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REVIEW – OPEN ACCESS

Thorax CT Findings in Novel Coronavirus Disease 2019 (COVID-19)

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ABSTRACT

Novel coronavirus disease 2019 (COVID-19) is a disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). COVID-19 has high mortality rates. It has become a severe pandemic worldwide. Real-time PCR testing is still the gold standard test method for the definitive diagnosis of COVID-19 despite the possibility of false negatives. Radiological imaging methods, especially computed tomography (CT), are important assistant methods in the diagnosis and management of the disease. This review presents the role of CT in COVID-19 pneumonia, its diagnostic accuracy, thorax CT findings of the disease and differential diagnosis.

Keywords: Coronavirus, computed tomography, lung, pneumonia

INTRODUCTION

The novel coronavirus 2019 (COVID-19) infection, which first appeared in Wuhan, Hubei Province, China in December 2019, has become an increasingly important pandemic worldwide. There have been more than 15 million cases and more than 619 thousand deaths worldwide so far (1). The first coronavirus case was identified on March 11, 2019, in Turkey. Radiological methods are not diagnostic tests in this disease, but they help diagnosis and differential diagnosis. PCR test results, which may take longer than expected, may cause challenges in the diagnosis phase. However, since computed tomography (CT) is easily accessible and its results are immediately available, it plays an important role in the diagnosis, follow-up and treatment of COVID-19 with clinical and typical findings (2–4). The American College of Radiology (ACR) recommends that CT should not be used for primary screening or as a primary test to diagnose COVID-19 pneumonia. According to ACR, CT should be used in small quantities and reserved for hospitalized, symptomatic patients with specific clinical indications (5).

CT Technique

A non-contrast thorax CT examination should be performed for patients requiring CT in the supine position. If contrast examination is required, for example, CT pulmonary angiography, non-contrast scanning should be considered before contrast is given. The contrast agent should be applied at a high injection rate (>3 ml/s). For good timing, bolus tracking is needed. When the threshold of 150 HU in the pulmonary trunk is reached, the patient is asked to breathe in and scanning is started immediately because the contrast agent may affect the interpretation of ground-glass density patterns. The thickness of the section must be under 5 mm. Images should be reconstructed with 1.0–1.5 mm section thickness. Choosing the parameters as follows can help minimize the radiation dose. kV: 100–120, mAs: 50–100, pitch: 1–1.5. Multiplanar reconstruction helps radiologist in localization, distribution and detection of lesions (6–8). In addition, thorax CT images obtained by three-dimensional volume rendering and maximum density projection techniques can assist in clearly viewing ground-glass opacities in the posterior segments of both lungs. Three-dimensional CT images may contribute to showing ground-glass opacities close to the anatomical contiguity with vascular structures (9) (Fig. 1).

CT Findings

Thorax radiography and CT can be used in the radiological diagnosis and maintenance of COVID-19 pneumonia. Portable thorax radiogram can be used in intensive care units for pediatric, young and pregnant patient groups since it can be used as a bed-side application and is easy to sterilize. However, direct radiography findings may be normal in early-stage COVID-19 pneumonia cases. Direct radiography findings are most extensive about 10–12 days after symptom onset. On the other hand, CT plays an important role in determining the stage, prevalence, non-infection conditions and complications of the disease. Recent studies show that the sensitivity of the CT varies between 60% and 98%, and the specificity between 25% and 53% in COVID-19 pneumonia (10–13).

