Introduction

Since the spread of COVID-19 last December, chest imaging has been of great importance for the diagnosis and management of patients with COVID-19 infection [1], since the infection can lead to severe acute respiratory syndrome (SARS) and death in a short amount of time. Some image methods are currently being used to detect the abnormalities of pneumonia caused by COVID-19, such as computed tomography (CT) or high resolution computed tomography (HRCT), computed X-Ray (CRX) and ultrasound (US), to help in the diagnosis and in the management of the patient [2]. Moreover, it also important to know how it manifests in the lungs, the location of the lesions, the progression of the disease and the abnormalities that can be present in the lungs [3]. A deep understanding of image methods is essential in order to determine which are good options to use, and how to look for the abnormalities found in infected patients with COVID-19. That is one of the key components in the diagnosis of patients with suspected infection so as to secure the best possible outcome for them [4,5].

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The objective of this review is to present the main image methods for COVID-19 detection and the pulmonary findings observed in the disease through the images of the reviewed studies.

**Main Findings in Chest Images of COVID-19**

The typical radiological characteristics in COVID-19 pneumonia involve bilateral, multifocal, multilobar ground-glass opacity (GGO) with patchy consolidations, a peripheral/subpleural, or posterior distribution (or both), principally in the lower lobes (Figure 1) [1-25]. GGO occurs in multiple interstitial and alveolar processes maintaining the bronchial and vascular margins [26], while consolidation is a region of opacification, which obscures the bronchial and vascular margins [27]. GGO or GGO with consolidation was the most frequent radiological features in COVID-19 pneumonia. Other typical radiological characteristics incorporate interlobular septal thickening, crazy-paving pattern, air bronchogram/traction bronchiectasis, halo sign/reverse halo sign, peripheral/subpleural involvement, and pleural thickening [1, 2, 5, 7-9, 12, 14, 17, 19-21, 24, 26]. Li and colleagues [28], summarized the findings in chest computer tomography (CT) as following:

1. Ground-glass opacities (GGO) (100% of the cases);
2. GGO pattern;
3. GGO location;
4. Consolidation;
5. Multilobe involvement;
6. Bilateral distribution;
7. Location of consolidation or GGO;
8. Pulmonary nodules surrounded by GGO;
9. Interlobular septal thickening;
10. Air bronchogram;
11. Halo sign;
12. Presence of cavitation;
13. Bronchial wall thickening;
14. Bronchiectasis;
15. Perilesional vessel diameter;
16. Lymphadenopathy (defined as lymph node with short-axis > 10mm);
17. Pleural effusion; and
18. Pericardial effusion.

Based on a several images studies, the American College of Radiology, Society of Thoracic Radiology, and Radiological Society of North America Radiology categorized the main findings of COVID-19 chest CT images as typical, indeterminate and atypical features, and negative for pneumonia) [29,30]. The typical features are peripheral bilateral GGOs, rounded GGOs, and reverse halo sign of organizing pneumonia. Indeterminate features diffuse, perihilar, or unilateral GGOs with nonrounded, nonperipheral distribution. Atypical features include isolated consolidations, tree-in-bud opacities, cavitation, and smooth interlobular septal thickening with pleural effusion (Table 1). Regarding the phase of the disease, Pan and colleagues [4] divided the progression of chest abnormalities/disease in 4 phases: early phase, progressive phase, severe phase, and dissipative phase (Table 2). Additionally, there are specific placements for abnormalities on the chest that can commonly occur in COVID-19 patients (Table 3) [31]. Zhang (2020) [32] observed 95.40% of the lesions caused by COVID-19 are in the middle and lower part of the lung, while 4.60% is in the upper part of the lung. The same author introduced a CT imaging score system to quantify the pathological changes in the lungs of patients with COVID-19 (Table 4).

**Computer Tomography (CT) High Resolution**

In addition to computed X-Rays, computed tomography (CT) is also able to show the main finding (GGO) in COVID-19 pneumonia. High-resolution CT (HR-CT) especially plays a crucial role in the early diagnosis of COVID-19 disease infection [28, 37, 38] due to a higher...
Figure 1. CT scans in a patient 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.

Source/Credit: Wu and Wang [1].
Table 1. Chest CT findings related to COVID-19 (expert consensus by Society of Thoracic Radiology, and Radiological Society of North America Radiology [30]).

