Interpretation of CT Scan Findings During the COVID-19 Pandemic

Ebrahim Nouri [1], Omolbanin Delashoub [2], Mohammad Ali Shahabi-Rabori [3], Reza Afzalipour [1, 4, *] and Salman Jafari [5]

[1]Department of Radiology, Faculty of Para-Medicine, Hormozgan University of Medical Sciences, Bandar Abbas, Iran
[2]Student Research Committee, Hormozgan University of Medical Sciences, Bandar Abbas, Iran
[3]Department of Anatomical Sciences, Afzalipour Faculty of Medicine, Kerman Medical University, Kerman, Iran
[4]Molecular Medicine Research Center, Hormozgan Health Institute, Hormozgan University of Medical Sciences, Bandar Abbas, Iran
[5]Department of Radiology, School of Paramedicine, Hamadan University of Medical Sciences, Hamadan, Iran

*Corresponding author: Department of Radiology, Faculty of Para-Medicine, Hormozgan University of Medical Sciences, Bandar Abbas, Iran. Email: reza.afzalipour@hums.ac.ir

Abstract

Studies have documented criteria for the prevention, diagnosis, and treatment of COVID-19 pneumonia as more information has become available about its symptoms and complications. Similar to other coronavirus-induced cases of pneumonia, COVID-19 pneumonia causes acute respiratory problems. The chest CT scan, which is easily available in almost all areas, is a common imaging technique for diagnosing pneumonia. Its findings, which are accompanied by high speed, quality, and accuracy, allow the radiologist to easily identify affected areas of the lungs and to determine typical radiological features of patients with pneumonia caused by COVID-19. These features include ground-glass opacity, multifocal patchy consolidation, and interstitial changes with the peripheral distribution. The highest incidence occurs in the 4th and 5th lobes, where about 50% to 75% of the lesions observed. For infected patients, the CT scan protocol includes administration of HRCT technique in the inspiration phase with spiral 4-slice devices and higher. Scan parameters also include KV: 100 - 120, and mAs: 20 - 30, thickness = 1 - 2 mm, spiral, single breath-hold, and Pitch = 0.8 - 1.5, which are determined for all patients. Since there are restrictions on using ionizing radiation for pregnant women, it is recommended to initially conduct PCR tests. If necessary, typical radiography with an abdominal shield can be used for women in the first trimester of pregnancy, and the HRCT technique in low doses can be used for those in the second and third trimesters.

Keywords: COVID-19, CT Scan, Typical Symptoms, Ground Glass, CT Scan Follow-Up

1. Context

In December 2019, new cases of an unknown and novel viral pneumonia were reported in Wuhan (China). Since then, as more information were becoming available, a series of criteria for prevention, diagnosis, and treatment of this unknown disease, which is named COVID-19, are identified.

Similar to other cases of pneumonia, COVID-19 causes acute respiratory problems, which may result in acute respiratory distress syndrome (ARDS). However, not all patients with COVID-19 develop hypoxemia (decreased blood saturation) or respiratory distress (it is a life-threatening condition caused by damage to the lungs and requires mechanical ventilation to breathe) during hospitalization (1). Since no vaccine or treatment is identified for COVID-19, early diagnosis of the disease, and rapid isolation of healthy patients are crucial. It's shown that by creating high-quality images, the chest CT scan can reveal high levels of infections and lung involvement, which helps radiologists to quickly diagnose lung-related diseases, such as pulmonary embolism (it is called the presence of a blood clot or sometimes fat in one of the pulmonary arteries or the tissue of the lungs) (2). Since CT has a high sensitivity (95% - 97%), it plays a great role in diagnosing the COVID-19. In total, about 88% of patients with the virus have a positive CT (3, 4).

Although compared to other diagnostic tools such as simple chest x-ray and PCR test, CT has several benefits, but it also has disadvantages, such as the inconsistency between the severity of the disease and the severity indicated by CT images. For example, in some cases, the CT scan findings show the severe involvement of lung tissues in patients with good health status. In such cases, often, the person is not hospitalized, and health care providers recommend s/he to stay home and receive medication (3, 5).

Since on the first day of infection, the lungs are normal, and there is no presentation of the disease, one of the disadvantages of this diagnostic technique is not diagnosing

the disease in the early days, an issue which is reported by various studies (6).