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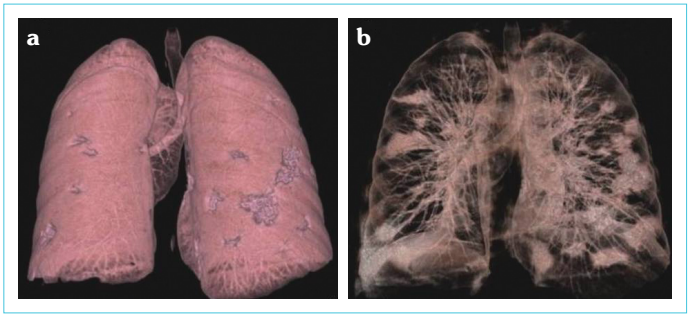

Figure 1. 47-year-old woman with a positive RT-PCR. (a) Three-dimensional volume rendering technique clearly shows ground-glass opacities at the posterior segments of both lungs, and (b) three-dimensional maximum intensity projection technique demonstrates ground-glass opacities close anatomical adjacency with vascular structures

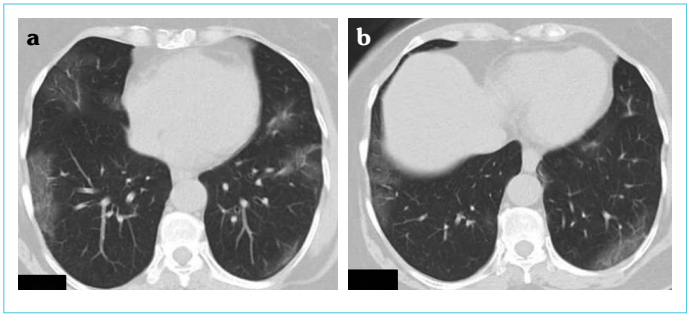

Figure 2. 58-year-old woman with a positive RT-PCR. Axial unenhanced thorax CT images (a, b) in parenchyma window show bilateral, multifocal and peripheral ground glass-opacities

Anatomical Distribution of Lesions

In COVID-19 pneumonia, the basal and posterior sections of the bilateral lungs are more frequently affected, while the middle lobes are involved less frequently. Rarely, cases with upper lobe involvement can be seen. The disease most often affects both lungs (82.2%), subregions (54.5%), peripheral parts (87.1%) and multifocal areas (54.5%) (10, 13). The most frequently involved lung segments are the dorsal segment of the lower right lobe (86%), the posterior basal segment of the lower right lobe (85%), the lower right lower lobe segment (80%), the dorsal segment of the lower left lobe (76%) and the posterior basal segment of the left lower lobe (81%). The lower lobes are the most commonly involved lobes and the right middle lobe is the least commonly involved lobe (14, 15). Irregular multifocal distribution is more common than the diffuse disease; however, unilateral and even unifocal involvement can be seen, especially in early cases (10, 16, 17). Only peribronchial distribution, which is seen only in 4% of the patients, is defined (18).

Typical CT Findings

Thoracic CT findings of COVID-19 pneumonia have been reported in a wide range in different recent studies. However, common CT findings in all studies are bilateral, subpleural, peripheral ground-glass opacities, which are among the early-stage findings of the disease. Ground glass densities are the earliest findings seen in 34%–98% of patients in different studies (19, 20) (Fig. 2a, b). Other early-stage findings are air space consolidations and bronchovascular thickening. Consolidation is seen especially in the elderly population, and in a smaller number of cases. Consolidation can sometimes be seen as superimposed on ground-glass opacities in the early period (21) (Fig. 2a, b). The studies of Salehi et al. (22) covering 919 patients found consolidation in 31.8% of the patients. Consolidation in COVID-19 pneumonia often lies in segmental style and/or along bronchovascular structures scattered across subpleural regions. This rate varies between 2–69% in different studies (17, 19). As the disease progresses, the density of the areas of consolidation, especially ground-glass opacities, and tendencies of consolidation increase and progress to the upper parts of the lungs. Multifocal, irregularly bounded nodules with minimal ground glass patterns can be seen in 3–13% of cases with COVID-19 pneumonia (23). Reticulation is a late-stage finding of the disease due to intralobular and interlobular septal thickening and is another common finding after ground-glass opacities and consolidation (Fig. 3). The incidence varies between 1% and 59%

