Detection of Coronavirus Disease (COVID-19) using Radiological Examinations

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Abstract

An outbreak of Coronavirus disease 2019 (COVID-19) occurred in China. The causative agent of COVID-19 is Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). The disease rapidly spreads from China to the world by trading and traveling. Until April 24, 2020, approximately 2,544,792 cases were confirmed with 175,694 deaths throughout the world. The highest number of cases were identified from the United States of America (USA) whereas the mortality rate is high in Portugal. The diagnosis of COVID-19 is based on Computed Tomography Scanning (CT Scan) and Real-Time Reverse Transcription Polymerase Chain Reaction (qRT-PCR). Assessing the extension of pathology, the exact location of the area involved, and assessment of the disease severity makes CT scan superior to other modalities. This review shows that real-time polymerase chain reaction and imaging technology both play an important role in the diagnosis of COVID-19. However, imaging modalities have more importance in diagnosis and screening than qRT-PCR. The qRT-PCR was positive in 81.3% whereas CT scan abnormality was observed in 89.8%. Bilateral lobe (51.4%) abnormality was found more than a single lobe (21.5%) in COVID-19 infected patients. The CT scan reports show a high-level abnormality in right lower lung lobe than others in COVID-19 infected patients. The CT scan evaluates different manifestations such as the presence of ground-glass opacities, consolidations, crazy paying linear, cavitation, discrete nodules, pleural effusion, and lymphadenopathy. It is concluded that imaging technology especially CT scan and X-rays play an important role in the screening and diagnosis of COVID-19 infected patients in limited access to qRT-PCR regions. The common radiological manifestation was also determined, which will be helpful for the radiologist to diagnosed COVID-19 infected patients in the early stages. Follow up studies required regarding the radiological examinations.

Keywords: Computed Tomography scanning, Consolidation, COVID-19, Ground glass opacity, Real-time polymerase chain reaction

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INTRODUCTION

The Coronavirus disease 2019 (COVID-19) is caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), which was reported from China. The COVID-19 shed from Wuhan to whole China and to the rest of the world. The newly discovered SARS-CoV-2 belongs to the family Coronaviridae and order Nidovirales. Severe Acute Respiratory Syndrome (SARS), and the Middle East Respiratory Syndrome (MERS) also belong to the same family. The SARS and MERS also belong to the same groups. For the first time, the SARS outbreak was reported in Southern China and was rapidly declared global threat in March 2003. About 8,000 cases were identified with 774 deaths throughout the world. Similarly, MERS was reported from Saudi Arabia in 2012, resulting in 2,494 cases with 858 deaths. Until April 24, 2020, a total of 2,544,792 confirmed cases with 175,694 deaths globally occurred with COVID-19. The mortality rate of MERS was highest among the SARS, MERS, and COVID as shown in Fig. 1.

Transmission, Clinical Manifestation, Diagnosis, and Treatment of COVID-19

It is reported that COVID-19 was spread in the local market of Wuhan City, with seafood and animal meat. The transmission from Wuhan city to the rest of China occurred by traveling of infected individuals. Then, it spread to the world by a similar mechanism of the infected population. The transmission of COVID-19 occurred by respiratory droplets and close contact with infected person. The COVID-19 infection causes respiratory distress from mild to severe. The common symptoms are fever, dry cough, fatigue and myalgia, shortness of breath, pneumonia, dizziness, and other comorbidities. A few rare symptoms are also noted in COVID-19 infected persons such as headache, rhinorrhea, and hemoptysis. The pulmonary disorders may lead to severe respiratory disorders and even death. The susceptible patients such as immunocompromised and older aged individuals are more prone to COVID-19. Not only the COVID-19 infected patients having the symptoms are a source of infection but the asymptomatic patients in the incubation period can also be the source of infection. Therefore, early diagnosis is crucial for the identification of asymptomatic patients.

