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Chest computed tomography severity score in patients admitted to intensive care unit with COVID-19 pneumonia

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Abstract:

BACKGROUND AND AIM: This study aimed to investigate the association of the chest computed tomography severity score (CT-SS) with mortality in patients who were admitted to the intensive care unit (ICU) with coronavirus disease 2019 (COVID-19) pneumonia.

METHODS: In this single-center retrospective observational study, we reviewed the radiological and medical records of 45 patients with confirmed COVID-19, requiring ICU admission during a 4 month period. The chest CT-SS was used to evaluate the severity of lung involvement.

RESULTS: Forty-five patients who admitted to the ICU with COVID-19 and had undergone chest CT scans on admission were enrolled. There wasn't a significant difference in total CT-SS neither between patients who died and those who survived [median (interquartile range) 22 (11–30) vs 16 (9–18), p=0.20] nor between patients who underwent invasive mechanical ventilation and those who did not [median (interquartile range) 22 (12–30) vs 15 (8–17), p=0.17]. The median of CT-SS was 17 (2–39) (n=23 vs n=22). The area under the curve for estimation of mortality according to CT-SS was 0.611 at a 95% CI of 0.434–0.788 (p=0.20).

CONCLUSIONS: The total CT-SS, obtained from the chest CT on admission to the ICU, was not associated with an increased risk of mortality in patients admitted to ICU with COVID-19 pneumonia.

Keywords:

Chest, coronavirus infections, invasive mechanical ventilation, lung diseases, mortality, tomography

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Introduction

Approximately 5% of coronavirus disease 2019 (COVID-19) patients require care in the intensive care unit (ICU) and mechanical ventilation due to severe viral pneumonia.[1–5] Although the diagnosis of COVID-19 depends on real-time polymerase chain reaction (RT-PCR) results, chest computed tomography (CT) findings can help clinicians identify lung involvement, which is the main feature of the disease. The most common chest CT findings are multifocal ground-glass opacities and peripheral consolidation in COVID-19 patients.[6,7] Although these findings are not specific to COVID-19, the severity of lung involvement is expected to be related to chest CT findings.[8,9] The chest computed tomography severity score (CT-SS) can be used to assess the severity of pulmonary parenchymal abnormalities in patients with COVID-19.[8] In a prospective study result, including 44 (18%) of 235 patients with confirmed COVID-19 who were admitted to the ICU, a CT-SS of >17 was found to be useful in predicting 30-day mortality.[10]

This single-center, retrospective observational study aimed to investigate the relationship of thoracic CT-SS with the requirement of invasive mechanical ventilation (IMV) and mortality in patients with COVID-19 pneumonia.

Materials and Methods

Study design and settings

This retrospective cohort study was designed at Tepecik Training and Research hospital and approved by the Local Ethics Committee of Tepecik Training and Research Hospital (No.: 2020/05-04, Date: April 27, 2020) and the Ministry of Health of the Turkish Republic.

Study population

We retrospectively reviewed the records of all patients admitted with a diagnosis of COVID-19 to the ICU of a tertiary referral hospital between March 15, 2020, and July 15, 2020. Patients with clinical and radiological features of COVID-19 and positive RT-PCR test results for coronavirus and who had undergone chest CT scans before or on admission or within 24 h of admission to the ICU were included. Patients who died within 24 h of ICU admission were excluded. Other exclusion criteria were loss of CT data, chronic lung disease findings (bronchiectasis, fibrotic changes) by CT that may have led to misinterpretation, RT-PCR results unavailable or negative, and terminal cancer.

Data collection

Clinical data were obtained from medical and radiological imaging records. These data included age, gender, Acute Physiology and Chronic Health Evaluation (APACHE) II scores, Glasgow Coma Scale (GCS) scores, comorbidities, nosocomial infections, medications, need of mechanical ventilation, duration of IMV, time from symptom onset to ICU admission, duration of hospital and ICU stay, and laboratory tests [blood chemistry, procalcitonin (PCT), C-reactive protein (CRP), arterial blood gas and complete blood count].

