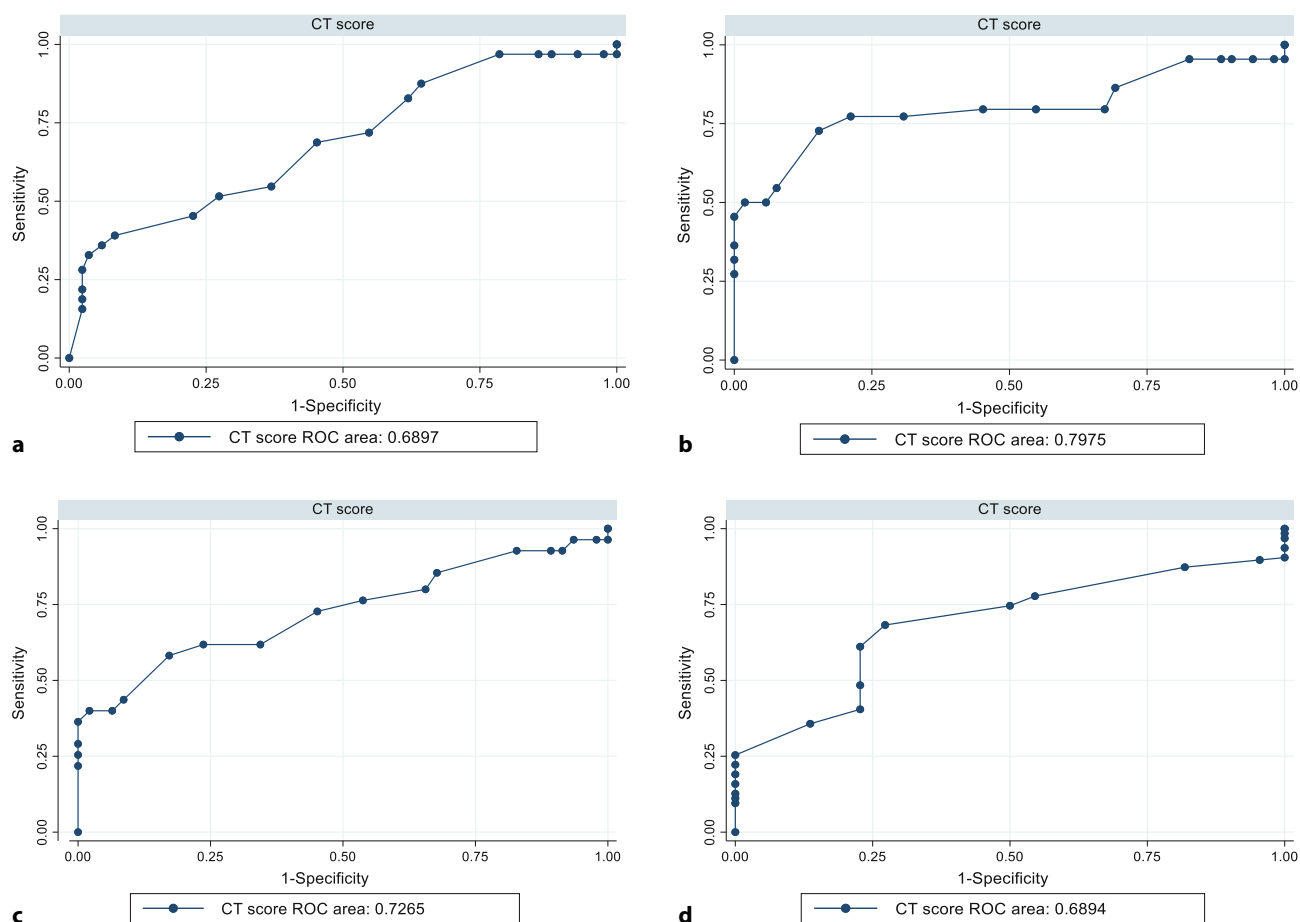
The ROC curve was plotted for the clinical value of CT severity scores in distinguishing the patients based on the severity of disease (moderate vs. severe/critical), mortality, intubation requirement, and ICU admission (Fig. 1). The AUC of CT severity score for discriminat-

ing recovered patients from deceased individuals was 0.726 (95% CI 0.63–0.82), and the optimal CT severity score threshold was 15.5 with 61.8% sensitivity and 76.3% specificity. The best CT severity score cut-off for discriminating patients based on the severity of disease was 12.5 with 68.3% sensitivity and 72.7% specificity (AUC = 0.689, 95% CI 0.585–0.793). In addition, with a CT severity score cut-off of 15.5, the sensitivity of 70.8% and 51.6% (AUC = 0.69, 95% CI 0.60–0.776), and specificity of 78% and 72.6% (AUC = 0.797, 95% CI 0.7–0.89) for intubation and ICU admission were reported, respectively.