The American Radiological Association and the World Health Organization (WHO) have emphasized that CT scans should not be considered as a sole screening and follow-up procedure. It can be used only when the physician has suspected the non-specific symptoms of the disease. Therefore, the prescription of CT for asymptomatic cases should be avoided. Although CT is useful for diagnosing the coronavirus, it is not considered as a screening test because of the harmful effects of the X-rays and the possibility of disease spreading through performing the procedure. Therefore, it is only recommended in certain cases with a doctor's prescription for cases who have symptoms such as severe shortness of breath, severe cough, fever, and other flu-like symptoms and those who need hospitalization (7).

As mentioned in this research, there are other diagnostic tests, such as a PCR (copying of the DNA or RNA sequence is the target sample, which can be used to diagnose various diseases, such as infectious diseases) and a simple chest x-ray (CXR) in addition to the CT. In the following, a comparison of CT scan and other diagnostic techniques for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is provided (8, 9).

## 2. Comparison of CT Scan with Other Diagnostic Tools

2.1. PCR Test

With a sensitivity around 97%, in nearly 75% of cases with a suspected or indistinct RT-PCR, CT scan is reported as positive (4). The CT scan of a 29-year-old man suspected for COVID-9, whose RT-PCR test was negative, is shown in Figure 1. The CT findings indicate a ground glass view, in both axial and coronal views, in small parts of the lung; therefore, the patient's clinical symptoms were confirmed (10).

However, it is not possible for everyone to take this test due to various reasons, such as the unavailability of laboratory diagnostic kits. For this reason, sometimes, Chest CT is the first diagnostic method (10). Besides, CT is more economical than PCR.

### 2.2. Comparison of CT scan with CXR (,).

If the chest x-ray is positive, a CT scan is still needed to determine consolidation or hazy opacity. It should be noted that the chest x-ray is not sensitive enough to diagnose the disease. A radiography on the left, which is simple and almost natural, is shown in Figure 2, but the
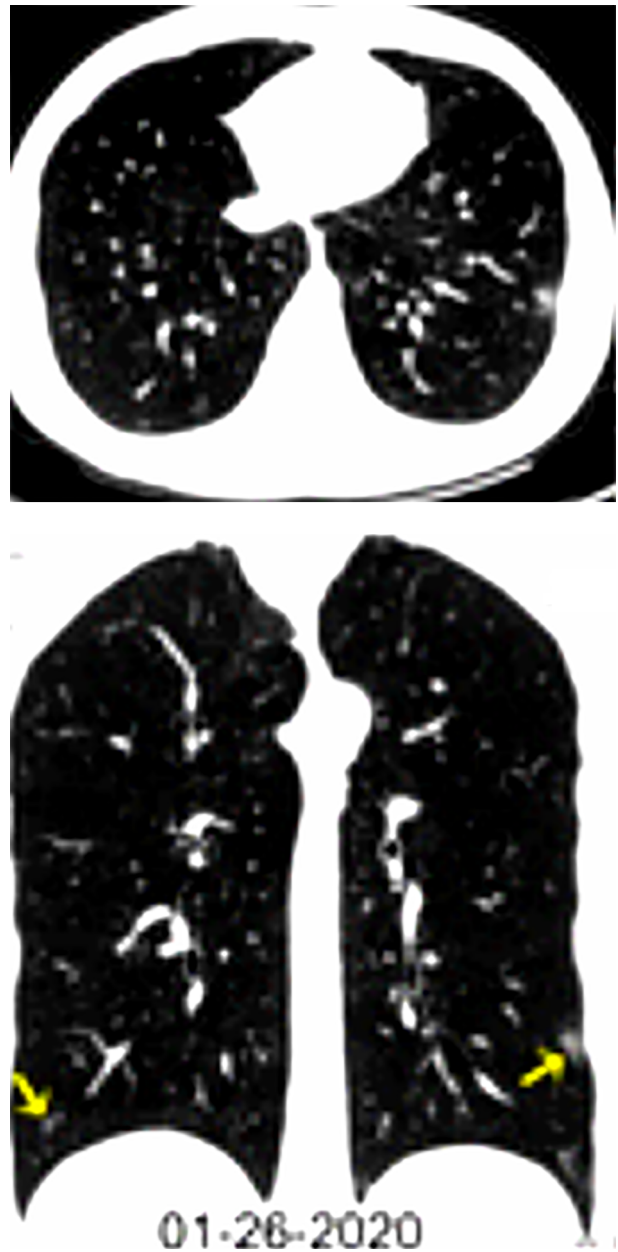
Figure 1. Chest CT scan of a 29-year-old man suspected for COVID-19, whose RT-PCR test was negative.

ground glass and linear opacities are seen by taking a CT scan (graph on the right).

