Original Article

Evaluation of the value of chest CT severity score in assessment of COVID-19 severity and short-term prognosis

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Abstract

Background: Evaluations have shown that the severity of pulmonary involvement is very important in the mortality rate of patients with coronavirus disease 2019 (COVID-19). The purpose of this study was to evaluate the value of chest CT severity score in assessment of COVID-19 severity and short-term prognosis. **Materials and Methods:** This study was a cross-sectional study with a sample size of 197 patients, including all patients admitted to Rasoul Akram Hospital, with positive polymerase chain reaction, to investigate the relationship between computed tomography (CT) severity score and mortality. The demographic data and CT scan findings (including the pattern, side, and distribution of involvement), co-morbidities, and lab data were collected. Finally, gathered data were analyzed by SPSS-26. **Results:** 119 (60.4%) patients were male, and 78 (39.6%) were female. The mean age was 58.58 ± 17.3 years. Totally, 61 patients died; of those, 41 (67.2%) were admitted to the intensive care unit (ICU), so there was a significant relation between death and ICU admission (*P* value = 0.000). Diabetes was the most common co-morbidity, followed by hypertension and IHD. There was no significant relation between co-morbidities and death (*P* value = 0.13). The most common patterns of CTs were interlobular septal thickening and ground glass opacities, and a higher CT severity score was in the second week from the onset of symptoms, which was associated with more mortality (*P* value < 0.05). **Conclusion:** Our study showed that a patient with a higher CT severity score of the second week had a higher risk of mortality. Also, association of the CT severity score, laboratory data, and symptoms could be applicable in predicting the patient's condition.

Keywords: COVID-19, CT severity score, PCR (polymerase chain reaction). PCR

Introduction

Coronavirus disease (COVID-19), caused by a novel coronavirus named severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has spread to 223 countries with more than 186 million confirmed cases and more than 4 million deaths. According to the latest guidelines for the diagnosis and treatment of pneumonia caused by COVID-19, the confirmation of COVID-19 should be done by reverse transcription polymerase chain reaction (RT-PCR), but due to the limitations of sample collection, the total positive PCR in combined throat/nasal swabs was reported about 30–60% in the initial presentation.[1-5] Computed tomography (CT) is the most sensitive tool for diagnosing COVID-19, and several radiological patterns are seen in different phases of disease.[5] Among different patterns of chest CT scan, ground glass opacities (GGOs) and mixed GGO with consolidation are reported as the most common patterns in COVID-19 patients.[6] Although definite diagnosis

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relies on real-time reverse-transcriptase-polymerase chain reaction,[7] chest CT is a valuable modality to measure the extent of lung involvement and propose a treatment plan.

Several studies have shown that PCR-based methods have limited sensitivity, but chest CT scan shows abnormalities in several COVID-19 patients.[7-9] For asymptomatic subjects or patients with initial negative RT-PCR but clinically symptomatic, CT scanning has a higher sensitivity compared to RT-PCR; however, CT has some disadvantages such as low specificity.[10]

Fang *et al.* in a cross-sectional study compared the chest CT and serial RT-PCR and showed that the RT-PCR positive rate was 59%, while the positive rate for chest CT was 88%. Also, 75% of patients with negative RT-PCR had positive chest CT for COVID-19.[11] In another study, Ai *et al.* compared the sensitivities of CT scan and RT-PCR; they reported that CT scan had 98% sensitivity for COVID-19, while this was 71% for RT-PCR.[10] Due to the shortages of the RT-PCR test and high sensitivity of CT scan for COVID-19 diagnosis, studies support the use of chest CT as an available method for screening patients with COVID-19.[10,11]

After it was found that the severity of the disease is related to the lung involvement severity and these areas become wider with the disease progress, the utility of CT findings is valuable to predict the severity of the disease in the early stages and effective management.[12,13] Assessment of the 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 patients' management. Recent studies support the role of chest CT scan as a valuable tool in prioritizing the patients in hospital triage.[14,15] Therefore, 7 CT severity score (CT-SS) was designed to identify the severity of COVID-19[16-22] [Table 1].

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.

Materials and Methods

Design

This study was a cross-sectional study to investigate the relationship between CT severity score and mortality rate in 197 patients. From March 2019 to June 2020, patients with COVID-19 pneumonia (confirmed by positive RT-PCR) who were admitted to Rasoul Akram Hospital in Tehran were retrospectively enrolled in the study.

The data were gathered by entering the patient code in the PACS and patient management system. The socio-demographic data including age, gender, hospitalization date, the current status of the patient (survivor or deceased), patient symptoms, co-morbid disease, and laboratory data were collected. Then CT scan findings, including the involvement side, pattern, and distribution and the segment severity involvement, were entered by an experienced radiologist in the collection form. To this aim, CT severity score system 4 was chosen because by using CT-SS, it was possible to distinguish the presence of small ground glass patches with less than 5% involvement.