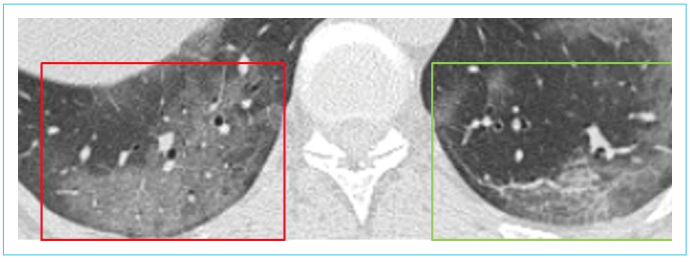

Figure 3. 58-year-old man with a positive RT-PCR. Axial unenhanced thorax CT image in parenchyma window shows ground-glass opacity superimposed with interlobular and intralobular septal thickening (reticulation, red frame) in the right lung, and subpleural fibrous stripes (green frame) with ground-glass opacities in the left lung

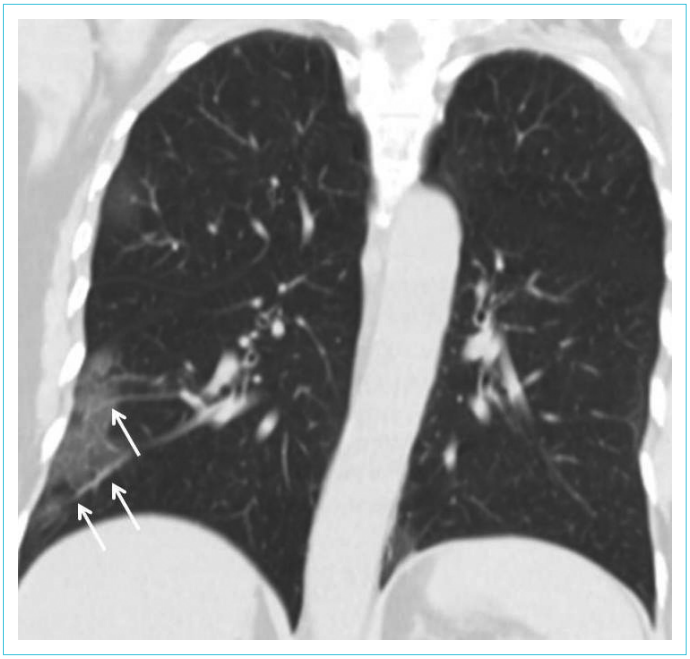

Figure 4. 58-year-old woman with a positive RT-PCR. Coronal reformatted unenhanced thorax CT image demonstrates peripheral ground-glass opacities and vascular dilatation (arrows) in the right lung

Table 1. Thorax CT findings in COVID-19 pneumonia

Typical findings	Atypical findings
Ground-glass opacities (±interlobular reticulation±consolidation)	Mediastinal lympadenopaty
Consolidation (multiple, subpleural, segmental or along the bronchovascular bundle)±halo sign	Pneumothorax
Nodule (multiple, irregular contour, periphe-ral ground-glass)	Cavitation
Crazy-paving appearance, reversed halo, vascu-lar dilatation, air bronchogram, bronchial dila-tation, subpleural fibrous stripes, air bubble	Lobar pneumonia, bronchopneumonia, centrilobular nodules, tree-in-bud appearance, peribronchial thickening
Pleural thickening	Pleural effusion
Bilaterality, peripheral and posterior distribu-tion, middle and lower zones, multilobar, ro-und-shaped	Unilaterality, upper zone involvement, perihilar involvement, diffuse involvement

Table 2. Structured thorax CT report recommended by BTSI in COVID-19[30]

Pattern	Appearance
Classic COVID-19 (100% confidential)	Peripherally, lower lobe predominant, multiple, bilateral[1] ground glass opacities (GGOs)
	±
	Crazy paving
	Peripherally consolidation[2]
	Air bronchogram
	Converse halo sign/perilobuler pattern[2]
Possible COVID-19 (71–99% confidential)	Peripherally, lower lobe predominant, bronchocentric consolida-tion
	Reverse halo /perilobular pattern[2]
	Limited GGOs
Indeterminate (<70% confidential)	Incompatible with the other three groups.
	Compatible with radiological appearance but has another diagno-sis such as ILD, CTD.
COVID-19 exclusion	Lobar pneumonia
(<70% compatible with another diagnosis)	Cavitation
	Tree in bud/nodularity
	Lymphadenopathy
	Pleural effusion
	Advanced pulmonary fibrosis

