European Review for Medical and Pharmacological Sciences 2020; 24: 4523-4528

Radiological role in the detection, diagnosis and monitoring for the coronavirus disease 2019 (COVID-19)

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Abstract. – OBJECTIVE: Coronavirus disease 2019 (COVID-19) has officially been declared a pandemic by the World Health Organization (WHO). Radiological examinations, especially computed tomography (CT), play an important role in the fight against COVID-19. A comprehensive and timely review of radiological role in the fight against COVID-19 remains urgent and mandatory. Hence, the aim of this review is to summarize the radiological role in the fight against COVID-19. This review of current studies on COVID-19 provides insight into the radiological role in the detection, diagnosis, and monitoring for COVID-19. The typical radiological features of COVID-19 include bilateral, multifocal, and multilobar ground glass opacification with patchy consolidation, a peripheral/subpleural or posterior distribution (or both), mainly in the lower lobes. A combination of chest CT and repeat Reverse Transcription-Polymerase Chain Reaction (RT-PCR) testing may be beneficial for the diagnosis of COVID-19 in the setting of strongly clinical suspicion. Chest CT may improve the sensitivity for COVID-19 diagnosis, but patients' exposure to radiation should be kept as low as possible especially for children and pregnant women patients.

Key Words:
COVID-19, Radiological features, Computed tomography, Ground glass opacification.

Introduction

In December 2019, a group of patients with pneumonia of unknown reasons was reported in Wuhan, Hubei province, China. Epidemiological evidence revealed that most of these patients were linked to a local seafood wholesale market in Wuhan, where poultry, snake, bats, and other live animals were also on sale illegally[1,2]. The gene sequence of the virus obtained from these patients was highly similar to that identified in bats[3]. On Jan 7, 2020, this disease was ultimately found to be caused by a new severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2; previously known as 2019nCoV) formally named by the World Committee on Virus Classification[4]. On February 12, 2020, the disease caused by this virus was named as Coronavirus Disease 2019 (COVID-19) by the World Health Organization (WHO). This virus has spread to over 100 countries, with more than 180,000 cases and over 7,000 deaths reported as of 17 March. Therefore, COVID-19 has officially been declared a pandemic by the WHO.

At present, the Real-Time Reverse Transcription-Polymerase Chain Reaction (RT-PCR) detection method for COVID-19 has been developed and applied in clinics.

RT-PCR remains the reference standard for the final diagnosis of COVID-19 infection, however, especially in the early stage of the outbreak in some countries, the high false negative rate[5] and the lack of RT-PCR assay limited the timely diagnosis of infected patients. Radiological examinations, especially chest computed tomography (CT), play an important role in the fight against COVID-19[6]. Chest CT plays an important role in the timely detection of lung infection abnormalities in the early phase and facilitates a larger public health surveillance and response systems[7,8]. Recent emerging studies have reported that the sensitivity of chest CT may be greater than RT-PCR[9,10]. Since February 13, 2020, chest CT findings have been recommended as the major evidence for confirmed clinical diagnosis especially in the severely epidemic area, such as Hubei. A comprehensive and timely review of the radiological role in the fight against COVID-19 remains urgent and mandatory. Hence, the aim

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of this review is to summarize the radiological role in fighting with COVID-19. To evaluate the recent trends in the radiological findings of COVID-19, we used PubMed and Web of Science with key search terms, including ''COVID-19'', ''SARS-Cov-2'', or ''2019nCoV'', with "radiology", ''imaging'', ''computed tomography'', or ''CT''. We summarize the radiological findings of COVID-19 researches for the following three main areas: (1) radiological role in the detection of COVID-19; (2) radiological role in the diagnosis of COVID-19; and (3) radiological role in the monitoring of COVID-19.

Radiological Role in the Detection of COVID-19

CT has become an important imaging method for the early detection of patients with COVID-19 pneumonia. Song et al[11] reviewed the CT findings in 51 confirmed patients. They found that pure ground-glass opacification (GGO) pattern was in 77% patients, GGO with interstitial and/or interlobular septal thickening in 75% patients, GGO with consolidation in 59% patients. GGO is a predominant CT imaging feature in COVID-19 pneumonia, especially in patients with few symptoms or low severity. However, GGO is often imperceivable on the chest radiography, on which the detection of this type of abnormality is very challenging even for a senior radiologist. In the future, the application of artificial intelligence in screening chest radiographs of suspected cases needs further research.