Data collection

The data collection form has been designed by the authors. The data were gathered by entering the patient code in the PACS and patient management system.

Tools

The study is cross-sectional, and the sample size includes all patients admitted to Rasoul Akram Hospital in Tehran with

Table 1: Seven proposed CT severity scoring systems.

CTSSs	Segmentation	Severity score for each segment	Maximum score
CTSS1	1–4 according to percentage of involvement (<25, 25–49, 50–74, >75)	Three zones in each lung are divided by carina and lower pulmonary vein	24
CTSS2	1–4 according to percentage of involvement (<25, 25–49, 50–74, >75)	The same zonal concept as CTSS1 with additional division of each zone into anterior and posterior regions divided by midpoint of diaphragm antero-posteriorly	48
CTSS3	1–4 according to percentage of involvement (<25, 25–49, 50–74, >75)	Five anatomic lobes of the lungs	20
CTSS4	1–5 according to percentage of involvement (<5, 5–25, 25–49, 50–74, >75)	Five anatomic lobes of the lungs	25
CTSS5	1–4 according to the diameter of the largest lesion in each lobe (<1 cm, 1–3 cm, >3 cm up to 50% of the lobe, >50% of a lobe	Five anatomic lobes of the lungs	20
CTSS6	No involvement=0 <50% involvement=1 ≥50% involvement=2	18 anatomic segments of the lung with an additional division of apico-posterior segment of the left upper lobe into apical and posterior divisions and anteromedial segment of the left lower lobe into anterior and medial segments	40
CTSS7	1–5 according to percentage of involvement (<5, 5–25, 25–49, 50–74, >75)	Five anatomic lobes of the lungs with additional consideration of the lingula as a separate lobe	30

a positive PCR test for COVID-19 between March 2019 to June 2020. It is estimated that during this period, about 150 hospitalized patients with positive PCR have been registered.

Ethical considerations

The ethical principles of research and the Helsinki Convention will be observed in all stages of the research. The principle of data confidentiality and confidentiality of patient information and their documents and records will be respected through the use of patient codes, and the information entered in the checklists will only be available to the plan administrators. The data obtained from the checklist are entered with the replacement code and then in the SPSS software.

Statistical analysis

Data were analyzed by IBM SPSS Statistics (v. 26.0). To report the frequencies and percentages of categorical variables, descriptive statistics were used, and only valid percentages are reported. The relationship between qualitative variables was compared through Chi-square test. T-test will be used to compare means, and analysis of variance (ANOVA) test will be used to compare more than two variables. A significance level of 0.05 will be considered.

Results

This study was a cross-sectional study to investigate the relationship between CT severity score and mortality rate. Totally 197 patients, within the age range of 17–98 and an average age of 58.58 ± 17.2, were involved in our study; more than half of them were female (60.4%, *N* = 119) [Table 2].

In the present study, 61 (30.96%) of patients died during hospitalization. Statistical analysis showed a significant difference in age between the deceased group and the survivor group (*P* value = 0.000) and also significant relation between age and gender with death (*P* value = 0.002 and 0.000, respectively).

Admission state

Totally, 44 patients (22.3%) were admitted to the intensive care unit (ICU), and according to the results, a total of 61 patients died. Of those, 41 (67.2%) were admitted to ICU, so there was significant relation between death and ICU admission (*P* value = 0.000) [Table 3].

Symptoms

The most common symptoms on admission were cough, dyspnea, and fever in 117, 114, and 111 patients, respectively [Table 4].

Co-morbidity present

80 (40.6%) patients had a co-morbidity, with diabetes being the most common (49 patients), followed by hypertension (43 patients) and IHD (33 patients). Therefore, there was no significant relation between co-morbidities and death (*P* value = 0.13).

Table 2: Demographic data in deceased and survivor groups

Variable	Deceased	Survivors	Total
Age			
Frequency	61	136	197
Minimum	22	17	17
Maximum	98	93	98
Mean	67.984	54.368	58.584
SD	16.013	16.239	17.32
P		0.000	
Gender			
Male	44	75	
Female	17	61	
Total	61	136	

The outcome was defined by survivor group or deceased group. In

Table 3: Comparison of the hospitalization in deceased and survivor groups

	Place of hospitalization		Total
	Ward	ICU	
Deceased			
Frequency	20	41	61
Percentage	32.8	67.2	100
Survivors			
Frequency	133	3	136
Percentage	97.8	2.2	100
Total			
Frequency	153	44	197
Percentage	77.7	22.3	100

Table 4: Frequency of patients' symptoms

Symptoms	Frequency	Percentage
Fever	111	56.3
dyspnea	114	57.9
Cough	117	59.4
Myalgia	66	33.5
Headache	14	7.1
Gastrointestinal symptoms	36	18.3
etc. (dizziness/loss of consciousness/ hemoptysis/convulsions)	9	4.6
Asymptomatic	2	1

We also then examined each of the co-morbidities separately. Analysis showed increasing odds of in-hospital death associated with IHD (*P* value = 0.00).