This means that, if it is negative, the patient will not be discharged. However, due to the patient's clinical symptoms, a negative chest x-ray still indicates the need for CT or PCR. Therefore, a sole chest x-ray is not helpful in diagnostic algorithms. Besides, it should be noted that there
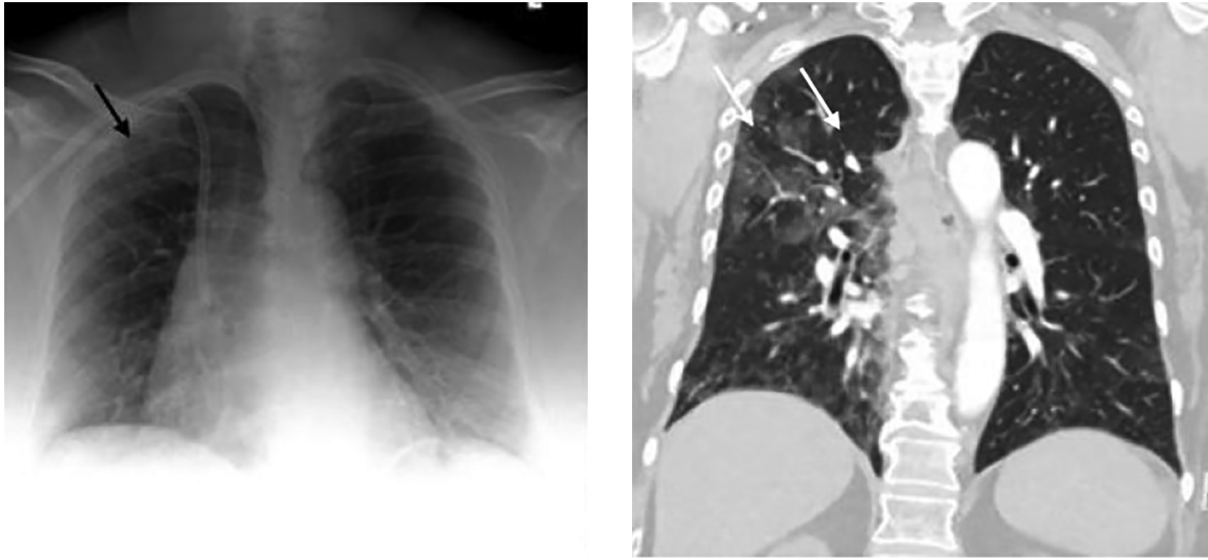
Figure 2. Radiography on the left is simple and almost natural, but the ground glass and linear opacities are seen by taking a CT scan (graph on the right) (12).

is a possibility of artifact (any error in imaging or image processing) and imaging problems in CXR photography, and, if not be performed properly, it may result in an incorrect diagnosis. CT is more sensitive than simple radiography for diagnosing pneumonia. Radiography is more useful in diagnosing other diseases caused by the coronavirus family, such as SARS and MERS. For COVID-19, it is used only when the patient is in the acute phase (characterized by respiratory problems and shortness of breath). In simple graphs, the patient's dose is much lower than the CT. However, in both methods, using abdominal shields (lead coating for radiation protection) is necessary, especially for pregnant women (11). Execution of radiography is easier than CT (7), its disinfection is easier than the CT device (radiographic device for photography), and it costs lower than CT and can be afforded by the low-income groups. In the following, the conditions of lungs CT of infected patients are examined according to the protocol published by the Iranian Radiological Association.

