Evaluation of chest CT-scan appearances of COVID-19 according to RSNA classification system

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Abstract

Background: The Radiologic Society of North America (RSNA) divides patients into four sections: negative, atypical, indeterminate, and typical coronavirus disease 2019 (COVID-19) pneumonia based on their computed tomography (CT) scan findings. Herein, we evaluate the frequency of the chest CT-scan appearances of COVID-19 according to each RSNA categorical group. Methods: A total of 90 patients with real-time reverse transcriptase-polymerase chain reaction (RT-PCR)-confirmed COVID-19 were enrolled in this study and differences in age, sex, cardiac characteristics, and imaging features of lung parenchyma were evaluated in different categories of RSNA classification. Results: According to the RSNA classification 87.8, 5.56, 4.44, and 2.22% of the patients were assigned as typical, indeterminate, atypical, and negative, respectively. The proportion of “atypical” patients was higher in the patients who had mediastinal lymphadenopathy and pleural effusion. Moreover, ground-glass opacity (GGO) and consolidation were more pronounced in the lower lobes and left lung compared to the upper lobes and right lung, respectively. While small nodules were mostly seen in the atypical group, small GGO was associated with the typical group, especially when it is present in the right lung and indeterminate group. Conclusion: Regardless of its location, non-round GGO is the most prevalent finding in the typical group of the RSNA classification systems. Mediastinal lymphadenopathy, pleural effusion, and small nodules are mostly observed in the atypical group and small GGO in the right lung is mostly seen in the typical group.

Keywords: COVID-19, CT-scan, pneumonia, primary care.

Introduction

Primary care can play an important role in the coronavirus disease 2019 (COVID-19) period by distinguishing patients with respiratory signs from others, creating an initial diagnosis, serving susceptible people to manage their nervousness about the COVID-19 virus, and decreasing the need for hospital facilities. In December 2019, a novel virus was isolated from the patients in Wuhan, China, which later was named 2019-nCOV and caused a significant detriment to global health. As of August 16, 2020, there was a cumulative sum of 21.2 million confirmed COVID-19 cases including 7,61,000 deaths. Currently, the polymerase chain reaction (PCR)-based method (specifically real-time reverse transcriptase-polymerase chain reaction, RT-PCR) has become the favored method in practice for the detection of viruses in clinically suspicious patients due to its high sensitivity and specificity. But the process is relatively

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To improve our understanding of the chest CT-scan features of COVID-19, our study aims to describe the frequency of chest CT-scan appearances of COVID-19 according to each categorical group.

**Materials and Methods**

**Patient population and study design**

This cross-sectional study was approved by the ethics committee of our medical university with approval ID: IR.TUMS.VCR.REC.1399.153. Written informed consent was obtained from all patients. If the patient was unable to provide informed consent, it was received from his/her relatives. The consecutive patients admitted to the emergency department of our hospital from July 1, 2020, to August 30, 2020, were enrolled in this study. Data on age, sex, cardiac characteristics, and lung parenchyma imaging features of all patients were recorded. The inclusion criterion was positive RT-PCR in a patient with COVID-19-pneumonia-related signs and symptoms such as fever, cough, dyspnea, myalgia, and anosmia.

Exclusion criteria were (a) negative or unknown RT-PCR results, (b) patients who refused chest CT or hospitalization, or (c) CT-scans that were not appropriate for evaluating lung parenchyma such as in those with severe motion artifact.

**CT acquisition technique and analysis**

After the RT-PCR swabs were taken, all patients underwent chest CT-scan in a supine position during end-inspiration without contrast medium injection. Chest CT was performed on a 16-slice CT-scanner (Siemens Healthineers, Erlangen, Germany) dedicated in our hospital only for patients with COVID-19.

Two radiologists in consensus with 13 and 22 years of experience evaluated the CT-scans and categorized each CT as no feature of COVID-19 pneumonia (negative), uncommonly or not reported features of COVID-19 pneumonia (atypical), non-specific features of COVID-19 pneumonia (indeterminate), and common features of COVID-19 pneumonia (typical).

**Statistical analysis**

The data were represented as frequency (percent) for categorical data and mean ± SD for continuous ones. The association of RSNA classification with sex, age, and cardiac variables was assessed using the Chi-square test (with exact P value). Data were analyzed by IBM SPSS Statistics 23.