Lab data

Totally, 80 (40.6%) and 95 (48.2%) patients had thrombocytopenia and lymphopenia, respectively. There was significant relation between thrombocytopenia, lymphopenia, and creatine kinase and death (*P* value = 0.013, 0.001, and 0.01, respectively). Also, analysis showed that there was no significant relation between abnormal LFT, ESR, CRP, and IL6 and death (0.08, 0.39, 0.54, and 0.45, respectively).

Table 5: Chest CT scan findings

Pattern	Total		1st week		2nd week		3rd week		More than a month	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
IST	103	56.3	43	48.3	52	72.2	7	46.7	1	14.3
Only GGO	82	44.8	52	58.4	22	30.6	5	33.3	3	42.9
Mixed	78	42.6	28	31.5	42	58.3	8	53.3	0	0.0
Vascular thickening	28	15.3	16	18	12	16.7	0	0.0	0	0.0
Only consolidation	12	6.6	3	3.4	7	9.7	1	6.7	1	14.3
Nodule	2	1.1	1	1.1	1	1.4	0	0.0	0	0.0

Table 6: CT severity index of the first and second weeks

Variable	Group	Frequency	Minimum	Maximum	Mean	SD	*P*
CT severity Index of the first week	Deceased	31	0	25	11.903	8.78	0.134
	Survivor	58	0	19	7.793	4.167	
	Total	89	0	25	9.225	6.435	
CT severity index of the second week	Deceased	19	1	22	14	6.009	0.001
	Survivor	53	0	25	9.83	4.445	
	Total	72	0	25	10.931	5.2011	

Patient hospitalization

The mean hospitalized period in deceased and survived patients was compared using the Mann–Whitney test. Investigations show that there was no significant difference between duration of patient hospitalization and death (*P* value = 0.096).

Chest CT evaluation

Of all, 107 (74.8%) underwent CT once, 32 (22.4%) underwent CT twice, and 4 (2.8%) underwent CT three times. Out of a total of 183 CT cases, 89 (48.6%) were performed in the first week of symptom onset, 72 (39.3%) were performed in the second week, 15 (8.2%) were performed in the third week, and 7 (3.8%) were delayed (after 1 month) [Table 5].

Totally, CT imaging findings were analyzed for all patients of the 197 cases. In our study, interlobular septal thickening (IST) (56.3%) was the most common finding. The other typical findings were GGO alone (44.8%) and GGO with consolidation (42.6%) [Table 5].

Moreover, CT images show unifocal involvement in 4 (2.2%), multi-focal involvement in 168 (91.8%) patients, and none of them in 11 (6%). The main pattern of distribution was mix (peripheral < central) (112 of 197, 61.2%); the other typical patterns of distribution were peripheral [42 (23%)], mix (peripheral = central) [17 (3.9%)], and mix (peripheral < central) [1 (5%)]. Pleural effusion, pulmonary nodules, lymphadenopathy, cavitation, and tree in bud were rare.

The mean of CT severity score was 9.8 ± 6.2 in the first week, 10.9 ± 6.4 in the second week, 11.7 ± 7.3 in the third week, and delayed 2.1 ± 2.3. The mean of CT severity score in the first week was 11.9 ± 8.78 in the deceased group and 7.79 ± 4.16 in the survivor group; there was no statistical relationship between the mean of first-week CT severity score and death (0.13). The mean of CT severity score in the second week was 14 ± 6 in the deceased group and 9.83 ± 4.44 in the survivor group; there was statistical relationship between the mean of second-week CT severity score and death (0.001) [Table 6].

Discussion

The aim of this study was to investigate the relationship between CT severity score and mortality rate in patients with a positive COVID-19 PCR test admitted to Rasoul Akram Hospital in Tehran from March 2019 to June 2020. Our study investigated the relationship between laboratory data and mortality; there was no significant relation between LFT, ESR, and CRP and mortality. However, thrombocytopenia, lymphopenia, LDH, and CPK had a significant relation with death. Serum levels of LDH and CRP are increased in COVID-19 as well as other inflammatory diseases, and patients with high serum levels of CRP and LDH had higher mortality rates. In another study conducted in Iran in 2020, initial assessment of COVID-19 patients, including symptoms, vital signs, and CRP, ESR, and LDH, had a positive correlation with the severity of lung involvement and unfavorable outcomes.[23]