Laboratory-based procedures and radiological examinations are both can be used for screening and diagnosis of COVID-19. The Real-Time Reverse Transcription Polymerase Chain Reaction (qRT-PCR) is considered as a reference or standard diagnostic technique but false-negative results in asymptomatic patients and human error can decrease the role qRT-PCR in the diagnosis of COVID-19. However, imaging technology especially the computed tomography scanning (CT-Scan) and X-ray can play a crucial role in the diagnosis of COVID-19 patients in early stages. There is no specific vaccine and drugs are available for COVID-19.

Current Status of COVID-19

According to the World Health Organization (WHO), the number of COVID-19 cases and deaths are increasing day by day throughout the world. Currently, the regions of America and Europe are the epicenter of SARS-CoV-2 after Wuhan, China. Till to April 24, 2020, a total of 2,544,792 reported cases with 175,694 deaths are globally identified. The highest number of cases are determined in European regions (1,251,458 cases and 113,336 deaths), followed by regions of America (957,402 cases and 478,12 deaths), Eastern Mediterranean regions (144,450 cases and 6469 deaths), Western Pacific regions (137,902 cases and 5818 deaths), South East
Asia regions (36,039 cases and 1498 deaths) and African Regions (16,829 cases and 748 deaths) as shown in Fig. 2.7

The cases in United State (US) was 800,926 having 5.0 mortality rate, followed by Spain 20,838 cases with 10.4% mortality, Italy 187,327 cases with 13.4% mortality, Germany 148,046 cases with 3.4% mortality, the United Kingdom 133,499 cases with 13.5% mortality rate, France 117,961 cases with 18.1% mortality, Turkey 98674 cases with 2.4% mortality, Iran 85,996 cases with 6.2% mortality and China 82,631 cases with 4.0% mortality as shown in Fig. 3 & 4.7

Clinical manifestation and role of radiology in Detection of COVID-19

Radiological examinations play a major role in the prompt identification of COVID-19. The typical finding of COVID-19 is multifocal ground-glass opacities, distributed peripherally, along with the patchy consolidations that are quite challenging to be picked on chest radiographs showing it as a normal chest X-ray initially.21 After a week or more, the Chest radiography of COVID-19 infected patients shows various abnormalities including air bronchogram, diffuse air space and patchy opacities, like other Coronavirus pneumonia.22,23 Due to its low contrast resolution, chest radiography was not considered as a standard imaging modality for finding Coronavirus Disease 2019 (COVID-19). Whereas, thin-slice CT scan Chest is preferred over chest X-ray because of its fast speed, accuracy, high sensitivity, improved contrast resolution, and early detection of COVID-19 pneumonia.17 The main COVID-19 pneumonia findings picked by CT scan Chest are multifocal bilateral ground-glass opacities with patchy consolidations, marked peripherally subpleural distribution and preferred posterior part or inferior lobe involvement reversed halo sign which is an area of rounded ground glass bounded completely or incompletely by a consolidation ring.3,20,21 While the rare findings on CT scan chest are pleural effusion, pulmonary cavitation, calcification, and lymph node enlargement.3,23-25 The CT scan of few severe patients shows diffuse mixed consolidations having ground-glass opacities present in bilateral lungs with air bronchial sign and bronchiectasis, giving the appearance of “white lung”.8 Thickening of interlobar septa and bilateral pleura with minimal pleural effusion is also

Fig. 2. Continental based cases of COVID-19
observed in few patients.\textsuperscript{16,26} A semi-quantitative scoring system ranged from 0 to 5 may be used for pulmonary abnormalities caused by COVID-19.\textsuperscript{27} Based on the previous findings, the right lower lobe is more affected by COVID-19, followed by the left lower lobe, left upper lobe, right upper lobe and middle lobe of left lung.\textsuperscript{28} Few patients had normal CT chest reports on initial examination, quite a few patients had a unilateral lung infection, and about 78% of patients suffered from a bilateral lung infection. Ground-glass opacity (GGO) is frequently observed in COVID-19 infected patients followed by consolidation, vascular enlargement, inter-lobar septal thickening, and mixed GGO.\textsuperscript{29}

Present Review Findings

A total of 6 studies were retrieved in which qRT-PCR and CT scan examination were compared. In total 6 studies, 1275 individuals were studied in which male patients were 599, and female patients were 676. Among the studied individuals, 81.3% were confirmed positive by qRT-PCR whereas, CT scan examination was found abnormal in 89.8% patients as shown in Table 1.