**Result**

Ninety-two consecutive patients were eligible for inclusion. Two patients were excluded due to their pregnancy and contraindication of CT. Eventually, 90 patients (65.6% males) with a mean age of 53.61 ± 16.15 years (ranging from 18 to 93 years) were included in this study. All enrolled patients had RT-PCR-confirmed COVID-19. According to the RSNA chest CT classification system, the patients were assigned to the categories of “typical,” “indeterminate,” “atypical,” and “negative” by the two expert radiologists with 13 and 22 years of experience. Each category was defined with their CT-scan findings. The proportion of the patients in each category of RSNA chest CT classification system is as follows: “typical” 87.8% [shown in Figure 1], “indeterminate” 5.56% [shown in Figure 2], “atypical” 4.44% [shown in Figure 3], and “negative” 2.22% [Table 1].

The frequency (percent) of each RSNA classification based on sex, age, and cardiac characteristics is displayed in Table 1. According to the analyzed data, the distribution of the RSNA categories was significantly different in the mediastinal lymphadenopathy (LAP) (P = 0.015) and pleural effusion (P = 0.002) status, where the proportion of “atypical” patients was higher in the patients who had LAP and pleural effusion.

Table 2 shows the total distribution of CT-scan features in the left and right lobes. Also, the distribution of four RSNA categories.
has been calculated in each of the CT-scan features for both the left and right sides. The CT features in both the lungs were similar except the small ground-glass opacity (GGO) that was more prevalent in the right lung; non-round GGO and consolidation which were more pronounced in the left lobe. Small GGO was seen in both typical and indeterminate groups, and especially when it was observed in the right lung, it was associated with typical findings of COVID-19. Moreover, the small nodule was mostly seen in the atypical group.

Table 3 shows the distribution of the RSNA classification based on the CT-scan features in the lower and upper lobes.

The small GGO was more prevalent in the upper lobes while consolidation, crazy paving, and reverse halo were more prevalent in the lower lobes. The distribution of typical and atypical features was not different between the upper and lower lobes.

Discussion

Infections have developed as emerging and life-threatening diseases in the last decade.\textsuperscript{[17-20]} The COVID-19 pandemic, besides its subsequent financial losses, has exposed thoughtful
Table 2: The distribution of RSNA classification based on CT-scan features in the left and right lobes

| CT-scan characteristics | Total n=90 | RSNA classification |
|-------------------------|-----------|---------------------|
|                         | Typical n=79 (87.8) | Indeterminate n=5 (5.6) | Atypical n=4 (4.4) | Negative n=2 (2.2) |
| Left                    |            |                     |                    |                    |
| GGOR                    | 7 (7.8)    | 7 (8.9)             | 0                  | 0                  |
| GGONR                   | 76 (84.4)  | 74 (93.7)           | 1 (20.0)           | 1 (25.0)           |
| GGO small               | 9 (10.0)   | 5 (6.3)             | 3 (60.0)           | 1 (25.0)           |
| Consolidation           | 44 (48.9)  | 43 (54.4)           | 0                  | 1 (20.0)           |
| Crazy paving            | 40 (44.4)  | 39 (49.4)           | 1 (20.0)           | 0                  |
| Reverse halo            | 12 (13.3)  | 11 (13.9)           | 0                  | 1 (25.0)           |
| Sub-pleural line        | 13 (14.4)  | 13 (16.5)           | 0                  | 0                  |
| Small nodule            | 4 (4.4)    | 0                   | 0                  | 4 (100)            |
| Cavitation              | 0          | 0                   | 0                  | 0                  |
| Interlobular septal thickening | 0        | 0                   | 0                  | 0                  |
| Peripheral pleural base | 75 (83.3)  | 71 (89.9)           | 4 (50.0)           | 0                  |
| Peripheral pleural sparing | 9 (10.0)  | 8 (10.1)            | 0                  | 1 (25.0)           |
| Axial                   | 19 (21.1)  | 18 (22.8)           | 1 (20.0)           | 0                  |
| Peribronchovascular     | 1 (1.1)    | 1 (1.3)             | 0                  | 0                  |
| Others                  | 4 (4.4)    | 0                   | 0                  | 4 (100)            |
| Right                   |            |                     |                    |                    |
| GGOR                    | 9 (10.0)   | 9 (11.4)            | 0                  | 0                  |
| GGONR                   | 73 (81.1)  | 71 (92.4)           | 0                  | 0                  |
| GGO small               | 23 (25.6)  | 20 (25.3)           | 3 (60.0)           | 0                  |
| Consolidation           | 39 (43.3)  | 37 (46.8)           | 1 (20.0)           | 1 (25.0)           |
| Crazy paving            | 39 (37.8)  | 34 (43.0)           | 0                  | 0                  |
| Reverse halo            | 11 (12.2)  | 11 (13.9)           | 0                  | 0                  |
| Sub-pleural line        | 11 (12.2)  | 11 (13.9)           | 0                  | 0                  |
| Small nodule            | 5 (5.6)    | 1 (1.3)             | 0                  | 4 (100)            |
| Cavitation              | 0          | 0                   | 0                  | 0                  |
| Interlobular septal thickening | 0        | 0                   | 0                  | 0                  |
| Peripheral pleural base | 73 (81.1)  | 70 (86.5)           | 3 (60.0)           | 0                  |
| Peripheral pleural sparing | 8 (8.9)   | 8 (10.1)            | 0                  | 0                  |
| Axial                   | 21 (23.3)  | 21 (26.6)           | 0                  | 0                  |
| Peribronchovascular     | 2 (2.2)    | 1 (1.3)             | 0                  | 1 (25.0)           |
| Others                  | 3 (3.3)    | 0                   | 0                  | 3 (75.0)           |

