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Characteristics of Computerized Tomography (CT) Scan in COVID-19 Patients and Their Relationship with Mortality Rate

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ABSTRACT

Background: The new coronavirus (Covid-19) has been forcing lots of burden on society and health care system. The definitive diagnosis of COVID-19 is made whether by Reverse Transcription-Polymerase Chain Reaction (RT-PCR) laboratory test or computerized tomography (CT) scan. Although different patients may represent with different CT scan characteristics, but, Dominant CT scan imaging findings in COVID-19 is reported to be bilateral glass opacities, multifocal spots, and interstitial changes with peripheral distribution. These findings and the severity of lung involvements in CT scan may help physicians to diagnose the disease and predict the outcomes.

Objectives: This study aimed to evaluate the demographic features in patients with Coronavirus Disease-2019 (COVID-19) and to determine the relationship between Computerized Tomography (CT) and mortality.

Methods: This retrospective study was conducted on the medical records of 212 patients with suspected COVID-19 admitted to the teaching hospitals of Shiraz University of Medical Sciences from February 20, 2009 to August 2020. The patients' CT images were also assessed and the frequency of abnormalities was determined.

Results: The Reverse Transcription-Polymerase Chain Reaction (RT-PCR) test was positive in 204 patients (99%). Consolidation was observed in all the 206 patients. The highest degree of lung involvement (90%) was observed in 69 patients (33.5%). Atoll sign was also diagnosed in 121 cases (58.7%). Besides, crazy-paving reticular lines, subpleural sparing, and bronchial distortion were observed in 129 (62.6%), 88 (42.7%), and 124 patients (60.2%), respectively. In addition, multi-segment was detected in the CT scan results of 194 cases (94.2%), which was higher compared to the single segment seen in 12 patients (5.8%).

Conclusion: CT scan is a relatively sensitive technique for diagnosing COVID-19. The study results revealed a significant relationship between CT scan and death. The disease severity was also accurate using this method.

1. Introduction

The new coronavirus (Coronavirus Disease-2019 or COVID-19) has been present since the beginning of 2020 and has spread worldwide (1). In January 2020, this global pandemic was declared a public health emergency by the World Health Organization (WHO) (2). The disease is highly contagious and can lead to lung involvement, acute respiratory failure, or organ failure in severe cases (3, 4). In Iran, the first case of this virus was identified on 20 February 2019 and so far (February 2020), there have been

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over 100,000 definitive infections in the country.

The definitive diagnosis of COVID-19 is made by RT-PCR laboratory test. Since the sensitivity of this laboratory test is not sufficiently high, a possible sampling error may occur (5,6), and diagnosis using this test takes a very long time, the use of lung Computerized Tomography (CT) scan is very important in rapid diagnosis and clinical decision making (7). Dominant CT scan imaging findings in COVID-19-induced lung infection have usually reported bilateral glass opacities, multifocal spots, and interstitial changes with peripheral distribution (8, 9). However, the manifestations of lung CT scan may be different in different patients and stages. Moreover, due to similarities with radiological findings of other lung infections, using CT scan as the only way to diagnose COVID-19 may be associated with errors and may not help diagnosing the disease in early stages (3).

In Iran, according to the protocol of the Ministry of Health and Medical Education titled "instructions on how to care for and diagnose COVID-19 in selected comprehensive health service centers (16 or 24 hours)", patients are classified into two groups: 1- in need of referral and hospitalization and 2- at a high risk for outpatient treatment. In the group of patients in need of referral and hospitalization, mainly diagnostic imaging services are performed in the hospital according to the disease routine and patients' physical conditions. High-risk group patients, on the other hand, are classified into two categories, namely people with immunodeficiency and people with underlying diseases. Lung CT scan is performed for immunocompromised patients, while chest X-ray is used for patients with underlying diseases. These diagnostic services are provided while all these patients are sampled for RT-PCR laboratory tests upon arrival at the service centers (10).

2. Objectives

The present study aims to evaluate the characteristics for diagnosis and severity of involvement in primary imaging, their adaptation to the course of the disease, and their relationship with mortality.