3. CT scan conditions for patients with COVID-19

To perform CT, the following conditions should be met: fever above 37.5, dry cough, lymphocytes under 1100, and a PCR test positive (7). The CT should be performed as follow:

CT scan devices that are produced over the last 15 - 20 years can take spiral form pictures. To take such photos, the device starts to rotate evenly, instead of rotating cross-sectional and preparing separate scans. Simultaneously,

the patient passes through the gantry of the device and the X-ray quickly passes through the patient's body in a spiral and spring-like manner. In this method, several rows of detectors (multi-detector or multi-slice) replace the one-row detector, in contrast to older devices that use 4 rows of detectors or more. This novel method increases the system's ability to collect data and enables high-resolution CT scans (HRCTs).

3.1. High-Resolution CT (HRCT) Has Two Main Types

High dose and low dose, which are almost the same, and the difference is in the MAS level of the device. In high-dose HRCT, the MAS ranges from 100 to 150, which is routinely used for patients undergoing HRCT for the first time. In low-dose HRCT, the MAS ranges from 20 to 30 to reduce the dose which absorbs by the patient. It mainly uses for follow-up of patients who had high-dose HRCT, and their problem is not identified properly. Low-dose HRCT is used for all patients with both primary diagnosis and follow-up according to the protocol provided by the Iranian Rheological Society and faculty members of the Department of Radiology of Shahid Beheshti University of Medical Science (12-14).

3.2. Pitch-Factor

In spiral imaging, the patient is fixed, and the bed and tube both move simultaneously. The distance that the bed moves in 360-degree rotation to the tube calculates by dividing the cross-sectional thickness by the machine pitch.

By increasing the Pitch ratio, the scan volume and speed both increase, but the image quality decreases.

The recommended Pitch for patients suspected to COVID-19 ranges from 0.8 to 1.5 (4).

3.3. Single Breath Hold

According to the protocols published in Iran, the CT should be performed once a breath is taken and in a deep breath (12, 15).

3.4. Slice Thickness

It is defined as the thickness of the cuts obtained from the desired member. The cross-sectional thickness selects according to the type of CT scan and the organ's size (cutting thickness). This thickness is considered as much as 1 mm to 3 mm (8, 12).

3.5. Position

The patient lies down (supine position), and hands should be next to the to reduce artifacts (12).

3.6. Scan Range

From the top of the lungs to the adrenal glands (12).

3.7. The Desired Sections

Coronal and sagittal should be covered (3, 12).

The desired kilovoltage by corona patients in CT scans ranges from 100 to 120. mAs measure the radiation produced over a particular period (seconds) using an X-ray tube, which for patients suspected to COVID-19 ranges from 50 to 100 (12).

4. CT Scan Conditions of Pregnant Women

Imaging, especially CT scan, plays an important role in the diagnosis and follow-up of patients suspected to COVID-19. According to recently published studies, CT sensitivity is higher than PCR (the experiment that allows us to duplicate a specific sequence of DNA between two distinct sequences makes it possible to diagnose infectious diseases), which indicates a more favorable outcome (16, 17). However, as pregnant women are high-risk cases, there are restrictions on the use of ionizing radiation for them, especially in the first trimester (12). Therefore, imaging techniques containing ionizing radiation (radiology and CT scan) cannot be used for pregnant cases. However, if necessity, ionizing radiations can be applied following the scientific indications, clinical judgment, and the request of the treating physician, and by considering maximum

protection (17). For pregnant women, laboratory testing (e.g., PCR) should be prioritized when suspecting COVID-19. If necessary, one of the common imaging methods (i.e., lung radiography or non-contrast pulmonary CT scan) should be used at the request of the treating physician (11, 12). Since lung radiography has both lower risk and costs as well as higher diagnostic accuracy, compared to CT scan, it's the preferred method of physicians. Nevertheless, in some cases, the chest x-ray may be ordered for pregnant women, since X-ray has a high risk for these cases. If the lung radiography does not show any signs of the infection, and the patient presents clear clinical presentations that indicate the disease, the treating physician may order a without contrast chest CT. However, the physician should first inform the patient about the need for imaging, and the pros and cons that may occur due to receiving a high dose during the CT scan. Moreover, operators of the CT scan device should try to reduce the patient's absorption dose as much as possible (12, 16).

Several strategies are developed to reduce the patient's absorption dose (12), and the minimal radiological conditions should be used to reduce the absorption dose. The protocol published by the Iranian Radiological Association, which is low-dose HRCT and intends to reduce milliamperes per second in CT scans, should be used for patients suspected COVID-19 who have comorbidities such as coronary artery diseases.

