

The relationship between thorax computed tomography findings and prognosis in patients diagnosed with COVID-19

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Abstract. – OBJECTIVE: This study aimed to demonstrate the relationship between thorax computed tomography (CT) findings at the time of admission and prognosis using a semi-quantitative CT severity scoring system in patients diagnosed with coronavirus disease 2019 (COVID-19) who tested positive for reverse transcriptase polymerase chain reaction (RT-PCR).

PATIENTS AND METHODS: A total of 305 patients aged 18 years and older who were diagnosed with COVID-19 confirmed by RT-PCR and underwent thorax CT at the time of admission, were included in the study between March and July 2020. The demographic data of the patients, their presenting complaints at the time of admission, RT-PCR results, and thorax CT images were scanned retrospectively from electronic medical records. Lesions on thorax CT were evaluated for the presence of ground glass opacity, consolidation, and septal thickening and scoring.

RESULTS: No significant relationship was found between mortality and CT score or other parameters. A significant relationship was found between admission to the intensive care unit and CT scoring ($p=0.014$), aortic diameter ($p=0.032$), chronic pulmonary disease ($p=0.004$), halo sign ($p=0.031$), mortality ($p<0.001$), fever ($p=0.038$), and dyspnea ($p=0.031$). A statistically significant difference was detected in the score parameter between discharged patients and intensive care unit patients who survived and those who died ($p<0.001$). In the parameter of the number of lobes, a statistically significant difference was found only between discharged patients and intensive care unit patients who survived ($p=0.016$).

CONCLUSIONS: Thorax CT is an advisor for early diagnosis, treatment, and prognosis assessment of the disease. Semiquantitative CT severity scoring can provide valuable information about the prognosis of the patient.

Key Words:

COVID-19, Thorax CT, CT severity score.

Introduction

Thorax CT plays a significant role in the identification of risk factors associated with the prognosis of the disease, determining diagnosis and treatment algorithms, and planning treatment at an early stage. Previous studies¹ have shown that older age, comorbid chronic diseases, and ARDS are associated with increased mortality in critically ill patients diagnosed with COVID-19. It has been demonstrated^{2,3} that thorax CT plays a crucial role in assessing the severity of COVID-19. Bilateral, multilobar infiltration, age, hypertension, low lymphocyte count, bacterial superinfection, and smoking have been found²⁻⁴ to be associated with the severity of the disease.

While a negative RT-PCR result does not rule out a diagnosis of COVID-19, multiple test repetitions may be required. Recent studies^{5,6} have emphasized the importance of thorax CT examination in cases where there are false-negative RT-PCR results in COVID-19 patients and have reported⁷ a CT sensitivity of 98%.

A relationship has been found⁸ between disease progression and laboratory tests such as age, leukocyte count, lymphocyte count, and C-reactive protein.

In this study, we aimed to investigate the relationship between the thorax CT findings at the time of admission and the prognosis of patients diagnosed with COVID-19 and tested positive with RT-PCR with a semiquantitative thorax CT severity scoring system.

Patients and Methods

A retrospective study was planned by including those among 750 patients who underwent thorax CT, tested positive with RT-PCR, and were

admitted for hospitalization and follow-up at the Kayseri City Hospital pandemic outpatient clinic between March 15 and July 1, 2020. Patients under the age of 18 (n=28) and patients with normal thorax CT findings (417) were excluded from the study. The initial thorax CT, clinical symptoms at admission (fever, cough, dyspnea, sore throat, running nose, nausea, diarrhea, fatigue, muscle ache, headache), and laboratory tests (white blood cell count, lymphocyte count, neutrophil count, hemoglobin level, C-reactive protein level) were re-evaluated. The presence of comorbidities in patients was also examined. Whether the patients required mechanical ventilators was evaluated retrospectively. All patients were treated with the standard treatment protocol determined by the National Scientific Committee during their hospital follow-ups⁹. Discharge was performed in cases where there was no fever for more than 3 days, absence of respiratory distress, improvement in lung inflammation observed on CT, and two consecutive negative RT-PCR test results.