3. Patients and Methods

All COVID-19 patients who were admitted to the teaching hospitals of Shiraz University of Medical Sciences from February 20, 2019 to August 2020 were enrolled retrospectively based on convenience sampling and their chest CT scan results were reviewed retrospectively. Demographic data including national identity code, age, and sex, PCR and CT scan findings, and the exact feature of consolidation (single C, multiple C, peripheral C, central C, upper C, lower C, diffuse C, round C, Ground-Glass Opacities (GGOs), single GGOs, multiple GGOs, peripheral GGOs, central GGOs, lower GGOs, upper GGOs, round GGOs, and diffuse GGOs were recorded. The radiographic parameters were evaluated by an expert radiologist.

3.1. Inclusion Criteria

The inclusion criteria of the study were having clear conditions prior to infection, having a CT scan at the time of admission, and death.

3.2. Exclusion Criteria

In case of a negative PCR test, the patients were excluded.

3.3. Statistical Analysis

The data were entered into the SPSS software, version 16 (IBM Corp., Armonk, N.Y., USA) and were analyzed using descriptive and inferential statistics. Descriptive data were expressed as frequency (percentage) or mean (± SD). The classified data (relationship between lung involvement and chest CT scan results) were compared using chi-square and Fisher's tests. Additionally, t-test was used to compare the age and level of lung involvement. Then, they were considered for analysis in two categories: below 50% and above 50%. $P < 0.05$ was considered statistically significant.

3.4. Ethical Consideration

Written informed consent was obtained from all the participants. They were completely informed about the study objectives and were assured about the confidentiality of their information. Attempts were also made to keep the records anonymous. Furthermore, all the procedures were in accordance with the ethical standards of the institutional and/or national research committee as well as with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Approval was granted by the Ethics Committee of Shiraz University of Medical Sciences (code: IR.SUMS.MED.REC.1400.019).

4. Results

A total of 212 patients were enrolled. The mean age of the patients with lung involvement < 50% was 66.2 ± 20.7 years and that of the patients with lung involvement > 50% was 68 ± 17 years, but the difference was not statistically significant ($P = 0.492$). Chest CT scans were evaluated for a total of 206 patients dying from COVID-19. Among these patients, 93 were female (45.1%) and 113 were male (54.9%).

According to Table 1, there was a significant difference between the patients with lung involvement above 50% and below 50% in terms of the frequencies of single C, multiple C, peripheral C, central C, upper C, lower C, diffuse C, round C, single GGOs, multiple GGOs, central GGOs, upper GGOs, diffuse GGOs, atoll sign, crazy-paving reticular lines, subpleural sparing, and bronchial distortion.

Most findings of consolidation were observed in all the 206 patients. The rate of multiple consolidations (91.7%, 189 cases) was higher compared to single consolidation (7.3%, 15 cases). Additionally, consolidation was found in the peripheral lobe in 72.3% of the patients (149 cases), the central lobe in 79.1% (163 cases), the upper lobe in 79.1% (163 cases), and the lower lobe in 89.3% (184 cases). Therefore, more integration was detected in the lower lobe. Furthermore, diffuse consolidation (62.6%, 129 cases) was more frequent in comparison to rounded consolidation (45.6%, 94 cases). GGOs were also observed in the 206 cases at different locations: in the peripheral lobe in 98.1% of the patients (202 cases), the central lobe in 82% (169 cases), the upper lobe in 86.4% (178 cases), and the lower lobe in 99% (204 cases). Thus, GGOs were mostly observed in the lower area. Besides, the frequency of multiple GGOs (193, 93.7%) was higher than that of single GGOs (33, 16%).

Table 1. Demographic Data of the Patients Participating in the Study Based on the Degree of Lung Involvement