1: >1 lesion can be unilaterally (it is usually bilateral); 2: e.g.; Organised pneumonia patterns

in different studies (10, 12, 18). Other typical CT findings include vascular dilatation (Fig. 4), traction bronchiectasis, air bronchogram, perilobular predilection, and air bubble, subpleural fibrous bands (Fig. 3) which are late-stage findings of the disease, structural distortion, pleural thickening, and pulmonary embolism (10, 21).

Atypical CT Findings

Cavitation, lobar pneumonia/bronchopneumonia, centrilobular nodules, tree-in-bud appearance, pneumothorax, pleural effusion, pericardial effusion, and mediastinal lymphadenopathy are atypical CT findings in COVID-19 pneumonia. These findings have been reported as rare or uncommon findings in COVID-19 pneumonia. Particularly, pleural effusion may occur as a complication of COVID-19 pneumonia. Rather than COVID-19, they are typically seen in other diseases that are also included in the differential diagnosis of COVID-19, such as bacterial pneumonia, necrotizing pneumonia. Air bubble, which is one of the typical findings of COVID-19, should not be confused with cavitation. Pleural effusion is rarely seen in COVID-19, but it is seen as a complication or advanced disease finding mostly (24–27).

Thorax CT findings of COVID-19 pneumonia are summarized in Table 1.

Temporal Changes of the CT Findings

Several studies are available in the current literature on the radiological course of COVID-19 pneumonia over time (19, 28, 29). According to the current literature, CT findings of COVID-19 pneumonia progress in four basic stages.

Stage 1- (Initial stage, 0–4 days): At this stage, the main CT finding is ground-glass opacities often seen in the lower lobes and posterior. However, CT may also be normal during this period (Fig. 5).

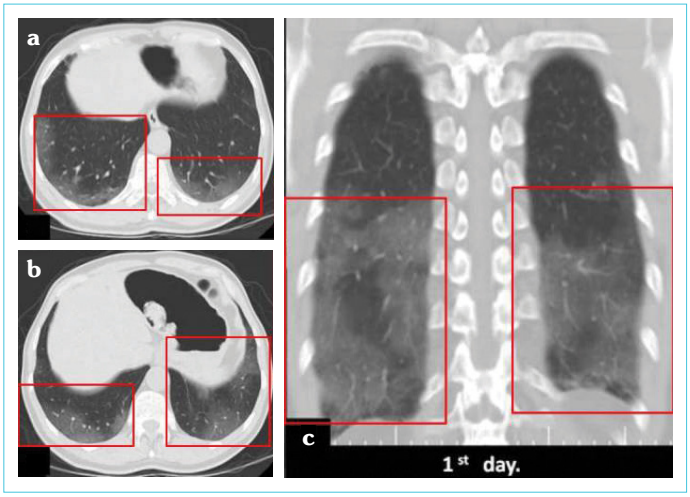

Figure 5. 64-year-old man with a positive RT-PCR. Unenhanced thorax CT examination performed at admission. The axial images (a, b) and a coronal reformatted image (c) show bilateral opacities of ground-glass density with a tendency to coalesce and concomitant vascular dilation, especially at posterior and lateral segments of lower lobes (red frames). These CT signs are compatible with stage 1 COVID-19 pneumonia