<table>
<thead>
<tr>
<th>Classification</th>
<th>Rationale</th>
<th>CT findings</th>
<th>Suggested reported language</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical</td>
<td>Commonly reported imaging features of greater for specificity for COVID-19 pneumonia</td>
<td>Peripheral, bilateral (multilobar) GGO*, consolidation, or visible intralobular lines</td>
<td>Commonly reported imaging features of COVID-19 pneumonia are present</td>
</tr>
<tr>
<td>Indeterminate</td>
<td>Nonspecific imaging features of COVID-19 pneumonia</td>
<td>Multifocal, perihilar, unilateral GGO or nonrounded or nonperipheral</td>
<td>Imaging features can be seen with COVID-19 pneumonia</td>
</tr>
<tr>
<td>Atypical</td>
<td>Uncommonly or not reported features of COVID-19 pneumonia</td>
<td>Isolated lobar or segmental consolidation, discrete small nodules, cavitation or interlobular septal thickening, pleural effusion</td>
<td>Imaging features are atypical or uncommonly reported for COVID-19 pneumonia, an alternative diagnosis should be considered</td>
</tr>
<tr>
<td>Negative</td>
<td>No features of pneumonia</td>
<td>No CT features to suggest pneumonia</td>
<td>No CT findings indicate pneumonia</td>
</tr>
</tbody>
</table>

*GGO: Ground-glass opacities.  
Source/Credit: Akçay and colleagues [30].

Table 2. Phase and findings in Chest CT-COVID-19 patients.

<table>
<thead>
<tr>
<th>Phase</th>
<th>CT Finding</th>
<th>Figure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early (0-4 days)</td>
<td>Single or multiple lesions distributed along with the subpleural areas or bronchi [33, 34]. Presence of nodular or patchy GGOs [30], with the blood vessels seen thickening and passing through the GGO [12, 35].</td>
<td>Figure 2</td>
</tr>
<tr>
<td>Progressive (5-8 days)</td>
<td>The number of lesions increased significantly. Original lesions are partially absorbed and new lesions with GGOs and the consolidations coexisted [7, 36]. Presence of distortion of local lung structures, bronchodilation, and focal atelectasis.</td>
<td>Figure 3</td>
</tr>
<tr>
<td>Severe (9-13 days)</td>
<td>Bilateral lesions with diffuse infiltration of all segments of the lungs, and manifesting as “white lung.” Air bronchograms suggested a large amount of cellular exudation in the alveolar cavity. Subsegmental atelectasis or reduction of lung volume was sometimes noted, and a small amount of pleural fluid could be seen bilaterally. Currently appears around 14 days after the onset of the disease, but in some cases developed rapidly [37, 38].</td>
<td>Figure 4</td>
</tr>
<tr>
<td>Dissipate (≥14 days after the onset of the initial symptom)</td>
<td>Gradual absorption of the lesions, leaving a few cord-like high-density shadows, indicative of fibrosis. This phase happens commonly after 14 days [28].</td>
<td>Figure 5</td>
</tr>
</tbody>
</table>

Source/Credit: Li and colleagues (adapted) [28].

sensitivity (98%) [39] compared with other images methods.

The HR-CT allows for an evaluation of lesions in the lungs, and, combined with clinical manifestations and laboratory diagnosis, such as RT-PCR, can confirm COVID-19 diagnosis and instruct the management of the patient in the early stage of the disease. In cases when the laboratory test is negative but the physician is suspicious of COVID-19 infection, the performance of an HR-CT is important because abnormalities in the lungs are present in the early stage of the disease sometimes [40, 41]. However, it is important to be aware of the radiation of CT. If the patient
### Table 3. Main location findings in the chest of COVID-19 patient [31].

<table>
<thead>
<tr>
<th>Phase</th>
<th>AbnL</th>
<th>GGO</th>
<th>Co</th>
<th>CPP</th>
<th>PE</th>
<th>Ca</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early</td>
<td>Lower lobes unilaterally or bilaterally</td>
<td>Yes</td>
<td>Sometimes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Progressive</td>
<td>Bilateral multilobe distribution</td>
<td>Yes</td>
<td>Sometimes</td>
<td>Yes</td>
<td>Sometimes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Severe*</td>
<td>Bilateral multilobe distribution</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Sometimes</td>
<td>Sometimes</td>
</tr>
<tr>
<td>Dissipate/</td>
<td>Bilateral</td>
<td>Sometimes</td>
<td>Sometimes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Absorption</td>
<td>(as a demonstration of the absorption)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

AbnL: abnormalities location; GGO: ground-glass opacity; Co: consolidation; CPP: crazy-paving pattern; PE: pleural effusion; Ca: cavitation; L: lymphadenopathy. *Presence of residual parenchymal bands.