Variable	Lung involvement				P-value
	Below 50% (n = 78)		Above 50% (n = 128)		
	N	%	N	%	
Gender (Male)	41	52.6	72	56.3	0.606
PCR	77	98.7	127	99.2	1
Consolidation	78	100	128	100	-
Single C	14	17.9	1	0.8	< 0.001
Multiple C	63	80.8	126	98.4	< 0.001
Peripheral C	41	52.6	108	84.4	< 0.001
Central C	47	60.3	116	90.6	< 0.001
Upper C	48	61.5	115	89.8	< 0.001
Lower C	63	80.8	121	94.5	0.002
Diffuse C	22	28.2	107	83.6	< 0.001
Round C	52	66.7	42	32.8	< 0.001
GGO	78	100	128	100	-
Single GGO	18	23.1	15	11.7	0.031
Multiple GGO	66	84.6	127	99.2	< 0.001
Peripheral GGO	75	96.2	127	99.2	0.153
Central GGO	45	57.7	124	96.9	< 0.001
Lower GGO	76	97.4	128	100	0.142
Upper GGO	54	69.2	124	96.9	< 0.001
Round GGO	32	41	68	53.1	0.092
Diffuse GGO	55	70.5	123	96.1	< 0.001
Atoll sign	13	16.7	108	84.4	< 0.001
Crazy-paving reticular lines	39	50	90	70.3	0.003
Subpleural sparing	8	10.3	80	62.5	< 0.001
Bronchial distortion	12	15.4	112	87.5	< 0.001
Single-segment	12	15.4	0	0	< 0.001
Multisegment	66	84.6	128	100	< 0.001
Asthma	1	1.3	2	1.6	1
COPD	3	3.8	6	4.7	1
Cancer	12	15.4	13	10.2	0.265

Abbreviations: PCR, polymerase chain reaction; GGO, ground glass opacities; COPD, chronic obstructive pulmonary disease.

The incidence of diffuse GGOs (86.4%, 178 cases) was also higher than that of rounded GGOs (48.5%, 100 cases).

The distribution of lung involvement has been presented in Figure 1. Accordingly, the highest lung involvement (90%) was observed in 69 patients (33.5%). Atoll sign was also diagnosed in 121 cases (58.7%). Other CT findings included segment, crazy-paving reticular lines, subpleural sparing, and bronchial distortion detected in 206 (100%), 129 (62.6%), 88 (42.7%), and 124 patients (60.2%), respectively. In addition, multi-segment was found in the CT scan results of 94.2% of the patients (194 cases), which was higher compared to the single segment seen in 12 patients (5.8%). Concerning the underlying diseases, 3 (1.5%), 9 (4.4%), and 25 patients (12.1%) had asthma, Chronic Obstructive Pulmonary Disease (COPD), and cancer, respectively.

5. Discussion

There has been much disagreement regarding the diagnostic value of chest CT scan among COVID-19 patients. In the previous studies comparing RT-PCR and CT scan, the sensitivity of the latter was calculated to be 97.2% (7). The results of two studies showed the lowest sensitivity values for CT scan (97%; CI: 95-98% and 97%; CI: 88-99%). These two articles also evaluated the specificity of CT scan. They reported the lowest specificity of CT scan as 25% (CI: 22-30%) (7) and its highest specificity as 56% (CI: 45-66%) (10). In the study conducted by Zu et al., before starting the treatment, CT scans of pregnant women under investigation showed typical changes in viral pneumonia such as bilateral diffuse vitreous opacity, stained lungs, and fragmented margins. The lung lesions increased as the disease progressed, but the lesions disappeared after the treatment (11).

In the present study, the findings of consolidation were observed in all the 206 patients. The rate of multiple consolidations (91.7%, 189 cases) was higher than that of single consolidation (7.3%, 15 cases). Yu et al. also evaluated the CT scan results of seven patients with COVID-19 in 2020 and reported that 86% of the participants had large areas of multiple GGOs, while the rest had this problem with a lower degree of involvement (12). Furthermore, Nasrollahzadeh Sabet et al. assessed the reliability of CT scans in the diagnosis of COVID-19 in 2020. In that study, 212 hospitalized patients with a final diagnosis of COVID-19 were studied. Demographic information, medical history, signs and symptoms, and chest CT scans were collected and analyzed. Finally, the power of CT scan in diagnosing this disease was evaluated in comparison to the RT-PCR molecular test. According to the results, the sensitivity of CT scan in the diagnosis of COVID-19 was relatively high.