The examinations were performed using a 16-detector multislice CT system (Somatom Sensation16, Siemens, Germany) without the administration of a contrast agent. The section thickness was set at 5 mm, and multiplanar reconstructions with a thickness of 1.5 mm were conducted. The CT scan protocol was tube voltage of 120 kVp; mAs 30-70, pitch = 1.84. The thorax CT scans were evaluated by two radiologists with 10 and 15 years of experience, using both mediastinal and parenchymal windows. The thorax CT findings were evaluated according to the Fleischner Society Glossary of Terms for Thoracic Imaging¹⁰. The findings were retrospectively re-evaluated in terms of ground glass opacity, consolidation, reticular-linear opacities, pleural effusion, and mediastinal lymphadenopathy. Morphologically, patchy/segmental, round/nodular halo and reversed halo, crazy paving, reticular, and linear opacities were evaluated. The laterality of the lesions was determined. The peripheral/central and anterior/posterior location was determined. The peripheral location was identified as the outer one-third of the lung, while the central location was identified as the inner two-thirds of the lung. The affected lobes were also detected. The percentage of the lungs affected by the identified lesions was calculated using the semiquantitative thorax CT severity scoring system. In the scoring system, a score of 1 was given to lesions involving 1-25% of each lung lobe, a score of 2 to lesions involving 26-50%, a score of 3 to lesions involving 51-75%, and

a score of 4 to lesions involving 76-100% of lung lobes. The total severity score was determined by summing five lobe scores (in the range of 0-25).

Statistical Analysis

SPSS (ver. 22.0; IBM Corp., Armonk, NY, USA) software was used for statistical analysis in evaluating the findings obtained in the study. During the evaluation of the study data, the suitability of the parameters for normal distribution was assessed using the Shapiro-Wilk test. During the evaluation of the study data, in addition to descriptive statistical methods (mean, standard deviation, frequency), Student's *t*-test was used for comparing quantitative data with normal distribution between two groups. It was observed that the groups did not exhibit homogeneous distribution according to the Shapiro-Wilk test. Therefore, binary logistic regression analysis was carried out to determine the clinical-radiological parameters that could predict intensive care admission and mortality criteria. The significance was evaluated at $p < 0.05$ level.

Results

The mean age was 49.8 ± 17 . A total of 305 patients were included in the study, consisting of 158 males (51.8%) and 147 females (48.2%). The number of dead patients was 21 (6.9%), the number of discharged patients was 284 (93.1%); the number of patients admitted to the intensive care unit was 44 (14.4%). The mean age of dead patients was 75.7 ± 10 (52-91), while the mean age of discharged patients was 47.9 ± 15.9 (18-93).

The distribution of symptoms among the patients was as follows: fever 33.4% (102/305), cough 52.1% (159/305), dyspnea 29.5% (90/305), nausea 10.2% (31/305), sore throat 16.4% (50/305), running nose 1.6% (5/305), fatigue 23.6% (72/305), muscle ache 14.1% (43/305), diarrhea 9.5% (29/305), headache 4.9% (15/305). The distribution of clinical findings and comorbidities among dead patients, patients admitted to intensive care unit, and discharged patients is summarized in Table I. The summary of thorax CT findings is given in Table II. No statistically significant correlation was found between any parameter and mortality. There was a statistically significant relationship between intensive care unit admission and certain categories (Table III). 95.2% (20/21) of the dead patients were admitted to the intensive care unit. 45.5% (20/44) of the

Table I. Distribution of clinical findings and accompanying diseases according to patients admitted to the intensive care unit, dead and discharged.

Clinical findings	Deaths	ICU	Discharges	Total
Fever	13	29	73	115 (37.7%)
Cough	12	31	128	171 (56%)
Dyspnea	12	26	64	102 (33.4%)
Nausea	1	6	25	32 (10.49%)
Sore throat	1	2	48	51 (16.7%)
Runny nose	0	1	4	5 (1.6%)
Fatigue	5	9	63	77 (25.2%)
Muscle ache	4	7	36	47 (15.4%)
Diarrhea	1	3	26	30 (9.8%)
Headache	0	1	14	15 (4.9%)
Hypertension	9	15	43	67 (21.9%)
Diabetes mellitus	3	8	24	35 (11.4%)
Chronic obstructive pulmonary disease	2	11	13	26 (8.5%)
Congestive heart failure	2	7	6	15 (4.9%)
Chronic renal disease	1	1	1	3 (0.9%)
Cancer	1	1	2	4 (1.3%)

Table II. Distribution of thorax CT findings according to patients admitted to the intensive care unit, dead, and discharged.