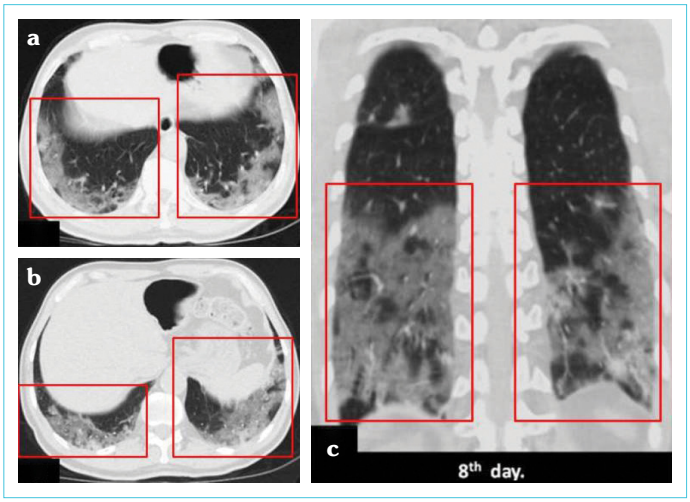

Figure 6. 64-year-old man with a positive RT-PCR. Unenhanced thorax CT taken on the 8th day. The axial images (a, b) and a coronal reformatted image (c) show an increased diffuseness of opacities of ground-glass density with concomitant patchy areas of consolidation and interlobular septal thickening (red frames). These CT signs are compatible with stage 2 COVID-2 pneumonia

Stage 2- (Progressive stage, 5–8 days): At this stage, increase in ground-glass opacities to which consolidation is added and prominence in bronchovascular structures, interlobular and intralobular septal thickening are observed (Fig. 6).

Stage 3- (Peak stage, 9–13 days): At this stage, findings of an increase in the areas and intensity of consolidation and secondary complications are observed. The most severe findings are seen at this stage. This stage contains fewer specific findings for

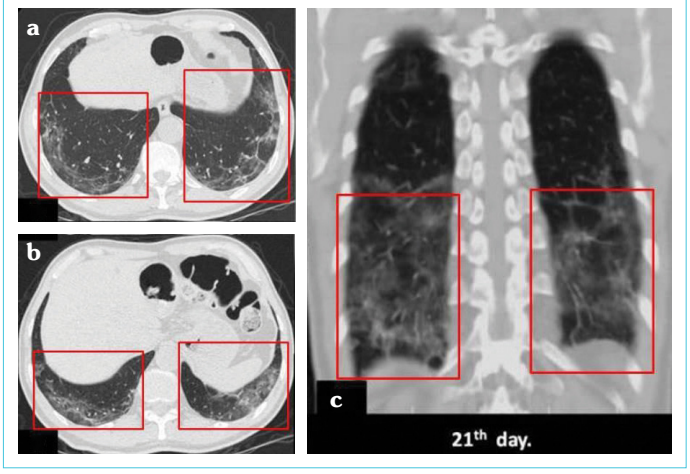

Figure 7. 64-year-old man with a positive RT-PCR. Unenhanced thorax CT taken on the 21st day. The axial images (a, b) and a coronal reformatted image (c) show markedly resorbed ground-glass opacities and concomitant areas of consolidation involving both lungs, with parenchymal fibrotic changes and subpleural linear streaks now accompanying the above findings at the same locations (red frames). These CT signs are compatible with stage 4 COVID-19 pneumonia

COVID-19 lung involvement. Similar findings can be seen in atypical and viral pneumonia, especially organized pneumonia.

Stage 4- (Absorption stage, ≥14 days): At this stage, the gradual decline in lesions is observed in 75% of the patients. The most important findings of this stage include the marked decrease in the prevalence of areas of consolidation, the crazy-paving pattern and parenchymal fibrotic bands, mainly subpleurally located. In our patient, CT examination performed on the twenty-first day revealed that the areas of consolidation were significantly resorbed and parenchymal fibrotic changes and subpleural linear lines accompanied in the same localizations (Fig. 7). Some studies suggest that parenchymal fibrotic bands and lines may be associated with the healing stage of the disease and may be an indicator of the stabilization of the disease.