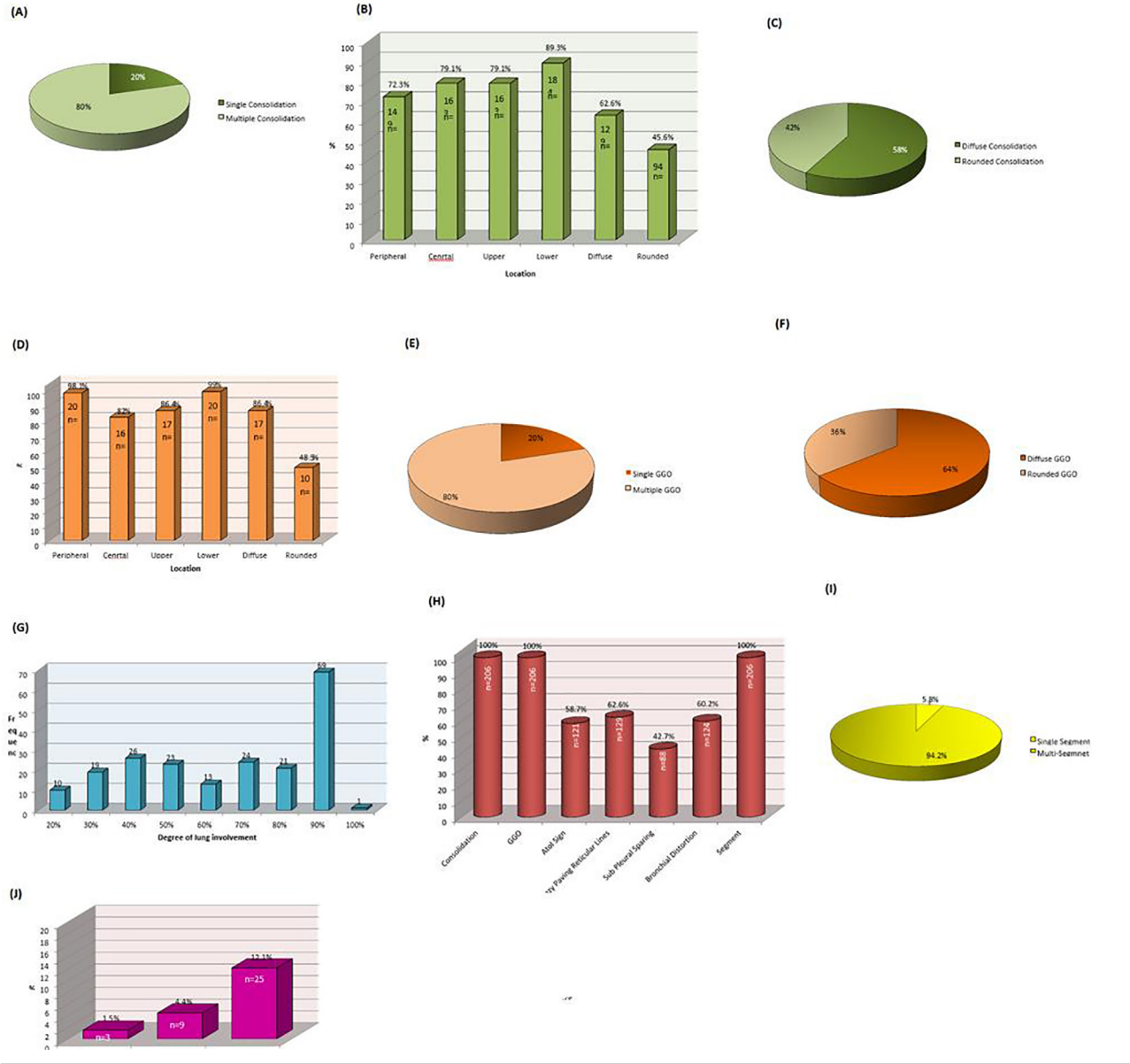

Figure 1. (A) Findings of Multiple and Single Consolidations in CT Scan Results; (B) The Place of Consolidation in the CT Scan Findings; (C) Diffuse Consolidation Compared to Rounded Consolidation in CT Scan Results; (D) Ggos Location in CT Scan Results; (E) Multiple Ggos and Single Ggos in CT Scan Results; (F) Diffuse Compared to Rounded Ggos in CT Scan Results; (G) Distribution of Lung Involvement in The Patients Under Study; (H) Chest CT Scan Results; (I) The Frequency of Multi-Segment and Single-Segment in CT Scan Findings; (J) Underlying Diseases in the Patients. GGO, Ground-Glass Opacity; CT, Computerized Tomography.