Radiologic findings	Deaths	ICU	Discharges	Total
Ground-glass opacity (GGO)	2	5	95	102 (33.4%)
Consolidation (C)	1	4	9	14 (4.6%)
GGO-C	7	19	136	162 (53.1%)
GGO-C-septal thickening	14	18	6	38 (12.5%)
Halo sign	0	2	10	12 (3.9%)
Reversed Halo sign	0	1	17	18 (5.9%)
Peripheral distribution	2	15	187	207 (67.9%)
Central distribution	0	0	4	4 (1.3%)
Peripheral/central distribution	18	28	47	94 (30.8%)
Craniocaudal (upper lobe)	1	3	17	21 (6.9%)
Craniocaudal (lower lobe)	1	2	51	54 (17.7%)
Craniocaudal (upper-lower lobe)	19	39	172	230 (75.4%)
Anterior distribution	1	1	7	9 (3%)
Posterior distribution	1	7	115	123 (40.3%)
Anterior-posterior distribution	19	36	118	173 (56.7%)
Laterality (unilateral lung)	4	6	40	50 (16.7%)
Laterality (bilateral lung)	17	38	195	250 (83.3%)
Focality (unilateral)	2	3	28	33 (10.8%)
Focality (multilateral)	5	21	199	225 (73.8%)
Focality (diffuse)	13	19	15	47 (15.4%)
Shape (nodular)	1	5	140	146 (47.9%)
Shape (patchy)	17	30	38	85 (27.9%)
Shape (nodular-patchy)	2	7	65	74 (24.2%)

patients admitted to the intensive care unit died. One person died without being admitted to the intensive care unit (ICU) (4.8%; 1/21).

Kruskal-Wallis' analysis was conducted to determine whether there were statistically significant differences between the groups in terms of score, number of lobes, aortic diameter, and pulmonary artery diameter (Table IV). A statistically significant difference was registered in

the score parameter between discharged patients and both dead patients and ICU-admitted patients ($p<0.001$). However, there was no significant difference between dead patients and discharged intensive care unit admitted patients. Regarding the number of affected lobes, there was a statistically significant difference between patients who were only discharged and discharged intensive care unit admitted patients ($p=0.016$). There was

no significant difference among the other groups. Regarding the aortic diameter parameter, there was a significant difference between dead patients and discharged intensive care unit admitted patients ($p=0.03$), while no statistically significant difference was found among the groups in terms of the pulmonary artery diameter parameter.

Significant relationships were registered between CT severity scoring and CRP, white blood cell count, neutrophil count, and hemoglobin levels (0.00, 0.012, 0.04, 0.029, respectively). However, no significant correlation was observed between CT severity scoring and lymphocyte and monocyte counts.

Discussion

Significant relationships were found between ICU admission and CT severity scoring, halo sign, dyspnea, fever, and COPD, as well as mortality.

The overall mortality rate in the general population was 1.4-8%¹¹. In our study, the mortality rate was found to be 6.9%, and the requirement for intensive care was found to be 14.4%. According to the literature, the reason for the high rates observed is due to the inclusion of CT-positive patients in the study. Although old age, underlying chronic diseases, immunosuppression, and metabolic syndrome conditions such as obesity have been associated with severe illness and death in many studies in literature, a definitive cause has not been determined. In our study, a significant relationship was found between severe illness and old age, as well as the comorbidity of COPD.

The most common CT finding in COVID-19 pneumonia is described as ground-glass opacities, which typically exhibit a bilateral, peripheral, multilobar, and posterior distribution, as reported in various studies¹²⁻¹⁴. Ground glass opacity was observed¹⁵ alone, as well as with different findings such as consolidation, interlobular septal thickening, and vascular dilatation. In our study, the most common pattern was nodular ground glass opacity and consolidation areas with peripheral

Table III. Clinical-CT findings showing a significant relationship with ICU admission.

Intensive care need	p-value
Score	0.014
Aort diameter	0.032
Chronic obstructive pulmonary disease	0.004
Halo sign	0.031
Mortality	0.000
Fever	0.038
Dispnea	0.031

* CT: Computed tomography, ICU: Intensive care unit, $p<0.005$ is significant.

distributions. Both lung involvement, multifocality with involvement of upper-lower lobes, and involvement of anterior-posterior regions together were more commonly observed. In the meta-analysis conducted by Zarifian et al¹⁶, the reported rates were as follows: GGO (77.18%, 72.23-81.47%), reticulations (46.24%, 38.51-54.14%), air bronchogram (41.61%, 32.78-51.01%), bilateral lung involvement (75.72%, 70.79-80.06%) and peripheral involvement (65.64%, 58.21-72.36%). The frequency of consolidation as a single finding was 14%. Pan et al¹⁷ reported in their study that consolidation was rarely seen in the early stages and became more prominent and diffuse in the later stages.