Chest CT was included into the new diagnostic criteria that by the National Health and Health Commission of China in Hubei province on February 12, 2020. On that day, the diagnoses of COVID-19 surged in Hubei Province. This new diagnostic criteria were employed to ensure timely treatment and isolation measures due to the delays of RT-PCR testing and the large group of patients with respiratory symptoms in the Hubei province. Chest CT may have higher sensitivity for diagnosis of COVID-19 than initial RT-PCR[12], because RT-PCR can be affected by low patient viral load and improper clinical sampling[13,14]. Two studies[9,15] indicated that many cases eventually confirmed with COVID-19 might be initially negative in several times RT-PCR tests, but lung abnormal lesions might be initially detected by chest CT. Fang et al[10] recruited 51 patients who performed RT-PCR assay and chest CT within 3 days. They found that 50/51 (98%) patients had positive CT results while only 36/51 (71%) patients had initially positive RT-PCR results. They also demonstrated that the sensitivity of chest CT was higher than RT-PCR. Moreover, Ai et al[12] investigated correlation of chest CT and RT-PCR testing in 1014 cases of COVID-19. They concluded that chest CT had a high sensitivity for diagnosis of COVID-19. In addition, Xie et al[9] included a group of 167 patients who underwent both initial RT-PCR assay and chest CT scanning on the same day. They found that 5/167 (3%) patients initially had negative RT-PCR results but positive CT results. In contrast, 7/167 (4%) patients had negative CT results but positive RT-PCR results[9]. Similarly, another retrospective study found that 3/21 (4%) patients showed negative findings on first-time chest CT in RT-PCR-confirmed patients, for whom a follow-up chest CT revealed positive findings in 2 patients[16]. Furthermore, Xu et al[17] reported that first-time baseline chest CT did not show any abnormalities in 21/90 patients (23%). The role of CT in the detection of COVID-19 remains totally undefined. However, CT scanning may serve as an important supplementary examination method for RT-PCR screening in the highly suspected patients of COVID-19 infection. RT-PCR remains the reference standard for the final diagnosis of COVID-19 infection.

Radiological Role in the Diagnosis of COVID-19

To date, a total of 26 case series[6,9-12,16-36] have investigated the radiological characteristics of COVID-19. The typical radiological features of initial CT in COVID-19 cases include bilateral, multifocal, multilobar GGO with patchy consolidations, a peripheral/subpleural or posterior distribution (or both), mainly in the lower lobes (Figure 1)[6,9-12,16-35]. GGO is a fuzzy increase in attenuation that occurs in various interstitial and alveolar processes preserving the bronchial and vascular margins[37], while consolidation is a region of opacification obscuring the bronchial and vascular margins[38]. GGO or GGO with consolidation were the most common radiological features. Other common radiological features include interlobular septal thickening, crazy-paving pattern, air bronchogram/traction bronchiectasis, halo sign/reverse halo sign, peripheral/subpleural involvement, and pleural thickening[6,11,16-18,21,23,26,28-30,34,36]. Pleural effusion, pericardial effusion, lymphadenopathy, cavitation, and pulmonary emphysema, pneumothorax are uncommon findings[11,17]. Furthermore, a PET/

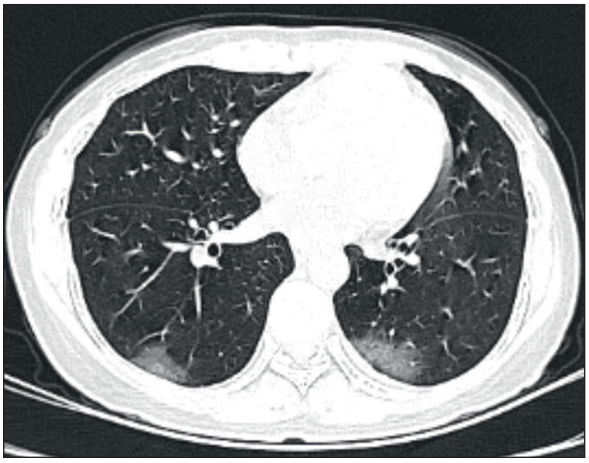

Figure 1. Patchy ground-glass opacity pattern. A 43-old-year woman with close contact history presenting with fever. Scan obtained on illness days 2 showed patchy pure ground-glass opacity in bilateral lower lobes.

CT study revealed that pulmonary lesions typically showed high 18 F-FDG uptake and lymph node could be involved[32].