A chest CT-SS defined by Yang et al.[8] was used to evaluate the severity of pulmonary abnormalities in COVID-19 patients. Patients were divided into groups according to who had undergone IMV and who had not and between patients who died and those who survived. CT-SS between the groups was compared.

Chest CT image analysis and chest CT-SS

Chest CT images were evaluated by a radiologist with more than 10 years of experience in CT imaging, unaware of the clinical data. The first CT scans obtained during or before ICU admission were examined with a window width of 1500 Hounsfield units of the lung parenchyma. To assess COVID-19 severity, the chest CT-SS developed by Yang et al.[8] was used. By this scoring system, 18 segments of both lungs were divided into 20 regions, and lung opacities in these 20 regions were evaluated.[8] A score of 0 was given if parenchymal opacification was 0% for each region, 1 if less than or equal to 50%, 2 if it contained more than 50%. The total chest CT-SS was the sum of the scores of the 20 lung regions.[8]

Data analysis and statistical methods

The data were presented as the number of cases, percentage, mean±standard deviation and median [interquartile range (IQR)]. Categorical comparisons were performed using the Chi-squared test or Fisher's exact test. Continuous variables between the groups were compared using Student's t-test or the Mann–Whitney U test. Receiver operating characteristic (ROC) with the area under the curve (AUC) were calculated to investigate the predictive value of continuous variables to predict mortality. The relationship between continuous variables, which were not nor-

Table 1: Clinical characteristics of patients in the death and survival groups

Characteristics	Death (n=19)	Survived (n=26)	p
Age, (years)	73 (69–86)	63 (49–79)	0.02
Female, n (%)	10 (52.6)	12 (46.2)	0.66
Glasgow coma scale score	13 (8–15)	15 (8–15)	0.06
APACHE II score	17 (10–19)	13 (8–16)	0.23
SOFA score	10 (7–14)	2 (1–2)	<0.001
Comorbidities (n)			
Hypertension	9	11	1.00
Type 2 diabetes	7	4	0.77
Coronary heart disease	8	7	0.66
FiO_2	0.5 (0.21–0.8)	0.3 (0.21–0.8)	0.05
PaO_2, (mmHg)	45 (40–63)	40 (32–56)	0.40
pH	7.39 (7.32–7.47)	7.45 (7.42–7.49)	0.24
Blood lactate (mmol/L)	1.4 (1.2–2.1)	1.9 (1.4–2.2)	0.42
Lymphocytes ($\times 10^9\ \mu L^{-1}$)	0.9 (0.6–1.5)	1.1 (0.8–1.6)	0.11
C-reactive protein, n (mg/dl)	93 (38–164)	74 (43–88)	0.32
Lactate dehydrogenase (U/L)	426 (319–537)	332 (187–403)	0.03
Aspartate transaminase (U/L)	37 (25–54)	29 (26–42)	0.15
Alanine aminotransferase (U/L)	23 (17–33)	24 (21–33)	1.00
Hospital stay (days)	15 (7–25)	25 (13–31)	0.06
ICU stay (days)	11.5 (4.5–21)	13 (5–19)	0.80
Total CT-SS	22 (11–30)	16 (9–18)	0.20
Ground-glass opacification, n	13	15	0.22
Concoliadation, n	6	7	0.76

Datas are shown as n (%) or median (IQR). APACHE: Acute physiology and chronic health evaluation, SOFA: Sequential organ failure assessment, ICU: Intensive care unit, CT: Computed tomography, SS: Severity score

mally distributed, was tested by Spearman's correlation. A value of $p<0.05$ was considered significant. Statistical analysis was performed with SPSS version 22.0 (SPSS, Inc., Chicago, IL, USA).

Results

During the 4 months, 50 COVID-19 patients were admitted to our ICU. Two patients died within 24 h after ICU admission, and 3 patients had not undergone CT on admission or within 24 h of admission. After these patients were excluded, 45 COVID-19 patients who had chest CT scans on admission were enrolled in the study. The SARS-CoV-2 RT-PCR test was positive in all patients of the study population.