Key Features in CT Reporting

There are different suggestions for reporting formats to facilitate a common language, achieve standardization and patient management in reporting COVID-19 lung CT findings. The most frequently used in the current literature are the classifications proposed by the British Society of Thoracic Imaging (BSTI) (Table 2) and Society of Thoracic Radiology (STR) & American College of Radiology (ACR) & Radiological Society of North America (RSNA) (Table 3). In both classifications, CT findings are classified into four categories (30, 31).

Radiological Differential Diagnosis

CT features of COVID-19 pneumonia have a lot of similarity with atypical bacterial pneumonias, especially other viral pneumonia [severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS)]. Although the solitary lesion affecting the unilateral lung is often defined in SARS, it is frequently observed in

Table 3. Expert consensus statement on reporting chest CT findings related to COVID-19 31 (endorsed by ACR, RSNA, and STR)

Classification	Rationale	CT Finding	Suggested reported language
Typical	Commonly reported imaging features of greater for specificity for COVID-19 pneumonia	Peripheral, bilateral (multilobar) GGO*, consolidation, or visible intralobular lines	Commonly reported imaging features of COVID-19 pneumonia are present [Cov19Typ]
Indeterminate	Nonspecific imaging features of COVID-19 pneumonia	Multifocal, perihilar, unilateral GGO or nonrounded or nonperipheral	Imaging features can be seen with COVID-19 pneumonia [Cov19Ind]
Atypical	Uncommonly or not reported features of COVID-19 pneumonia	Isolated lobar or segmental consolidation, discrete small nodules, cavitation or interlobular septal thickening, pleural effusion	Imaging features are atypical or uncommonly reported for COVID-19 pneumonia, an alternative diagnosis should be considered [Cov19Aty]
Negative	No features of pneu-monia	No CT features to suggest of pneumonia	No CT findings present to indicate pneumonia [Cov19Neg]

Purple for report coding

ground-glass opacities and consolidation affecting the middle and lower zones of the lungs. In MERS, it is difficult to differentiate radiological findings from COVID-19, and bilateral ground-glass opacities, consolidation and septal thickening are common CT findings. Similar to COVID-19, there is subpleural and lower lobe involvement. However, pleural effusion and pneumothorax are more common. In influenza virus infection, centrilobular nodules, pneumatocele formation and lymphadenopathy are common CT findings. Bacterial pneumonia occurs mostly in the form of lobar or bronchial pneumonia. The most common CT findings are widespread patchy consolidation areas and ground-glass opacities are less common. Mycoplasma pneumonia occurs mostly in school-age children. In mycoplasma pneumonia, 80% of patients present bronchial wall thickening, centrilobular nodules and patchy ground-glass opacities in CT. The ground glass pattern, reticular opacities and septal thickening with early CT findings may show similar features with COVID-19 pneumonia in pneumocystis pneumonia observed in immunosuppressed patients. However, in pneumocystis pneumonia, it is diagnostic that lesions are more frequently located in perihilar-central. In addition, non-infectious conditions (alveolar hemorrhage, pulmonary edema, pulmonary thromboembolism, acute coronary syndrome, interstitial lung diseases, drug reactions, etc.) must be taken into consideration in the differential diagnosis. Among non-infectious causes, pulmonary edema is the most common cause of widespread ground-glass density in CT. However, contrary to COVID-19, central location is typical for pulmonary edema by preserving the peripheral parts of the lungs. Despite imaging findings, it might be challenging to make a differential diagnosis of COVID-19 in some cases. In such cases, clinical and laboratory findings, being in the pandemic region, and contact history may contribute to the differential diagnosis (8, 32–34).

CONCLUSION

In CT, COVID-19 pneumonia has a combination of multifocal, patchy or nodular ground-glass opacities and consolidation, with the peripheral, subpleural distribution of the lesions, and especially lower lobe involvement. Chest CT, especially thin-section chest CT, plays an important auxiliary role in the early diagnosis of COVID-19, the prevalence and temporal course of the disease, complications, and differential diagnosis. However, CT should not be a routine diagnosis or screening method in patients with COVID-19 pneumonia.

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