Nonetheless, the high rate of false-positive results from this technique and the subsequently made decisions could lead to an increase in the financial burden on health and treatment systems. Hence, caution should be considered while making decisions based on CT scan findings (13).

In a retrospective study, chest CT scans of 121 symptomatic patients with COVID-19 in four centers in China were reviewed from 18 January 2020 to 2 February 2020 in order to determine the common CT findings regarding the time between the onset of symptoms and the initial CT scan [zero to 2 days (36 patients), 3 to 5 days (33 patients), and 6 to 12 days (25 patients)]. The symptoms of COVID-19 infection on imaging were bilateral and peripheral ground glass and stabilizing lung operations. It is noteworthy that 20.36 patients (56%) had normal CT scans at the beginning. At longer times after the onset of symptoms, CT findings were more frequent including stabilization, bilateral and lateral disease, more general lung involvement, linear opacities, and rounded consolidation. Additionally, lung lateral involvement was observed in 10.36 primary patients (28%), 25.33 middle patients (76%), and 22.25 final patients (88%) (14). In this study the consolidation sites were as follows: 72.3% in the peripheral lobe (149 cases), 79.1% in the central lobe (163 cases), 79.1% in the upper lobe (163 cases), and 89.3% in the lower lobe (184 cases). In addition, diffuse consolidation was more frequent (62.6%, 129 cases) in comparison to rounded consolidation (45.6%, 94 cases). GGOs were also observed in 206 cases at different locations: 98.1% in the peripheral lobe (202 cases), 82% in the central lobe (169 cases), 86.4% in the upper lobe (178 cases), and 99% in the lower lobe (204 cases). Thus, GGOs were mostly detected in the lower area. The

frequency of multiple GGOs (193 cases, 93.7%) was higher than that of single GGOs (33, 16%). Besides, the incidence of diffuse GGOs (86.4%, 178 cases) was higher than that of rounded GGOs (48.5%, 100 cases). Furthermore, the highest lung involvement (90%) was observed in 69 patients (33.5%). Overall, the dominant CT scan findings in pulmonary infection caused by COVID-19 were bilateral GGOs, multifocal patchy consolidation, and interstitial changes with peripheral distribution (8, 9). However, the manifestations of lung CT scan can be different in various patients and stages. Consequently, the use of CT scan as the only way to diagnose COVID-19 may be associated with errors and it may not be useful for diagnosing the disease in the early stages due to similarities with the radiological findings of other lung infections (3).

The current study results showed that high consolidation in patients with lung involvement below 50% increased the risk of death. In the study carried out by Talebi et al. in 2020, High-Resolution CT (HRCT) scans of all patients were normal (2.2%). Other findings included GGO (43.3), consolidation (15.7), pleural effusion (10.1), Acute Respiratory Distress Syndrome (ARDS) (2.2), cardiomegaly (7.3), and bronchiectasis (2.2), which were observed in 40%, 20%, 24%, 4%, 8%, and 4% of the patients who died, respectively (15). In that study, death occurred in the patients with high consolidation and GGOs, which was in agreement with the findings of the current research.

5.1. Conclusion

CT scan is a relatively sensitive technique for diagnosing COVID-19, revealing an accurate estimation of the disease severity. The results indicated that high consolidation in patients with lung involvement below 50% increased the risk of death. However, the patients with lung involvement below 50% who had no consolidation and only had a high GGO were more likely to survive death.

5.2. Ethical Approval

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5.3. Informed Consent

Written Informed consent was obtained from all individual participants included in the study. A copy of the written consent is available for review by the Editor of this journal. The purpose of this research was completely explained to the patient and they were assured that their information will be kept confidential by the researcher. This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the ethical committee of Shiraz University of Medical Sciences.

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Authors' Contribution

H.B.D. conceived the idea for the manuscript and in cooperation with M.B. and A.S. interpreted the patient data and carried out the treatment. M.S, H.B., and M. K drafted the manuscript. S. H. J and S. R, F. Z. and S. M. revised the manuscript and act as the guarantors of the manuscript. All authors read and approved the final manuscript

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