In both CT and lung radiography, necessary cautions should be taken for local protection of the fetus (e.g. use of lead coating on the patient's abdomen).

In the first trimester, more caution should be taken because of the high possibility of radiation damages to the fetus. Therefore, in the first trimester, lung radiography should be performed while using a lead shield to protect the abdomen, and if the radiography is normal, a CT scan of the lung should be requested. Nevertheless, in the second and third trimesters, the CT scan can be the first option.

Using lead abdominal coverage is necessary, especially in the first trimester, so that the accepted position is the exit of the areas below the aperture from the imaging field.

The allowed dose in pregnant women is less than 50 mGy. The embryo-absorbed dose from the mother is 0.002 mGy in the lung radiography and 0.2 mGy in lung CT scan. No negative effect on fetal health is reported for this amount of radiation (12). In the following, the symptoms and classification of these methods are described.

5. Evaluating the Observed Symptoms in 5 Lobes of the CT Scan of COVID-19 Patients to Determine the Extent of the Lungs Involvement

Pan et al. (2), at the Radiology Department of Union Hospital in Wuhan, decided to develop a system for classifying images of lung CT scans of COVID-19 patients. They aimed to evaluate the changes in CT scans of COVID-19 patients from the early stages of the disease to hospital discharge after recovery (3).

Philips ingenuity core 128 and Siemens somatom definition were used to performing lung CT scans. The Philips device could proceed imaging with low energy and dose, which creates images with minimal noise, based on the ALARA programs.

The device of Siemens Company can be used for patients with different ages and conditions (e.g. children, obese patients, emergency patients) by reducing the artifact of images as well as the absorbed dose up to 60% (3).

A scoring system was defined according to the extent that the lobes of a lung are affected by the coronavirus. A score ranging from 0 to 5 is considered to reflect the degree of lung lobe involvement, given that there are 5 lobes in both lungs. In this scoring system, the minimum and maximum scores are zero and 25, and the assessment is visually (2, 3). The description of the scoring system is as follows (18):

Zero: No lung involvement;

One: involvement in less than 5% of the lung (Figure 3).

Two: involvement in about 26% to 49% of the lung;

Three: involvement in about 50% to 75% of the lung;

Four: involvement in more than 75% of the lung.

In this paper, a pattern (model) is obtained that shows the involvements in 5 lobes based on their level (18):

1 Lobe: Less than 5% involvement;

2 Lobes: 5% to 25% involvement;

3 Lobes: 25% to 50% involvement;

4 Lobes: 50% to 75% involvement;

5 Lobes: 75% to 100% involvement.

As shown in figure 4, it was found that the virus mostly affects the lower and posterior lobes. This assessment was performed visually and no specific device has been applied (19).
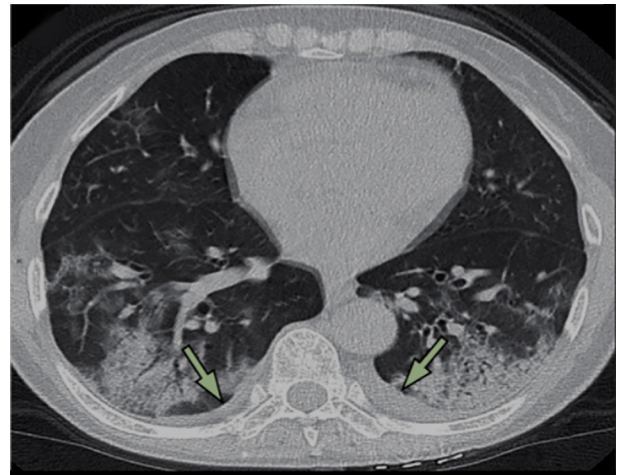
6. Corona Demonstration on CT Scan Images