Clinical characteristics of the patients who died and survived are shown in Table 1. Age was higher in patients who died [73 (69–86) vs 63 (49–79), p=0.02]. The sequential organ failure assessment (SOFA) score and lactate dehydrogenase were higher in patients who died ($p<0.001$ and p=0.03, respectively). Gender, comorbidities, APACHE II score, and PaO_2 were different between groups. Clinical characteristics of the patients in the IMV and without IMV groups are shown in Table 2. Age was higher in patients who needed IMV [76.5 (69–86) vs 58 (48–74), p=0.001]. The SOFA score, APACHE II score, and the number of days in the ICU were higher in patients who died ($p < 0.001$, p=0.02, and p=0.03, respectively). Gender and PaO_2 comorbidities were not differentiated between groups.

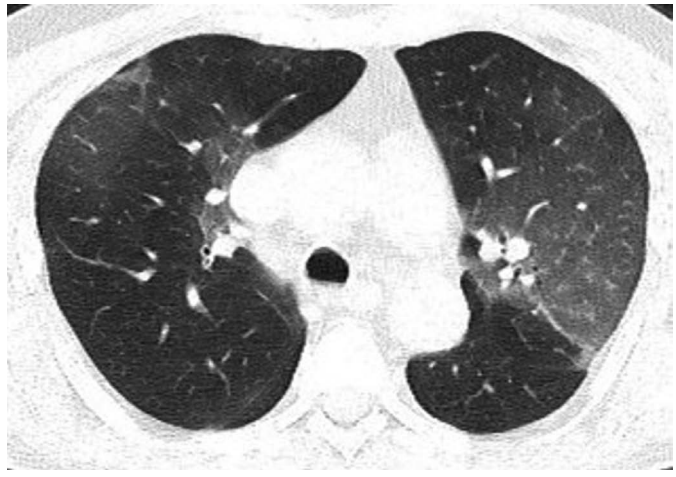

Figure 1: Ground-glass predominancy in a patient with COVID-19 pneumonia

Table 2: Clinical characteristics of patients who needed IMV and those who did not

Characteristics	IMV (n=24)	Without IMV (n=21)	p
Age (years)	76.5 (69–86)	58 (48–74)	0.001
Female, n (%)	11 (45.8)	11 (52.4)	0.66
Glasgow coma scale score	12.5 (8–15)	15 (13–15)	0.02
APACHE II score	17.5 (11–26)	14 (8–14)	0.02
SOFA score	9 (5–13)	1 (1–2)	<0.001
Comorbidities (n)	12	8	0.72
Hypertension	5	6	1.00
Type 2 diabetes	9	6	0.81
Coronary heart disease			
FiO_2 on the day of CT	0.45 (0.21–0.8)	0.30 (0.21–0.8)	<0.001
PaO_2 (mmHg)	55 (44–70)	40 (32–56)	0.40
pH	7.30 (7.28–7.47)	7.45 (7.42–7.49)	0.24
Blood lactate (mmol/L)	1.4 (1.2–2.1)	1.9 (1.4–2.2)	0.04
Lymphocytes ($\times 10^9\ \mu L^{-1}$)	0.9 (0.6–1.4)	1.1 (0.8–1.5)	0.24
C-reactive protein (mg/dl)	85 (40–158)	78 (48–103)	0.78
Lactate dehydrogenase (U/L)	414 (137–986)	332 (193–402)	0.12
Aspartate transaminase (U/L)	33 (23–52)	32.5 (27–45)	0.83
Alanine aminotransferase (U/L)	23 (16–29)	24.5 (22–41)	0.24
Hospital stay (days)	20 (8–30)	21 (13–30)	0.68
ICU stay (days)	18 (7–24)	9 (5–13)	0.03
Total CT score	22 (12–30)	15 (8–17)	0.17
Ground-glass opacification, n	16	12	0.66
Concoliadation, n	5	8	0.85

Dates are shown as n (%) or median (IQR). APACHE: Acute physiology and chronic health evaluation, SOFA: Sequential organ failure assessment, ICU: Intensive care unit, CT: Computed tomography

The most common CT findings included ground-glass opacification and consolidation [Figs. 1, 2]. There was predominant ground-glass opacification in 28 (68%) and consolidation in 13 (32%) of the patients with COVID-19 on ICU admission. There were no associations of predominant ground-glass opacification or consolidative opacification with mortality and IMV requirements (p=0.41 and p=0.44, respectively).