According to present study, there was no significant correlation between the CT severity score in the chest CT finding during 7 days of symptom onset and death, but there was significant correlation between the CT-SS in the chest CT finding during 7–14 days of symptom onset and death. Shang *et al.* in a study illustrated that changes in chest CT were difficult to assess quantitatively in the first–third weeks. Although CT score had correlations with arterial blood gas indices, unlike in our study, this study did not investigate the correlations with CT severity score and mortality.[24]

Another review conducted in Iraq in 2021 reported that chest CT can predict the disease severity by showing the percentage of lung involvement and so give an idea about the prognosis. A higher CT severity score is significantly correlated with male gender, older age

group patients, and likely positive PCR test,[25] but the relationship between CT severity score and death was not evaluated. It seems that in the first week of the onset of symptoms, clinical indications have been effective factors in the hospitalization of patients, and CT severity score is not a suitable indicator of lung involvement, prognosis, and death because in some cases, follow-up illustrated a reduction in lung involvement. On the other hand, the CT severity score in the second week from the onset of symptoms coincides with the peak of the disease and the severity of the involvement, and it seems that the severity of the lung involvement at the peak of the disease causes the relationship between the CT severity score and mortality.

Two separate studies conducted in China in 2020 examined patients with COVID-19. In the first study, which was conducted on 78 patients with COVID-19, it was shown that the average severity score in the group of patients with severe symptoms was significantly higher than that in patients with mild symptoms.[15] In the other study, 102 patients with COVID-19 were studied based on a positive PCR test. This study showed that CT severity score was significantly higher in people with severe disease.[21]

In our study, IST was the most common finding. The other typical findings were GGO alone and GGO with consolidation. Pleural effusion, pulmonary nodules, lymphadenopathy, cavitation, and tree in bud were rare. Moreover, CT images showed unifocal involvement in 4 (2.2%) and multi-focal involvement in 168 (91.8%).

In another study conducted in China, chest CT imaging in 56 patients showed multiple patchy lesions and GGO, which were mainly in the lower outer pulmonary zones of bilateral lungs and in about one-third of the cases were accompanied by relative consolidation. Cavitation and pleural effusion were not observed in any cases.[26] In another study in France, the most common involvement patterns were GGO and consolidation with bilateral involvement, which were in agreement with our findings.[27]

Consistent with our study, in several studies, the typical manifestation was GGO, and bilateral lung involvement, mostly in the lower lobes, has been seen.[21,22,28]

In present study, in the first 2 weeks, the frequency of GGO was decreased from 58.4 to 30.6%, while in the same period, the mixed pattern (GGO + consolidation) has increased from 31.5% to 58.3%, which indicated that GGOs convert to the consolidation. In other words, it seems that the lung CT findings start with GGOs and can rapidly evolve into a consolidation pattern, and this trend is observed in the majority of patients. Another study in China showed that COVID-19 is accompanied by consolidation or progress toward consolidation within 1–3 weeks,[5] which is a finding that is largely similar to the finding of our study on the transformation of ground glass lesions to consolidation in the course of the disease.

Abnormal lung CT findings can be present even in asymptomatic patients, and lesions can rapidly evolve into a diffuse GGO predominance or consolidation pattern within 1–3 weeks after onset of symptoms, peaking at around 2 weeks after onset.

Also, in our study, most of the lesions were located in the peripheral part of the lung parenchyma or as a combination of peripheral and central lesions. In other studies conducted in Iran, bilateral parenchymal abnormalities were seen in 96.6% of patients, while unilateral involvement was seen in only 3.4% of patients, and the distribution of lung involvement was more in the lower region.

The results of two other studies in China and France were in agreement with our findings, in which the pattern of GGO involvement was bilateral involvement with maximum distribution in the lower lung region.[26,27,29] None of the patients had pure involvement of central areas, and it can be concluded that in the case of pure central involvement, the diagnosis of COVID-19 should be doubted and should be re-evaluated for other diagnoses. In our study, the highest intensity of involvement was observed in RLL (right lower lobe) and LLL (left lower lobe), and the lowest intensity of involvement was seen in RML (right middle lobe). Considering that involvement of the lower lobes is observed in many pulmonary diseases including pulmonary edema, it can be concluded that in the case of predominant involvement of the lower lobes, COVID-19 must be included in the differential diagnoses list.

Limitations

The present contribution is limited by a small sample size, and also, this is a retrospective analysis performed in a single center and was not a general sample of the population. Third, because of the short time for case collection, although we have outlined the main patterns of evolution seen on CT imaging in patients with COVID-19 pneumonia, long-term radiological follow-up is needed to confirm our findings.

Conclusion

Our study showed that a patient with a higher CT severity score of the second week is associated with a higher risk of mortality. Also, association of the CT severity score, laboratory data, and symptoms could be applicable in predicting the patient's condition.

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Conflicts of interest

There are no conflicts of interest.

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