![Fig. 3. Number of Cases and Deaths with COVID-19 in several countries](image-url)
It was observed that bilateral lobes (51.4%) of lungs were more affected than single lobe (21.5%) of the lung. Both right and left lung was affected in COVID-19 with a percentage of 67.7% and 66.9% respectively. Among the four regions of lungs; right lower lung lobes were more affected than right upper lung lobes. Similarly, the left lower lung lobe was more affected than the left upper lung lobe as shown in Table 2.

CT scan manifestation of Coronavirus Disease (COVID-19)

Ground Glass Opacity was commonly reported in COVID-19 infected patients mostly noted in bilateral lungs. Consolidation is the second most common CT scan manifestation in the COVID-19 patients. Consolidations may be present in the patchy form, either distributed segmentally or in sub-pleural areas. The reticular pattern is

![Graph showing mortality rate of COVID-19 in various countries]

**Fig. 4.** The mortality rate of COVID-19 in various Countries

**Table 1.** Comparison of RT-PCR and CT scan reports in patients infected with COVID-19

| Authors            | Study Country | No. of Patients | Male | Female | Mean Age | RT-PCR Positive | CT Abnormality | References |
|--------------------|---------------|-----------------|------|--------|----------|-----------------|----------------|------------|
| Pan et al.         | China         | 21              | 06   | 15     | 40±9     | 100%            | 80.5%          | 23         |
| Li et al.          | China         | 51              | 28   | 23     | 55±33    | 100%            | 96.1%          | 29         |
| Fang et al.        | China         | 51              | 29   | 22     | 45±10    | 71%             | 98%            | 30         |
| Bernheim et al.    | New York      | 121             | 61   | 60     | 45±3     | 88%             | 76%            | 31         |
| Ai et al.          | China         | 1014            | 467  | 547    | 51±15    | 59%             | 88%            | 32         |
| Zhang et al.       | China         | 17              | 8    | 9      | 48±6     | 70%             | 100%           | 33         |
mostly observed in patients of age more than 50 years or when the disease gets longer. Crazy paving pattern and cavitation was also reported in COVID-19 infected patients. Discrete nodules was another CT scan manifestation in COVID-19 infected patients. Halo sign, lymphadenopathy, and vascular enlargement was also reported in COVID-19 infected patients as shown in Table 3 & 4.

### Differential Diagnosis of Coronavirus Disease (COVID-19)

Initially, every type of infection appears normal on Chest X-ray but with time, the signs become apparent as soon as infection causes