6.1. Typical Findings

These findings are common in CT images: Ground-glass opacity (GGO) is the glass opacity. These fading wastes
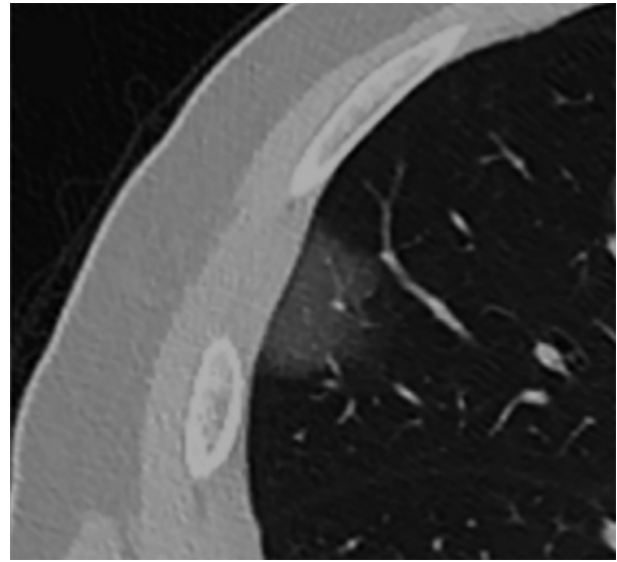

Figure 3. CT scan of a 25-year-old patient with seven days of severe fever, dry cough, and positive RT-PCR test. The involvement score is one (with less than 5% involvement) (18).


Figure 4. CT scan of a 63-year-old woman. Her CT scan was performed 17 days after the onset of the symptoms. It can be observed that consolidation and pleural effusion involvement are mostly located in the posterior and lower lobes (18).

do not affect arteries and bronchiole branches. The effect of these structures may be seen within the opacities, which can be seen in peripheral areas of each lung. These glass opacities may or not be associated with consolidation if the consolidation surrounds the opacity of ground glass. This type of opacity is named Reversed halo sign (Figure 5) (2, 8, 19).

These wastes are usually bilateral, meaning that both
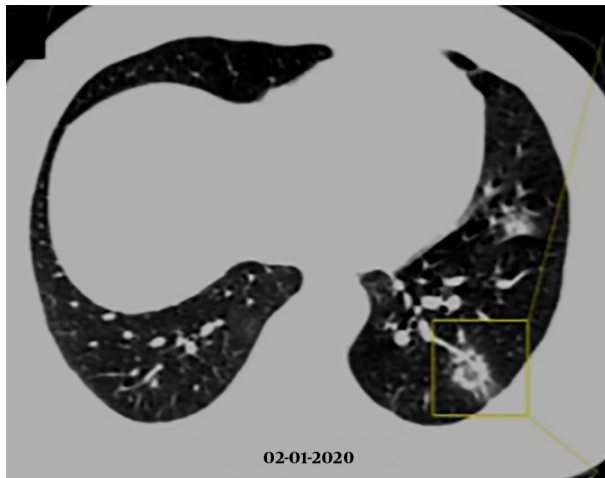
Figure 5. CT scan of a 34-year-old man with a 4-day fever. His RT-PCR test was positive and reversed halo sign is observed (3).
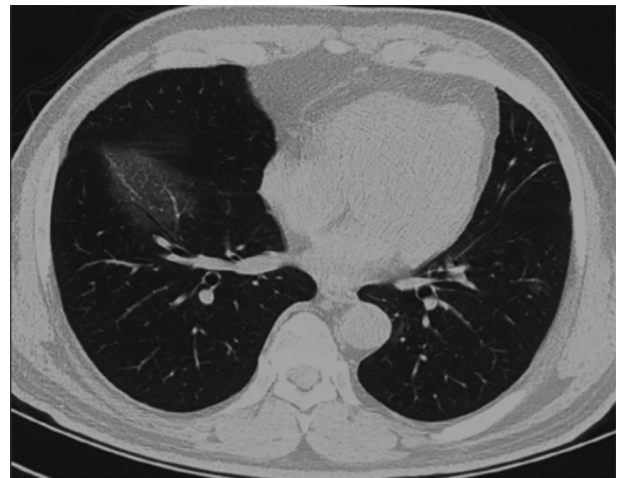
Figure 6. CT scan of a 56-year-old woman with chest pain, shortness of breath, a history of heart disease, and a negative RT-PCR test.

lungs are involved at the same time. They are peripheral and are found mostly around the lungs, not in the central part of the lungs. They are also subpleural. In other words, they are located between the pleura and the chest wall. Crazy paving appearance is a subset of GGO wastes with differences in this opacity (interlobular septal thickening is thickened and overlapped) (20). Peribronchovascular thickening is attributed to the thickening of vascular structures and the bronchiole tree in the lungs, which is divided into other subsets (21).