GGO: Ground-glass opacity, GGOR: Round GGO, GGONR: Non-round GGO. Note: Data represented as frequency (percent)

issues of admission, prices, care quality, injustices, and health care differences. It has bared the lacking of thoughtful primary care, the undependability of employer-sponsored health insurance, complete discrimination, and other limitations of a system turned on its head deprived of a base of primary care.

Although it is believed that the definitive diagnosis of COVID-19 relies mainly on the RT-PCR, radiologic findings and radiologist interpretations play an important role in early diagnosis, patient selection, and further, patient management. Overall, GGO was the most common finding in different studies which was consistent with our study. It is defined as increased opacity of the lung, along with intact visualization of vascular and bronchial markings, and more commonly caused by partial replacement of the air in the alveoli. In our classification, among different detected GGOs, non-round GGO was more commonly seen. With a little difference, it was more pronounced in the left lobe compared to the right lobe (84.4% vs. 81.1%) and the lower lobes compared to the upper lobes (82.2% vs. 80.0%). All of them were dominantly categorized as “typical” according to the RSNA classification. Consolidation, yet another typical sign of COVID-19 pneumonia, which is defined by an increase in the attenuation of pulmonary parenchyma that obscures the underlying margins of the vessels and airway walls that result in air bronchogram sign, likewise, was seen more commonly in the left lobe compared with the right lobe (48.9% vs. 43.3%) and lower lobes compared with the upper lobes (47.8% vs. 23.3%). As far as the disease progression reverse halo sign and crazy-paving pattern are considered among later manifestations, which in our study were seen in 25.5% (consisting of 13.3% in the left lobe and 12.2% in the right lobe) and 82.2% (consisting of 44.4% in the left lobe and 37.8% in the right lobe), respectively, these may be because our RT-PCR-confirmed patients were at different phases of the disease at the time of the diagnosis and CT-scan. Interestingly “small nodule” as one of CT-scan findings were dominantly categorized in the “atypical” group of the RSNA classification. Moreover, in a meta-analysis, it was demonstrated that many CT-scan findings had a significant correlation with disease severity with consolidation and crazy-paving patterns among them. These data guide us toward better recognition of disease progression, and most importantly, patient management throughout the temporal pattern of COVID-19. Due to many
different radiologic patterns seen through the disease’s temporal course, various academic radiologic societies developed their criteria of diagnosis. The RSNA Consensus Statement was one of those which recommended describing the findings in the following four categories: no feature of COVID-19 pneumonia (negative), uncommonly or not reported features of COVID-19 pneumonia (atypical), non-specific features of COVID-19 pneumonia (indeterminate), and common features of COVID-19 pneumonia (typical).

In our study among 90 patients with RT-PCR-confirmed COVID-19, 79 patients (87.8%) were presented in the “typical” group, 5 patients (5.6%) in the “indeterminate” group, 4 patients (4.4%) in the “atypical” group, and 2 patients (2.2%) were negative for COVID-19 based on the RSNA guideline. Yet, another classification system for the definition and evaluation of the COVID-19 patients was developed by the Dutch Radiologic Society named CO-RADS. CO-RADS categorizes the possibility of COVID-19 pulmonary involvement on a scale of 1 (very low) to 5 (very high) and it is used in the evaluation of patients with moderate to severe disease.