### Table 2. Lungs Morphology reported through CT scan in patients infected with COVID-19

| Authors         | Single lung lobe | Two or more lobes | Right upper Lung Lobes | Right lower Lung lobe | Left upper Lung lobe | Left lower Lung lobe | References |
|-----------------|------------------|-------------------|------------------------|-----------------------|----------------------|----------------------|------------|
| Yen et al.      | NA               | NA                | 67 %                   | 76 %                  | 76 %                 | 81 %                 | 21         |
| Pan et al.      | 42%              | 42%               | NA                     | NA                    | NA                   | NA                   | 23         |
| Bernheim et al. | 15 %             | 12 %              | 44 %                   | 65 %                  | 48 %                 | 63 %                 | 31         |
| Wang et al.     | 9.1 %            | 5.5 %             | NA                     | 3.6 %                 | NA                   | 3.6 %                | 34         |
| Miao et al.     | 41.6 %           | 44.6 %            | 41.9 %                 | 71.0 %                | 48.4 %               | 66.1 %               | 35         |
| Miao et al.     | 16.7 %           | 83.4 %            | 48.1 %                 | 79.6 %                | 51.9 %               | 74.1 %               | 36         |
| Fu et al.       | 66.7 %           | 72.2 %            | 72.2 %                 | 100 %                 | 66.7 %               | 88.8 %               | 37         |
| Chung et al.    | 5.5 %            | 71 %              | 67 %                   | 76 %                  | 67 %                 | 67 %                 | 38         |
| Song et al.     | 8 %              | 39 %              | 84 %                   | 90 %                  | 84 %                 | 90 %                 | 39         |
| Xu et al.       | 13 %             | 59 %              | 53 %                   | 66 %                  | 53 %                 | 61 %                 | 40         |
| Lomoro et al.   | 2.4 %            | 85.7 %            | 92.9 %                 | 92.9 %                | 92.9 %               | 90.5 %               | 41         |

| Authors         | I    | II   | III  | IV   | V    | VI   | VII  | VIII | IX   | X    |
|-----------------|------|------|------|------|------|------|------|------|------|------|
| Yen et al.      | 86 % | 62 % | NA   | NA   | 1 %  | NA   | NA   | NA   | 86 % | 21   |
| Pan et al.      | 75%  | 41%  | 25%  | NA   | NA   | NA   | NA   | 42%  | 54%  | 23   |
| Bernheim et al. | 34 % | 34%  | 20%  | 1%   | NA   | 1%   | 1%   | 60%  | 40%  | 31   |
| Wang et al.     | 27.3%| 27.3%| NA   | NA   | NA   | 0.9% | NA   | 56.4%| 43.6%| 34   |
| Miao et al.     | 62.9%| 19.4%| 27.4%| 1.6% | NA   | NA   | NA   | 67.7%| 54.8%| 35   |
| Miao et al.     | 70.4%| 22.2%| 29.6%| 1.3% | 19.7%| 5.3% | NA   | 40.8%| 27.6%| 36   |
| Chung et al.    | 57%  | 29%  | 19%  | NA   | NA   | NA   | NA   | 76%  | 33%  | 38   |
| Song et al.     | 77%  | 55%  | NA   | NA   | 22%  | 8%   | 6%   | 84%  | 86%  | 39   |
| Xu et al.       | 72%  | 13%  | 12%  | NA   | NA   | 4%   | 1%   | 59%  | 51%  | 40   |
| Lomoro et al.   | 95.2%| 25.9%| 57.1%| NA   | 7.1% | 14.3%| 64.3%| 28.6%| 41   |
| Wang et al.     | 45%  | 23%  | 3%   | NA   | NA   | NA   | NA   | 85%  | 75%  | 42   |
| Lu et al.       | 76.9%| 64.2%| 61.5%| NA   | 16.5%| NA   | NA   | 82.4%| 60.9%| 43   |
| Li et al.       | 97.6%| 63.9%| 36.1%| NA   | NA   | NA   | NA   | 90%  | 85%  | 44   |
| Liu et al.      | 76%  | 24%  | NA   | NA   | NA   | NA   | NA   | 65%  | NA   | 45   |
| Xia et al.      | 60%  | 50%  | NA   | NA   | 15%  | NA   | NA   | 50%  | 30%  | 46   |
| Han et al.      | 86%  | 41%  | 40%  | NA   | NA   | NA   | NA   | 65%  | 97%  | 47   |
| Wu et al.       | 91%  | 63%  | 29%  | NA   | NA   | 6%   | 4%   | 95%  | 53%  | 48   |
| Wu et al.       | 87.0%| 21.7%| NA   | NA   | 13.9%| NA   | NA   | 80.4%| 69.6%| 49   |
| Yoon et al.     | 35%  | 5%   | 10%  | NA   | NA   | NA   | NA   | 97%  | 75%  | 50   |