6.2. Uncertain Findings

When the images indicate the infection with COVID-9, but clinically the diagnosis cannot be confirmed, the imaging findings are uncertain. In such cases, multiple or diffused ground glass wastes without a specific distribution pattern can be observed. These symptoms may indicate other diseases and lead to false diagnosis. Therefore, a CT scan should be performed to confirm the findings (2, 8, 19, 22). In Figure 6, a CT scan of a 56-year-old woman with chest pain, shortness of breath, a history of heart disease, and a negative RT-PCR test is shown. Only the ground glass view can be observed in her CT scan. Since the clinical symptoms were low, and her laboratory test was negative, the possibility of comorbidity was high. Therefore, a follow-up CT scan was performed (8).

6.3. Atypical Findings

These findings include mediastinal lymphadenopathy, enlarged mediastinal lymph nodes, pleural effusions, or tree-in-bud fluid.

There are several nodules on the sides of the bronchiole that have increased thickness. Pneumothorax (air leak into the space between lungs and chest) and consolidation without ground-glass opacity can be observed. 31% of radiological findings are in this category (6). In Figure 7, the chest CT scan of a 42-year-old woman with pain in her chest and high fever for about two weeks is shown. Only the consolidation view can be observed in this radiograph, and there is no ground glass view. In such cases, consultation with the Center for Radiology is necessary. RT-PCR and CT scan tests should be performed for follow-up (8).
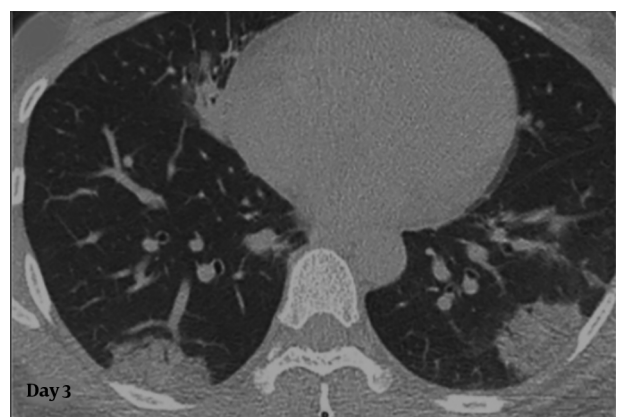
Figure 7. Chest CT scan of a 42-year-old woman with pain in her chest and high fever for about two weeks.

In Figure 8, CT scan of a 65-year-old man with severe chest pain and a history of pneumonia is shown. Typical

symptoms are not seen, but the tree-in-bud opacity view is well visible. This view is rare in CT scans of COVID-19 patients, and there is a possibility of comorbidity (16).

6.4. Negative Findings

Evidence on the corona pneumonia, consolidation, and ground glass are not sufficient (6). Besides, there are uncertainties about symptoms observed in radiographic images. However, these symptoms are very non-specific and may be related to the existence of other diseases. It is recommended to pay special attention to the patient's clinical symptoms and medical history, and the PCR test should be performed (2, 8, 19, 22). Uncertain findings of the new COVID-19 are listed in Table 1.

7. Interpretation of CT Scan Images of Patients

The involvement in patients is in the form of peripheral opacity, often bilateral and mainly with ground-glass opacity, crazy paving (c.paving), and consolidation. These patterns may be seen in various stages. However, the predominant involvement is as follows (2):

The first to fourth day: ground-glass opacity (GGO) involvement occurs in 20% of patients (the lowest CT score);

Fifth to the eighth day: crazy paving and consolidation can be observed;

Ninth to the thirteenth day: consolidation (the highest CT score is on the 10th day and in this phase);

Fourteenth day: Residual GGO and parenchymal bands are more likely to be observed. Figure 9 is an example of a common image of a COVID-19 patient. In Figure 9A, which is taken three days before the onset of the symptoms, a small area of localized GGO density with a slight density in the lower right lobe of the lung is shown. In Figure 9B, which is taken on the seventh day of infection, the GGO densities are widely known and published with a crazy-paving pattern. In Figure 9C, which is taken on the eleventh day of the disease, GGO densities with new density are visible. In Figure 9D, which is taken on the twentieth day, GGO densities are scattered, and normal lung parenchymal structures are observed (2).