Moreover, the Royal Australian and New Zealand College of Radiologists also recommends a guideline for reporting which initially categorizes the findings by the fact that they are known and suspected or they are incidentally found, and then, into four categories in each title as follows: category 1: normal; category 2: indeterminate; category 3: typical; and category 4: other diagnoses favored.

The present investigation has some strong points. We analyzed a large sample of patients with COVID-19 infection in Iran. The demographic characters of the study population were assessed. All of the properties of the lower and upper chest CT were also evaluated in different RSNA classifications, which were unique and novel in their field. One limitation of the existing investigation is the absence of other diagnostic methods to assess the sensitivity and specificity of chest CT.

Table 3: The distribution of RSNA classification based on CT-scan features in the lower and upper lobes

| CT-scan characteristics | Total n=90 | RSNA classification |
|-------------------------|-----------|---------------------|
|                         | Typical n=79 (87.8) | Indeterminate n=5 (5.6) | Atypical n=4 (4.4) | Negative n=2 (2.2) |
| Lower | | | | |
| GGOR | 6 (6.7) | 6 (7.6) | 0 | 0 |
| GGGONR | 74 (82.2) | 72 (91.1) | 1 (20.0) | 1 (25.0) |
| GGO small | 10 (11.1) | 6 (7.6) | 3 (60.0) | 1 (25.0) |
| Consolidation | 43 (47.8) | 42 (53.2) | 0 | 1 (25.0) |
| Crazy paving | 32 (35.6) | 31 (39.2) | 1 (20.0) | 0 |
| Reverse halo | 14 (15.6) | 13 (16.5) | 0 | 1 |
| Sub-pleural line | 13 (14.4) | 13 (16.5) | 0 | 0 |
| Small nodule | 4 (4.4) | 0 | 0 | 4 (100) |
| Cavitation | 0 | 0 | 0 | 0 |
| Interlobular septal thickening | 74 (82.2) | 70 (88.6) | 4 (80) | 0 |
| Peripheral pleural base | 9 (10.0) | 8 (10.1) | 0 | 1 (25.0) |
| Peripheral pleural sparing | 18 (20.0) | 17 (21.5) | 1 (20.0) | 0 |
| Axial | 1 (1.1) | 1 (1.3) | 0 | 0 |
| Peribronchovascular | 4 (4.4) | 0 | 0 | 4 (100) |
| Upper | | | | |
| GGOR | 9 (10.0) | 9 (11.4) | 0 | 0 |
| GGGONR | 72 (80.0) | 71 (89.9) | 0 | 1 (25.0) |
| GGO small | 20 (22.2) | 18 (22.8) | 2 (40.0) | 0 |
| Consolidation | 21 (23.3) | 20 (25.3) | 1 (20.0) | 0 |
| Crazy paving | 33 (36.7) | 33 (41.8) | 0 | 0 |
| Reverse halo | 7 (7.8) | 7 (7.8) | 0 | 0 |
| Sub-pleural line | 8 (8.9) | 8 (10.1) | 0 | 0 |
| Small nodule | 5 (5.6) | 1 (1.3) | 0 | 4 (100) |
| Cavitation | 0 | 0 | 0 | 0 |
| Interlobular septal thickening | 0 | 0 | 0 | 0 |
| Peripheral pleural base | 68 (75.6) | 66 (83.5) | 2 (40.0) | 0 |
| Peripheral pleural sparing | 8 (8.9) | 8 (10.1) | 0 | 0 |
| Axial | 20 (22.2) | 20 (22.2) | 0 | 0 |
| Peribronchovascular | 2 (2.2) | 1 (1.3) | 0 | 1 (25.0) |
| Others | 4 (4.4) | 0 | 0 | 4 (100) |

GGO: Ground-glass opacity, GGOR: Round GGO, GGONR: Non-round GGO. Note: Data represented as frequency (percent)
Conclusion

By increasing our knowledge in the field of imaging features and patterns of COVID-19 pneumonia, different classification systems have been proposed for diagnostic and prognostic purposes. In the current study, the frequency of chest CT-scan appearances of COVID-19 according to each categorical group of the RSNA classification system was assessed in 90 RT-PCR confirmed cases. Regardless of its location, non-round GGO is the most prevalent finding in the typical group of the RSNA classification system. Mediastinal lymphadenopathy, pleural effusion, and small nodules are mostly observed in the atypical group and small GGO in the right lung is mostly seen in the typical group. Further studies aiming at comparing different imaging features between different classification systems are suggested to reach a consensus in reporting COVID-19 pneumonia between radiologists.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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