In the early period of the outbreak, the elderly patients made up the majority and pediatric patients were rather rare, thus children were thought to be not susceptible to COVID-19 virus. Nevertheless, along with the emerging of familial aggregation, children suffering from COVID-19 infection were gradually appeared. Li et al[22] included 5 children patients who performed chest CT. They found similar but more modest lung abnormalities (patchy GGO) in their small pediatric cohort relative to reports in adults. Additionally, Xia et al[31] included 20 pediatric inpatients who performed chest CT. They demonstrated that the radiological findings included consolidation with surrounding halo sign (10/20, 50%), GGO (12/20, 60%), fine mesh shadow (4/20, 20%), and tiny nodules (3/20, 15%)[31]. Consolidation with surrounding halo signs were common in children compared to reports in adults. Thus, they concluded that consolidation with surrounding halo sign might be a typical radiological sign in children. In addition, Liu et al[33] included 15 pregnant women patients of COVID-19 pneumonia. They found that pregnancy and childbirth did not aggravate the course of symptoms and chest CT features.

Chest CT may improve the sensitivity for COVID-19 diagnosis, but patients' exposure to radiation should be kept as low as possible, especially for children and pregnant women patients. Therefore, chest X-ray can be an alternative choice for imaging, particularly for serial monitoring, as demonstrated in the case report from United States[39]. Furthermore, ultrasound imaging can be another alternative technique for chest imaging[40], as demonstrated in the case report from Italy[41]. For CT scanning, low radiation dose mode should always be applied to minimize the radiation dosage[42].

Radiological Role in the Monitoring of COVID-19

Chest CT can be used to evaluate the disease severity of COVID-19 to guide clinical management. Huang et al[2] reported that severe patients on admission often presented with bilateral multiple lobular and subsegmental consolidation on their chest CT, while mild patients often presented bilateral GGO and subsegmental consolidation on their chest CT. Many radiological studies[6,11,18,19,23,28,35] have investigated the temporal changes of imaging findings following the stage of the disease. Song et al[11] found that an increased rate of consolidative opacities were associated with disease progression of COVID-19. Further, Shi et al[6] classified their patients into four groups according to the interval between symptom onset and the first CT scan: group 1 (scans done before symptom onset), group 2 (scans done ≤7 days after symptom onset), group 3 (>7 days to 14 days), and group 4 (>14 days to 21 days). Radiological characteristics were analyzed and compared across the four groups. The predominant lesions were unilateral and multifocal GGO in group 1, then, the lesions quickly evolved to bilateral, and diffuse GGO predominance in group 2. Thereafter, the prevalence of GGO continued to decrease, and consolidation and mixed patterns became more frequent in group 3 and group 4[6]. Moreover, Pan et al[18] performed a longitudinal follow-up study to observe the radiological changes between initial CT and follow-up CT with an interval of 3-14 days. The follow-up CT results showed that 85.7% patients progressed. The CT findings of disease progression included an increase in number and size or consolidation of GGO, enlarged fibrous stripe, and an increase in number and size or fusion of the nodules[18]. Furthermore, Pan et al[19] investigated the temporal course of CT changes in 4 stages with 4 day intervals. In early stages, most of their patients showed more GGO and fewer lobes number than that of the subsequent follow-up scans (Figure 2A, 2B). Nevertheless, increased number of involved lobes, increased crazy-paving pattern,