I- Ground-glass opacity; II- Consolidation; III-Crazy-paving, Linear; IV-Cavitation; V-Discrete nodules; VI-Pleural effusion; VII-Lymphadenopathy; VIII-Bilateral distribution; IX-Peripheral distribution; X-References
parenchymal changes such as consolidations, pleural effusion, edema, or other different types of opacities. A thin slice CT scan is the standard modality to rule out the exact nature and location of pathology. The thin slice CT scan shows the changes in the form of different opacities based on the degree of X-ray attenuation. The CT scan manifestations of viral and bacterial infection are the same as COVID-19 infected patients such as ground-glass opacity, consolidations, crazy paving patterns, nodules, halo sign, reticular pattern, or vessel enlargement but the changes occur through the proper pattern in COVID-19 infected patients. After the onset of symptoms, the common imaging features are the pure and mixed ground-glass opacities. At 0-5 days, mostly the pure ground-glass opacities are present while on illness days 0-12, the pure ground-glass opacities are followed by the mixed ones. Consolidation is the second common imaging feature that occurs along with ground glass opacities on illness days 6-11. The uncommonly seen reticular pattern was only obvious on illness days 18-23 or onwards. Other changes, such as nodules, edema, lymphadenopathy, and pleural effusion also occur in COVID-19 infected patients but they may also be associated with other diseases such as chronic obstructive pulmonary disease (COPD), hypertension, etc.

**CONCLUSION**

In conclusion, both laboratory and radiological examinations can diagnose COVID-19 in infected patients. Though qRT-PCR is considered as a standard reference to rule out the COVID-19 the false-negative results provided by qRT-PCR compromise its accuracy. While in radiological examinations, although X-ray plays an important role as an initial examination to detect the coronavirus disease, CT scan chest is preferred over X-ray modality because of its accuracy, improved contrast resolution, high sensitivity and ability to pick the disease in the initial phase, unlike X-ray which shows indefinite findings of most of the lung lesions.

The typical features of coronavirus detected on CT scan chest are bilateral ground-glass opacities, consolidations, reticular pattern, crazy paving pattern, halo sign, and nodules. Yet, most studies were done on epidemiology and

| Author | Country | Age | Gender | RT-PCR | Lungs Affected | CT Presentation | References |
|--------|---------|-----|--------|--------|----------------|-----------------|------------|
| Liu et al. | China | 41 | Female | Positive | Bilateral lung lobes | Ground glass opacity without consolidation | 22 |
| Lei et al. | China | 33 | Female | Positive | Bilateral lung lobes | Ground glass opacity | 22 |
| Zou et al. | China | 55 | Male | Positive | Right upper and left upper | Ground glass opacity with consolidation | 51 |
| Li et al. | China | 27 | Female | Positive | Right upper lobe | Nodule with ground-glass halo | 52 |
| Kong et al. | China | 59 | Female | Positive | Right Lower Lobe | Ground glass opacity | 53 |
| Kong et al. | China | 62 | Female | Positive | Left Upper Lobe | Small Solitary nodular Ground glass opacity | 53 |
| Kong et al. | China | 45 | Female | Positive | Right and Left upper lobe | Consolidation and crazy paying pattern | 53 |
| Liew et al. | China | 53 | Male | Positive | Left and right lower lobe | Peripheral Ground glass opacity in bilateral upper lobe | 53 |
| Shi et al. | China | 42 | Male | Positive | Left lower and right upper lobe | Presence of consolidation and ground glass opacity | 54 |
| | | | | | | Bilateral ground glass opacity | 55 |
the causes of COVID-19. While, this review article focuses on the role of radiology in detecting the disease along with the epidemiology, control, and prevention. Relying on the baseline CT scan features and not considering the follow-up scans of infected patients is the limitation of this study. Moreover, the article reviewed only those studies done during the early outbreak of the disease. However, the study depicts the importance of radiology in the diagnosis, prevention, and control of the COVID-19.

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