The total CT-SS was differentiated neither between patients who died and those who survived [22 (11–30) vs 16 (9–18), p=0.20] nor between patients who underwent IMV and those who did not [22 (12–30) vs 15 (8–17), p=0.17].

The median of CT-SS was 17 (9–29) (n=23 vs n=22). The total CT-SS was not associated with an increased risk of mortality in patients with COVID-19 pneumonia [Fig. 3]. The ROC curve to assess CT-SS as a predictor of mortality is shown in Figure 3. The AUC for prediction of mortality was 0.611 (95% CI of 0.434–0.788; p=0.20) and for prediction of the need for IMV was 0.640 (95% CI of 0.475–0.806; p=0.10) according to CT-SS [Figs. 3, 4]. CT-SS was not predictive for mortality and the need for IMV in patients admitted to ICU with COVID-19 pneumonia.

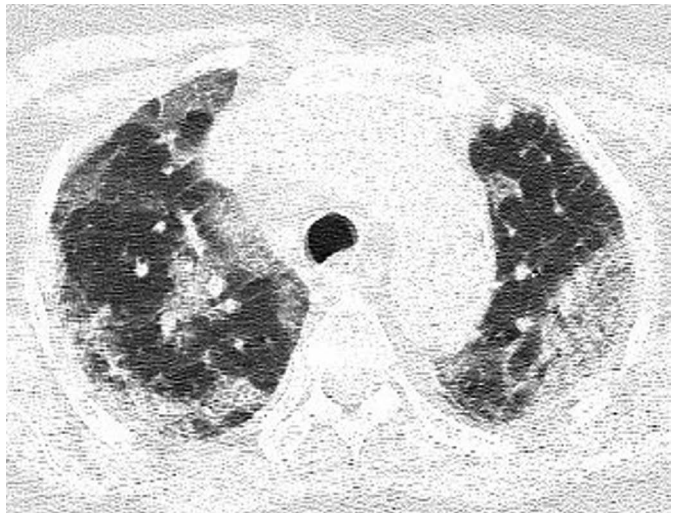

Figure 2: Consolidation predominancy in a patient with COVID-19 pneumonia

In the whole sample, among laboratory parameters including lactate, lymphocytes, CRP, lactate dehydrogenase, AST, ALT, and PCT, there was a positive correlation between CT-SS and CRP as well as between lactate dehy-

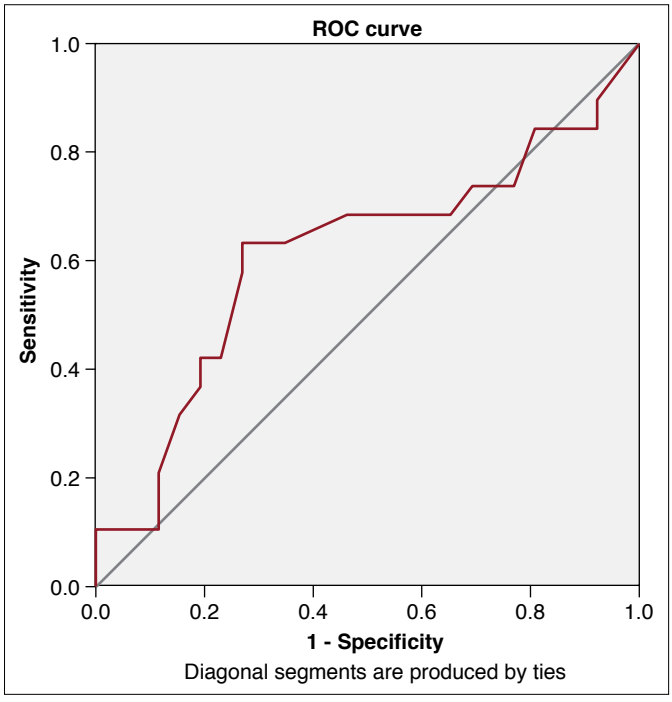

Figure 3: ROC curve of CT-SS for the estimation of mortality in COVID-19 patients