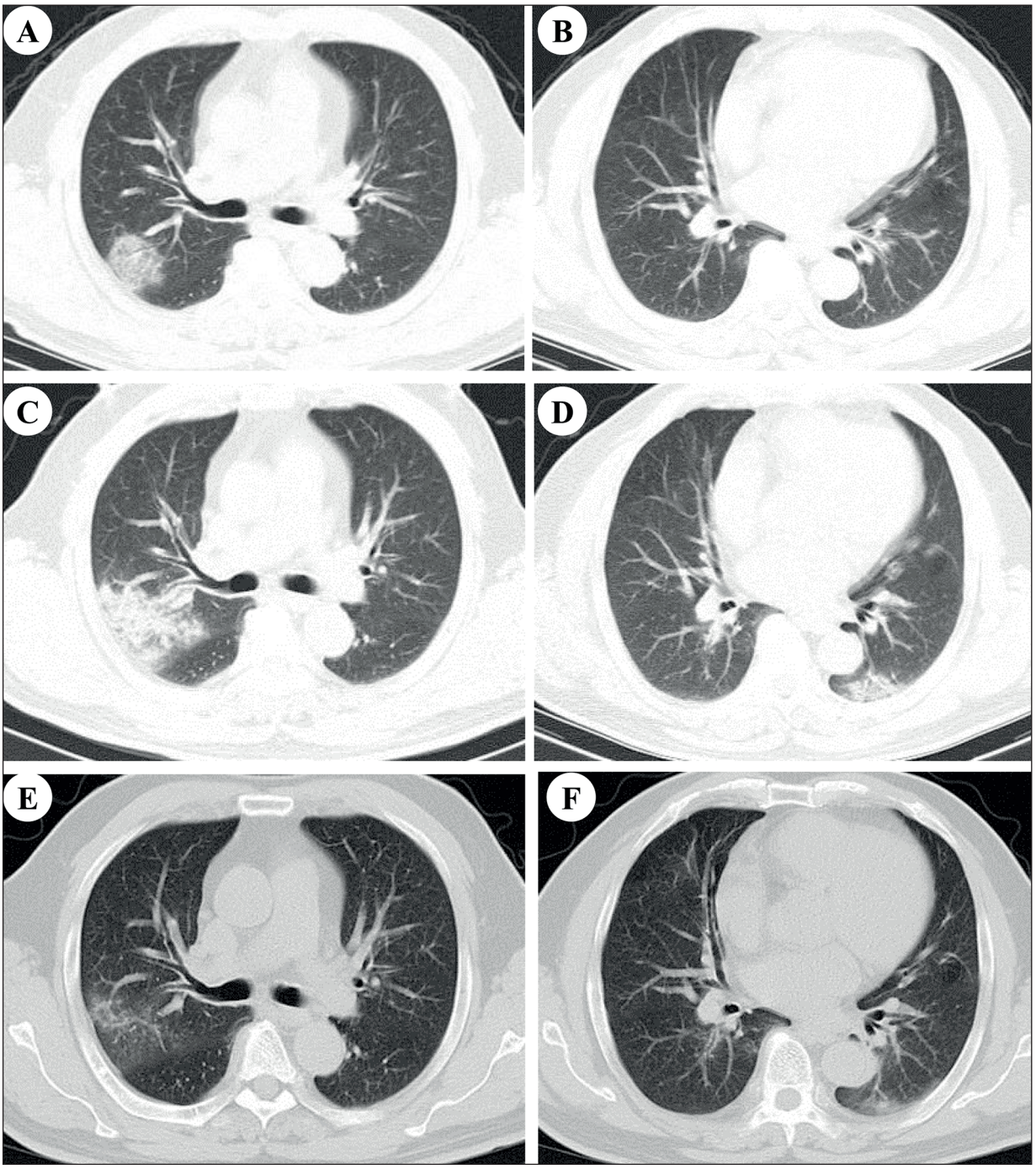

Figure 2. Series CT scans in a 66-year-old man with COVID-19 pneumonia. **A, B,** Scan obtained on illness days 2 showed ground-glass opacity with intralobular septal thickening (crazy-paving pattern) that affected posterior segment of right upper lobe. **C, D,** Scan obtained on illness days 8 showed increased consolidative opacities. Note that patchy ground-glass opacity newly developed in left lower lobe. **E, F,** Scan obtained on illness days 13 showed absorption of abnormalities, with pure ground-glass opacity left in the posterior segment of right upper lobe and posterior basal segment of left lower lobe.

and appearance of consolidation appeared in the majority of patients over time (Figure 2C, 2D)[19]. They concluded that the extent of lung abnormalities on CT peaked on day 10 after initial onset of symptoms. In the stage-4 (≥14 days), 75% of the patients showed disease improvement, including decreased number of involved lobes and resolution of crazy paving pattern and consolidation

(Figure 2E, 2F)[19]. As a support, another longitudinal study[35] analyzed the serial CT findings of 90 patients over time. They demonstrated that lung abnormalities were severest during illness days 6-11. The early follow-up CT often showed increased number of involved lobes, mixed pattern of GGOs, increased consolidative opacities, and pleural effusion because of disease progression[23,28]. Then, the later follow-up CT showed the resolution of GGO and appearance of fibrosis because of disease recovery[28].

Conclusions

Summarily, the typical radiological features of COVID-19 include bilateral, multifocal, multilobar ground glass opacification (GGO) with patchy consolidations, a peripheral/subpleural or posterior distribution (or both), mainly in the lower lobes. A combination of chest CT and repeat RT-PCR testing may be beneficial for the diagnosis of COVID-19 in the setting of strongly clinical suspicion. Chest CT may improve the sensitivity for COVID-19 diagnosis, but patients' exposure to radiation should be kept as low as possible especially for children and pregnant women patients.

Conflict of Interest

The Authors declare that they have no conflict of interests.

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