### Figure 2. Patient with coronavirus disease (COVID-19) pneumonia in the early stage.

A. Axial reconstruction. B. Coronal reconstruction. Several small patchy ground glass opacities and consolidations are scattered at both lungs more prominent at subpleural regions (CT images). C. Axial reconstruction. B. Coronal reconstruction. CT demonstrates multilobar and bilateral ground-glass opacities with rounded morphology, mostly in the periphery of both lungs. Source/Credit: A-B: Radiopaedia - Case courtesy of Dr Mohammad Taghi Niknejad, [Radiopaedia.org](https://radiopaedia.org/). From the case [rID: 75829](https://radiopaedia.org/cases/75829). C-D: Case courtesy of Dr Antonio Rodrigues de Aguiar Neto, [Radiopaedia.org](https://radiopaedia.org/). From the case [rID: 77010](https://radiopaedia.org/cases/77010).
**Figure 3.** Patient with COVID-19 pneumonia (progressive phase).

A. Axial reconstruction. Multifocal regions of consolidation and ground-glass opacifications. These have a peripheral and basal predominance. No pleural or pericardial effusion. B. Coronal reconstruction.
Source/Credit: Li and colleagues [28].

**Figure 4.** Patient with coronavirus disease (COVID-19) pneumonia (severe phase).

Axial reconstruction. Diffuse bilateral coalescent opacities and ground-glass opacities, mediastinal lymphadenomatosis.
Source/Credit: Case courtesy of Dr Sajoscha Sorrentino, [Radiopaedia.org](https://radiopaedia.org/rID:16290). From the case [rID: 16290].

**Figure 5.** Patient with coronavirus disease (COVID-19) pneumonia in dissipative phase.

Transforming ground-glass opacity to subpleural fibrous stripes.
Source/Credit: Case courtesy of Dr Vitalii Rogalskyi, [Radiopaedia.org](https://radiopaedia.org/rID:76319). From the case [rID: 76319].
Table 4. CT imaging score system to quantify the severity of pneumonia in the COVID-19 patients.

<table>
<thead>
<tr>
<th>Number</th>
<th>Performance Description</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Unilateral patchy shadow or ground-glass opacity</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>Bilateral patchy shadow or ground-glass opacity</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>Diffuse changes for (1) or (2)</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Unilateral solid shadow, striped shadow</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Bilateral solid shadow, striped shadow</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>Unilateral pleural effusion</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Bilateral pleural effusion</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>Increased or enlarged mediastinal lymph nodes</td>
<td>1</td>
</tr>
</tbody>
</table>

Source/Credit: Zhang Z. (2020) [32].

If the patient does not show clinical symptoms or has an RT-PCR negative but the physician suspects it is a COVID-19 case, an initial X-Ray could be satisfactory [32, 40, 41].

**Imaging Phases of COVID-19**

In the early phase of COVID-19, when the patient exhibits moderate clinical symptoms or no clinical symptom (Table 3), the chest CT could show nodular-shape-lesions (single or multiple) or patchy GGOs, indicating the spread of the disease with the invasion of the bronchioles and alveolar epithelium of the cortical lung tissues [5]. It could be followed by the thickening of interlobular and intralobular septa, and the appearance of halo signs around the nodules. The pathological basis may be congestion of alveolar septal capillaries, exudation of fluid into the alveoli, and interstitial edema of the interlobular septum [5, 4, 41].

In the progressive phase, the number of lesions increased, the GGOs and the consolidations coexisted due to the amount of cellular exudate accumulated in the alveolar cavity, which cause interstitial vasodilation and exudation, and fusion of alveoli. The “crazy paving appearance” is presented reflecting interstitial lesions [28].

In the severe phase, the lesions are bilateral with diffuse infiltration of all lungs’ segments, with the apparent of “white lung.” A large amount of cellular exudation suggests air bronchograms in the alveolar cavity. Also, subsegmental atelectasis or decrease of lung volume, as well as a small quantity of pleural fluid could be seen bilaterally. The clinical symptoms were compatible with the severe nature of clinical manifestations. Nevertheless, unlike SARS, the appearance of both pneumomediastinum and subcutaneous gas was uncommon [5, 37, 38]. The dissipative phase is similar early phase or presents gradual absorption of the lesions, leaving a few cord-like high-density shadows [5].

The dissipative phase is like the early phase or shows gradual absorption of the lesions, leaving a few cord-like high-density shadows [5].

**The Role of Chest X-Rays in COVID-19**

Bhat and colleagues [31] demonstrated that the value of computed chest X-Ray (CRX) is relatively low (30%-60%) in COVID-19 pneumonia [42], indicating that a normal chest X-Ray cannot exclude the presence of abnormalities in lung patients of COVID-19, especially in the early stages (Figure 6) [31, 42, 43]. For this reason, non-contrast chest CT is considered best for early diagnosis of viral disease in suspected patients with normal chest X-Ray [11, 44]. However, CXRs remain the initial imaging tool of choice but have a limited role in the diagnosis of the disease [31].

About the main findings, Wong and colleagues [45] found that consolidation was the most common finding on CXRs in COVID-19 patients with a peripheral, lower zone predominance.