### Discussion

COVID-19 is a global health issue. Early identification of the critical patients have various advantages, including appropriate critical care and reduction of mortality rate. Therefore, a new scoring tool could help the physician to predict the patient's risk of progressing to severe disease.

In our study, the mortality rate is slightly higher than in other studies [18]; however it should be stated that we only included hospitalized patients who had CT scan images available. The most common underly-



**Fig. 1** Receiver operator characteristic (ROC) curve for CT score: **a** intubation, **b** ICU admission, **c** mortality and **d** severity score



ing diseases identified in this study included diabetes mellitus and hypertension.

Individuals with these comorbidities were at increased risk of suffering a severe form of COVID-19 and have a higher mortality rate that it is consistent with similar studies [19, 20]. However, other comorbidities in those studies were not mentioned.

Based on our findings, lower WBC count, younger age, higher neutrophil count, better renal function (urea and creatinine), and higher albumin serum level, longer PT test, absence of pleural effusion correlated with the improvement of COVID-19.

Abnormal hematologic parameters (including increased WBC count, neutrophilia, and lymphopenia) may be as the result of cytokine storm [16], as well as renal function tests (blood urea nitrogen and creatinine), were associated with a higher risk of mortality. Castro et al. indicated these were associated with a greater risk of severe hospital course. They also reported that red blood cell abnormalities and primary pulmonary disease were associated with the risk of mortality [21].

The LDH and CRP serum levels are elevated in COVID-19 as well as other inflammatory diseases. According to our results, individuals with elevated CRP and LDH serum levels had a higher mortality rate. Other studies also reported high CRP and LDH as strong predictors for severity, and higher CRP levels were positively correlated with the lung involvement in CT imaging [22]. Albumin as a negative acute inflammatory factor was decreased in the deceased group in this study which is consistent with the Huang et al. study [23].

Similar to previous reports, the predominant imaging pattern of CT involvement in COVID-19 was GGO with occasional consolidation [24]. Most of our patients show the same patterns. All studies have reported consistent findings with bilateral lung involvement, mostly in the lower lobes [10, 24, 25]. In this study, we found that right lung involvement was slightly predominant over left lung involvement, which is not consistent with some studies [10].

Also, the presence of pleural effusion was significantly higher in cases with severe form of the disease. The CT severity score was higher in the severe/critical patients. However, no relationship was reported with between presence of pleural effusion and mortality rate. Cardiomegaly was significantly higher in the deceased group. These findings are consistent with the Homayounieh et al. study [26].

The semi-quantitative scoring method to determine the severity of CT findings was assessed in this study. This method was consistent with the Hafez et al. study [27]. The CT severity score in all lobes was significantly higher in severe/critical patients. A CT severity score threshold of 15 could identify the mortality risk of COVID-19 with a sensitivity of 61.8% and a specificity of 76.7%, while a CT severity score threshold of 12 could also predict the severity of

COVID-19 with a sensitivity of 68.3% and a specificity of 76.7%. Assessing the risk in the pandemic situation due to the limitation of equipment is critical. Based on the study by Yang et al., the CT severity score threshold to identify severe COVID-19 was 19.5 with a sensitivity of 83.3% and a specificity of 94%. The cut-off value of 18 was indicated as predictive of short-term mortality according to Francone et al. [25]. According to our results, we should consider patients with a total CT severity score above 12 to be at a higher risk of mortality and morbidity. These patients should be observed for possible intensive care requirements. According to Hilal et al. [28], patients with a CT severity score of above 7 had a longer hospital stay, lower intensive care supplements need, and decreased mortality rate. The serum CRP levels and CT features had a significant correlation in patients with a score above 7. The method of the scoring system in that study was claimed as a simple one that can be applied by the physician, while our scoring method requires radiologist reporting.

The CT severity score was higher in patients who died after adjustment of parameters in both groups in the Abbasi et al. study [18], and it is consistent with our results. Also, the CT severity score (Fig. 1) could be an acceptable prognostic factor for mortality and severity (area under the curve of 0.72). Therefore, admitting to ICU in the early phase of disease in patients with higher CT severity scores would be helpful. However, the optimal threshold for CT severity scores needs to be validated as there are limited studies in this field.

## Conclusion

A CT scan and semi-quantitative scoring method could be beneficial and applicable in predicting the patient's condition. However, for determining the best cut-off for the ROC curve, more studies are required.