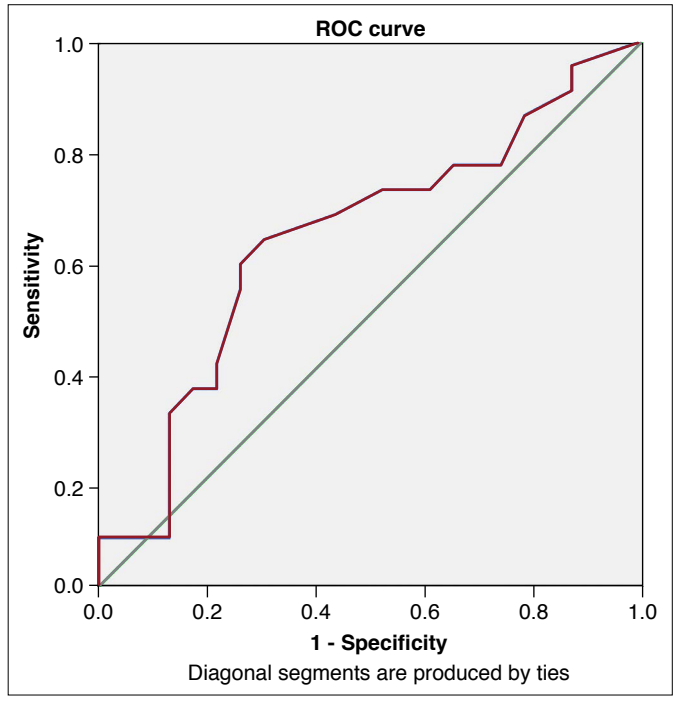

Figure 4: ROC curve of CT-SS for the estimation of need for IMV in COVID-19 patients

drogenase and aspartate transaminase (Spearman's correlation coefficient (rS)=0.54, p=0.004; rS=0.73, p=0.001; rS=0.63, p<0.001, respectively).

Discussion

Chest CT scanning is often used to estimate the severity of COVID-19 pneumonia.[9] We conducted this study to investigate whether chest CT severity scoring can be used in patients with COVID-19 admitted to ICU to provide information about prognosis and the need for IMV.

In this retrospective single-center study, the total CT-SS was not associated with an increased risk of mortality and need for IMV in patients with COVID-19 pneumonia. There is a positive correlation between CRP, lactate dehydrogenase, aspartate transaminase, and CT-SS.

In a study including elderly patients with COVID-19, the initial CT-SS was found to be valuable in predicting mortality (sensitivity of 83.3%, specificity of 77.3%, with an AUC value of 0.881 (cutoff > 14.5).[9] However, in this study population, 17 (17%) of 102 patients had dyspnea onset, and dyspnea was found to be higher in the group of those who died. The original scoring study included mild (n=84) and severe (n=18) COVID-19 patients.[8] All of our patients (n=45) had severe cases and were admitted to the ICU. The original study results showed a cut-off value of CT-SS to be 19.5 (83.3% sensitivity, 94% specificity) for severe patients.[8] In this study population, 15 of 18 severe patients and 5 of 84 mild patients had a CT-SS of >19.5. In a larger prospective study result, 44 (18%) of 235 patients with confirmed COVID-19 were admitted to the ICU with a mean CT-SS of 14.8.[10] They found an association of CT-SS with mortality and ICU admission. In this study, they also found that a CT-SS of >15 is predictive of ICU admission and >17 is predictive of 30-day mortality (both sensitivity and specificity were found to be >90%).[10] In our study, the median value of the CT-SS was the same as the cut-off point for 30-day mortality in the previous study. However, in our study including critically ill patients with COVID-19, we could not show the association between CT-SS and mortality. Unlike most studies on CT-SS, only critically ill patients were included in this study. Due to the high mortality rate in COVID-19 patients who were admitted to the ICU, it is difficult to predict mortality based on CT-SS.