Despite CT’s higher sensitivity when compared to other imaging methods, the issue lies in the transportation of the patient to the CT room. It is especially difficult for Intensive Care Unit (ICU) patients, for children and pregnant women due to the ionizing radiation, not to mention the risk of contamination to healthcare workers during the transportation and management of the infected patient. So, since infection control
issues associated with patient transportation to CT rooms, the difficulties concerning CT room decontamination, and the absence of CT available in parts of the world, the portable chest radiography (CXR) is a possible method for identification and follow up of lung abnormalities [31].

**Portable CXR**

According to Jacobi and colleagues [46], patterns of COVID-19 lung disease can be identified by conventional chest radiography; besides the gold-standard image methods is the chest CT. The grade of the disease’s severity is based on the percentage of lung involvement. So portable CXR will widespread availability and reduced infection control issues that currently limit CT utilization [46, 47].

Also, ground-glass densities observed on CT may often have a correlation that is difficult to detect on portable CXR (Figure 7). Often, reticular opacities following regions of ground-glass attenuation are more easily detectable on standard CXR (Figure 8). The obscure pulmonary opacities on CXR can sometimes be diffuse, causing the identification of the features a challenge for some clinicians (Figure 9) [46, 47].

Neri and colleagues [48] in a study about CT and artificial intelligence presented the

**Figure 6.** Patient with COVID-19 pneumonia (CXR and CT images).
recommendations of the Italian Association of Ultrasonography in Medicine and Biology, and the Italian Association of Scientific Medical Societies and the Italian Image Society of Medical Radiology (SIRM, in Italian) about the use of radiological methods for COVID-19 as follow:

1. Chest X-Ray could be a first-line imaging tool that permits the first assessment of patients, especially in the emergency room, and in regions that CT does not exist. Also, it could differ the diagnosis toward other possible causes of pulmonary parenchymal involvement than COVID-19 infection [49].

2. CT as an additional tool that shows typical features of COVID pneumonia, which the most common is bilateral ground-glass opacities involving mainly the lower lobes [50].

3. Ultrasound of the lungs as a monitoring tool also to evaluate the effectiveness of prone-supination maneuvers [51].

4. SIRM recommends as high priority, to ensure appropriate sanitation procedures on the scanning equipment after detecting any suspected or positive COVID-19 patients, since the risk of spreading the infection into the CT room.

The Point-of-Care Ultrasound (POCUS) Use

In addition to the CRX and CT, the most effective imaging methods used for COVID-19 also include the portable ultrasound (US), which has been tested and showed good results, especially for mitigating the risk of care takers contagion from Intensive Care Unit (ICU) patients. Ultrasound imaging can be an alternative method for chest imaging to follow up on COVID-19 pneumonia [52], as demonstrated in the case report from Italy [53]. Ultrasound can also distinguish between cardiogenic and noncardiogenic pulmonary edema [54] and can be deployed rapidly to exclude alternative causes of hypoxia in intensive care [55]. For consolidation, ultrasound has an accuracy of 97% (sensitivity 93%; specificity 93%), compared with 75% for chest radiography (sensitivity 68%; specificity 95%) and 36% for auscultation (sensitivity 8%; specificity 100%) [54].

There are advantages in the use of US: the test is cheap, involves no ionizing radiation, and the results are available instantly. Compared to a portable X-Ray or CT machine, ultrasound

Figure 7. Portable CXR x CT in a patient with COVID-19 pneumonia.

A. Portable CRX shows the presence of extensive bilateral ground-glass opacities as demonstrated on the recent CT. Also right IJV catheter and ETT noted. B. There are bilateral large areas of ground-glass opacities with crazy paving and, more evident at both bases, areas of consolidation. Enlarged mediastinal lymph nodes.

machines are faster to decontaminate due to their small size. POCUS has a high sensitivity for the pulmonary manifestations of COVID-19, such as ARDS and consolidation. Furthermore, POCUS can be used to monitor treatment response. US is professional dependent, which means more training to have US as a method of choice especially in ICU [56, 57]. Indeed, the main choice of POCUS is about the risk of contamination of healthcare staff, patients, and visitors when the patient is transferred to CT or CRX room.

Conclusion

Imaging methods to recognize indications of COVID-19 performs a critical role in the diagnosis and follow up of the patient with COVID-19 pneumonia. Despite CT having a better sensitivity when compared to CRX and ultrasound, the method brings a high risk of contamination to health professionals, visitors, room service, and staff of the hospital, as well as more ionization radiation for the patient. So, portable CRX and portable ultrasound could be a new tool with minimal risk of contamination and with good sensitivity. Currently, adding to the recommendation of CRX in the early stage, the CT is still preferable in the protocols to managing and diagnosing the patient with COVID-19 pneumonia.

References