The frequent co-occurrence of ground glass opacities and consolidation in CT scans taken at the time of patient admission indicates the patients' delayed application to the hospital. Patients who did not provide sufficient and accurate information about the onset of symptoms were not included in the study. In another study¹⁸, it has been shown that interlobular septal thickening, air bronchogram, pleural effusion, and consolidations were shown to be more commonly observed in severe disease, while only ground glass opacity areas were associated with mild disease. In our study, we also observed that the co-occurrence of ground glass opacities and septal thickening was more frequent in the severe disease group. There was a significant relationship between the halo

Table IV. Distribution of CT score, number of involved lobes, aortic and pulmonary artery diameter according to patients admitted to the intensive care unit, died patients, and discharged patients.

	Death	ICU (discharge)	Discharge
Score (mean \pm SD)	12.57 \pm 6.02	9.33 \pm 4.37	5.6 \pm 3.34
Number of lobe (mean \pm SD)	4.29 \pm 1.41	4.42 \pm 1.21	3.62 \pm 1.51
Aort diameter (mean cm \pm SD)	34.14 \pm 4.33	31.13 \pm 2.81	31.9 \pm 2.64
Pulmonary artery diameter (mean cm \pm SD)	26.52 \pm 5.14	25.42 \pm 2.14	24.65 \pm 2.24

sign and admission to the intensive care unit. In previous meta-analyses^{19,20}, the reported prevalence of the halo sign was 25%, while the reverse halo sign was reported to be 12%.

In the meta-analysis conducted by Wan et al²¹, the reported prevalence rates were as follows: GGO (69%, 58-80%), consolidation (47%, 35-60%), and air bronchogram (46%, 25-66%).

In the meta-analysis conducted by Madani et al²², a significant relationship was found between severe disease and bronchial thickening, crazy paving, linear opacity, GGO, and bilateral lung involvement. No significant relationship was found with consolidation.

In the study conducted by Yaltırık Bilgin et al²³, similar to our study, they found a significant association between mortality, intensive care requirement, and CT scoring. In the study conducted by Komurcuoglu et al²⁴, they found a significant relationship between disease severity, prognosis, and CT scoring.

In our study, similar to many other studies in literature, a significant relationship was found between CT scoring and CRP, leukocyte count, neutrophil count, and hemoglobin values. No significant relationship was found between lymphopenia and scoring. This condition may be secondary to bacterial superinfections.

Limitations

The limitations of our study include its retrospective design, and the inclusion of findings specific to the alpha variant of the coronavirus. Additional research is required to understand the differences in the course and manifestations of the disease associated with the Delta and Omicron variants. CT scoring is a semiquantitative method, visual assessments are used to calculate percentage measurements. Studies that utilize volumetric measurements will give more accurate results. For example, Zuo et al²⁵ found that accurate measurement of lesion volume and volume changes by AI technology is helpful in assessing the severity and development trend of the disease.

Conclusions

The thorax CT findings at the time of admission and semiquantitative CT scoring have been found to be associated with the prognosis of the disease and laboratory findings; thus, they can guide the early monitoring and treatment of patients who may require intensive care.

Ethics Approval

The ethics approval was obtained from the Ethics Committee of Kayseri City Hospital. Date/No. of approval: 06.08.2020/No. 138.

Conflict of Interest

All authors declare that they do not have any conflict of interest regarding the study.

Informed Consent

Informed consent was obtained from the relatives or from the patients included in the study.

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Availability of Data and Materials

The data generated and analyzed during the study are available from the corresponding author. They are not available publicly.

Authors' Contributions

The concept for research or article/hypothesis generation: EA. Planning the methods to generate the hypothesis: EA, TS, TUS, UC. Supervision and responsibility for the organization and course of the project and manuscript preparation: EA, IC. Supplying equipment, space, and personnel vital to the Project: AS, T TT, DKG. Discussion of the results, and approval of the final version of the work: EA, TS, IC.

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