Limited number of patients, individual variations including medications, respiratory support strategies, and inclusion of only critically ill patients may be the reasons

why the association between mortality and CT-SS could not be shown in this study.

The most common CT findings are ground-glass opacification, bilateral involvement, peripheral distribution, and multilobar involvement in patients with COVID-19.[6,11,12] In the early stages of COVID-19, patients showed more ground-glass opacification, and fewer involved pulmonary lobes. Over time, the crazy-paving pattern, an increased number of involved lobes and consolidations, occurred in severe COVID-19 patients.[7]

In a study, consolidations on initial chest CT were found to be more common in patients who died than in those who survived.[9] There was predominantly ground-glass opacification and consolidation in our patients with COVID-19 on ICU admission. We did not find an association of ground-glass opacification or consolidation predominancy with mortality and the requirement of IMV.

Acute respiratory distress syndrome (ARDS) is frequent in patients admitted to the ICU with COVID-19.[1] ARDS is a strong predictor of mortality.[13] The chest CT score is based on the severity and distribution of the pulmonary abnormality. The literature supports the argument that it is possible to predict the clinical course of ARDS with chest CT.[14,15] Pulmonary lesions which cause ARDS may be the reason for hyperinflammation.[16] In an Italian cohort of COVID-19 patients, inflammation markers (CRP, leucocytes, PCT), aspartate transaminase, and lactate dehydrogenase were shown to increase with severe lung involvement.[16] Early data on COVID-19 also showed that CRP and lactate dehydrogenase had been elevated in COVID-19 patients who died.[5] COVID-19 causes severe acute respiratory syndrome and hyperinflammatory syndrome.[17,18] In this study, a correlation was found between CT-SS and CRP, lactate dehydrogenase, and aspartate transaminase, indicating that these parameters are useful for detecting severe lung involvement.

This study had some limitations. It was a single-center study with a limited number of patients and did not consider individual variations, medications, and respiratory support strategies. In contrast to most studies on CT-SS, only critically ill patients were included in this study. Due to the high mortality rate in COVID-19 patients admitted to the ICU, it is difficult to predict mortality based on CT-SS.

Conclusion

In summary, in this single-center study, we observed that the total CT-SS was not associated with an increased risk of mortality and the need for IMV in patients admitted to ICU with COVID-19 pneumonia. The correlation between CT-SS and CRP, lactate dehydrogenase, and aspartate transaminase may reflect the association of inflammatory syndrome with the chest CT-SS.

Conflicts of interest

There are no conflicts of interest.

Ethics Committee Approval

The study was approved by the Izmir University of Health Sciences Tepecik Training and Research Clinical Research Ethics Committee (No: 2020/05-04, Date: 27/04/2020).

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Peer-review

Externally peer-reviewed.

Authorship Contributions

Concept – K.R., I.K.G., Y.P., N.S.G., Ç.Z., İ.S., T.Ç., A.S., U.U., N.Ş.; Design – K.R., I.K.G., Y.P., N.S.G., Ç.Z., İ.S., T.Ç., A.S., U.U., N.Ş.; Supervision – K.R., I.K.G., Y.P., N.S.G., Ç.Z., İ.S., T.Ç., A.S., U.U., N.Ş.; Funding – K.R., I.K.G., Y.P., N.S.G.; Materials – Y.P., N.S.G., I.K.G.; Data collection &/or processing – Y.P., N.S.G., I.K.G.; Analysis and/or interpretation – K.R., I.K.G., Y.P., N.S.G.; Literature search – A.S., U.U., Ç.Z., N.Ş., T.Ç., İ.S.; Writing – K.R., I.K.G., Y.P., N.S.G.; Critical review – K.R., I.K.G., Y.P., N.S.G., Ç.Z., İ.S., T.Ç., A.S., U.U., N.Ş.