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

## References

1. Rezaei M, et al. Dynamic changes of lymphocyte subsets in the course of COVID-19. *Int Arch Allergy Immunol.* 2021;182 (3):254–262. <https://doi.org/10.1159/000514202>.
2. Baghaei P, et al. Clinical manifestations of patients with coronavirus disease 2019 (COVID-19) in a referral center in Iran. *Tanaffos.* 2020;19(2):122.
3. Canovi S, et al. The association between clinical laboratory data and chest CT findings explains disease severity in a large Italian cohort of COVID-19 patients. *BMC Infect Dis.* 2021;21(1):157.
4. Cao Y, et al. Imaging and clinical features of patients with 2019 novel coronavirus SARS-CoV-2: a systematic review and meta-analysis. *J Med Virol.* 2020;92(9):1449–59.
5. Chung M, et al. CT imaging features of 2019 novel coronavirus (2019-nCoV). *Radiology.* 2020;295(1):202–7.

6. Song F, et al. Emerging 2019 novel coronavirus (2019-nCoV) pneumonia. *Radiology*. 2020;295(1):210–7.
7. Hope MD, et al. A role for CT in COVID-19? What data really tell us so far. *Lancet*. 2020;395(10231):1189–90.
8. Ai T, et al. Correlation of chest CT and RT-PCR testing for coronavirus disease 2019 (COVID-19) in China: a report of 1014 cases. *Radiology*. 2020;296(2):E32–E40.
9. Fang Y, et al. Sensitivity of chest CT for COVID-19: comparison to RT-PCR. *Radiology*. 2020;296(2):E115–E7.
10. Yang R, et al. Chest CT severity score: an imaging tool for assessing severe COVID-19. *Radiol Cardiothorac Imaging*. 2020;2(2):e200047.
11. Salahshour F, et al. Clinical and chest CT features as a predictive tool for COVID-19 clinical progress: introducing a novel semi-quantitative scoring system. *Eur Radiol*. 2021;p:1–11.
12. Rossi SE, et al. Tree-in-bud pattern at thin-section CT of the lungs: radiologic-pathologic overview. *Radiographics*. 2005;25(3):789–801.
13. Marjani M, et al. NRITLD protocol for the management of patients with COVID-19 admitted to hospitals. *Tanaffos*. 2020;19(2):91.
14. McRae MP, et al. Clinical decision support tool and rapid point-of-care platform for determining disease severity in patients with COVID-19. *Lab A Chip*. 2020;20(12):2075–85.
15. Organization, W.H. Clinical management of severe acute respiratory infection (SARI) when COVID-19 disease is suspected: interim guidance, 13 March 2020. : World Health Organization; 2020.
16. Mahmoudi S, et al. Immunologic features in coronavirus disease 2019: functional exhaustion of T cells and cytokine storm. *J Clin Immunol*. 2020;40(7):974–6.
17. Youden WJ. Index for rating diagnostic tests. *Cancer*. 1950;3(1):32–5.
18. Abbasi B, et al. Evaluation of the relationship between inpatient COVID-19 mortality and chest CT severity score. *Am J Emerg Med*. 2021;45:458–463. <https://doi.org/10.1016/j.ajem.2020.09.056>.
19. Roberts J, et al. Why is COVID-19 more severe in patients with diabetes? The role of angiotensin-converting enzyme 2, endothelial dysfunction and the immunoinflammatory system. *Front Cardiovasc Med*. 2020;7:392.
20. Wong CK, et al. Clinical presentations, laboratory and radiological findings, and treatments for 11,028 COVID-19 patients: a systematic review and meta-analysis. *Sci Rep*. 2020;10(1):1–16.
21. Castro VM, McCoy TH, Perlis RH. Laboratory findings associated with severe illness and mortality among hospitalized individuals with coronavirus disease 2019 in Eastern Massachusetts. *Jama Netw Open*. 2020;3(10):e2023934.
22. Booth AL, Abels E, McCaffrey P. Development of a prognostic model for mortality in COVID-19 infection using machine learning. *Mod Pathol*. 2021;34(3):522–531. <https://doi.org/10.1038/s41379-020-00700-x>.
23. Guan CS, et al. Imaging features of coronavirus disease 2019 (COVID-19): evaluation on thin-section CT. *Acad Radiol*. 2020;27(5):609–13.
24. Sun D, et al. Clinical features of severe pediatric patients with coronavirus disease 2019 in Wuhan: a single center's observational study. *World J Pediatr*. 2020;p:1–9.
25. Francone M, et al. Chest CT score in COVID-19 patients: correlation with disease severity and short-term prognosis. *Eur Radiol*. 2020;30(12):6808–17.
26. Homayounieh F, et al. Clinical and imaging features predict mortality in COVID-19 infection in Iran. *Plos One*. 2020;15(9):e239519.
27. Hafez MA. The mean severity score and its correlation with common computed tomography chest manifestations in Egyptian patients with COVID-2019 pneumonia. *Egypt J Radiol Nucl Med*. 2020;51(1):1–9.
28. Hilal K, et al. Correlation of computerized tomography (CT) severity score for COVID-19 pneumonia with clinical outcomes. *bioRxiv*. 2021.

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