References

1. World Health Organization website. Coronavirus disease (COVID-2019) situation reports. Geneva: World Health Organization. Available at: https://www.who.int/emergencies/diseases/novel-coronavirus-2019. Accessed Apr 16, 2021.
2. Wu Z, McGoogan JM. Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China: Summary of a report of 72 314 cases from the Chinese center for disease control and prevention. JAMA 2020;323:1239–42.
3. Guan WJ, Ni ZY, Hu Y, Liang WH, Ou CQ, He JX, et al. Clinical characteristics of coronavirus disease 2019 in China. N Engl J Med 2020;382:1708–20.
4. Yang X, Yu Y, Xu J, Shu H, Xia J, Liu H, et al. Clinical course and outcomes of critically Ill patients with SARS CoV 2 pneumonia

in Wuhan, China: A single cantered, retrospective, observational study. Lancet Respir Med 2020;8:475–81.

5. Zhou F, Yu T, Du R, Fan G, Liu Y, Liu Z, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: A retrospective cohort study. Lancet 2020;395:1054–62.
6. Salehi S, Abedi A, Balakrishnan S, Gholamrezanezhad A. Coronavirus disease 2019 (COVID-19): A systematic review of imaging findings in 919 patients. AJR Am J Roentgenol 2020;215:87–93.
7. Pan F, Ye T, Sun P, Gui S, Liang B, Li L, et al. Time course of lung changes at chest CT during recovery from coronavirus disease 2019 (COVID-19). Radiol 2020;295:715–21.
8. Yang R, Li X, Liu H, Zhen Y, Zhang X, Xiong Q, et al. Chest CT severity score: An imaging tool for assessing severe COVID-19. Radiol Cardiothorac Imaging 2020;2:e200047.
9. Li Y, Yang Z, Ai T, Wu S, Xia L. Association of "initial CT" findings with mortality in older patients with coronavirus disease 2019 (COVID-19). Eur Radiol 2020;30:6186–93.
10. Lieveld AWE, Azijli K, Teunissen BP, van Haaften RM, Kootte RS, van den Berk IAH, et al. Chest CT in COVID-19 at the ED: Validation of the COVID-19 reporting and data system (CO-RADS) and CT severity score: A prospective, multicenter, observational study. Chest 2021;159:1126–35.
11. Chung M, Bernheim A, Mei X, Zhang N, Huang M, Zeng X, et al. CT imaging features of 2019 novel coronavirus (2019-nCoV). Radiology 2020;295:202–7.
12. Shi H, Han X, Jiang N, Cao Y, Alwalid O, Gu J, et al. Radiological findings from 81 patients with COVID-19 pneumonia in Wuhan, China: A descriptive study. Lancet Infect Dis 2020;20:425–34.
13. Fan E, Brodie D, Slutsky AS. Acute respiratory distress syndrome: Advances in diagnosis and treatment. JAMA 2018;319:698–710.
14. Nishiyama A, Kawata N, Yokota H, Sugiura T, Matsumura Y, Higashide T, et al. A predictive factor for patients with acute respiratory distress syndrome: CT lung volumetry of the well-aerated region as an automated method. Eur J Radiol 2020;122:108748.
15. Ichikado K, Suga M, Muranaka H, Gushima Y, Miyakawa H, Tsubamoto M, et al. Prediction of prognosis for acute respiratory distress syndrome with thin-section CT: Validation in 44 cases. Radiol 2006;238:321–9.
16. Canovi S, Besutti G, Bonelli E, Iotti V, Ottone M, Albertazzi L, 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;21:157.
17. Tang Y, Liu J, Zhang D, Xu Z, Ji J, Wen C. Cytokine storm in COVID-19: The current evidence and treatment strategies. Front Immunol 2020;11:1708.
18. Gustine JN, Jones D. Immunopathology of hyperinflammation in COVID-19. Am J Pathol 2021;191:4–17.