This paper suggests performing a follow-up CT scan on the fourteenth day of infection and before the patient's discharge. In this research, follow-up CT scans were suggested for two groups of patients:

CT scans show increased lung tissue thickness for several months after the patient's recovery from the SARS coronavirus. One in every patient with SARS will experience persistent respiratory problems. In such cases, imaging findings show fibrosis of lung tissue and reticulation

between the lung lobes (intralobular reticulation). Lung tissue damage leads to air trapping in radiological images in 92% of SARS-recovered patients (23). Although the majority of MERS patients recover completely, in 33% of patients, evidence of pulmonary fibrosis is common in follow-up imaging. These patients were usually elderly with a history of long hospitalization in the intensive care unit (ICU). In these patients, most of the lung damages occur in the acute phase (24).

Based on the experiences of SARS and MERS, follow-up imaging for patients recovered from COVID-19 is necessary to examine the effects of chronic lung involvement, such as fibrosis, increased interbular thickness, and the formation of bubbles tissue in the lung (air trapping) (23, 24). In general, the chest CT scan is recommended for diagnosis and follow-up of COVID-19 patients. A follow-up CT scan is recommended for coronavirus-recovered people to examine the long-term or permanent effects of the virus on the lungs (6). The findings of CT scan images of COVID-19 patients depend on the severity of the disease after recovery. In 80% of cases with mild disease, people recover in a month or two. However, those with severe disease (in 20% of cases) may be intubated and hospitalized in ICU, and some of them die. Of those who recover from severe lung infections, the effects of the disease are persistent, and their lung volume decreases (6, 25).

8. Conclusions

Compared to CXR and RT-PCR, the CT scan is a better diagnostic method that can only be performed if the required conditions are met, including fever above 37.5°C, dry cough, lymphocytes under 1100, and a positive PCR test. In this case, the CT scan performs according to the following conditions.

The CT scan conditions for the affected patients are the use of the HRCT technique in the inspiration phase with spiral 4-slice devices and higher. Scan parameters also include KV: 100 - 120, mAs: 20 - 30, thickness = 1 - 2 mm, spiral, single breath-hold, and Pitch = 0.8 - 1.5, which were determined for all patients. However, when dealing with pregnant women, there are important issues that should be considered. In the first stage, PCR tests should be performed, and if necessary, typical radiography with an abdominal shield can be used for women in the first trimester of pregnancy. The HRCT technique, as low does, can be used for the second and third trimesters of the pregnancy.

Ground-glass and consolidation are typical symptoms
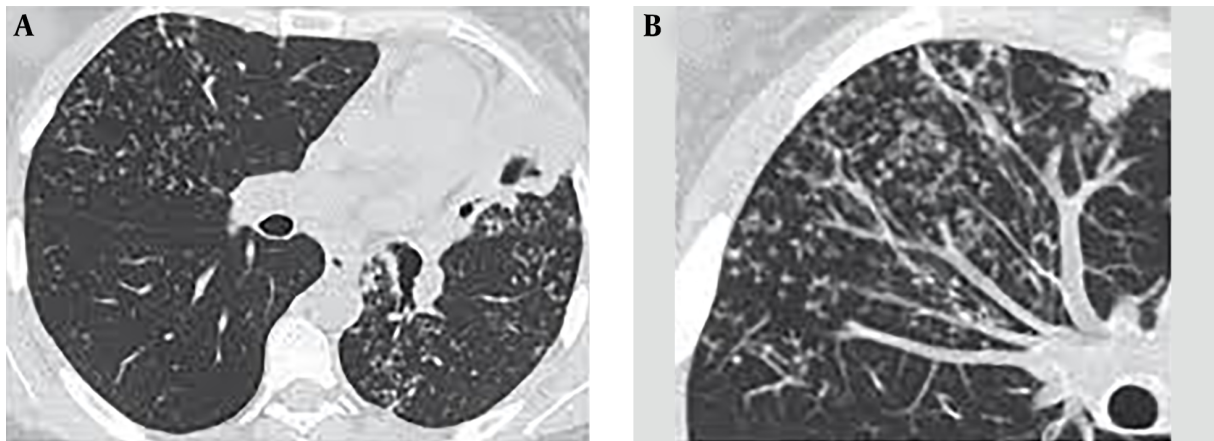
Figure 8. CT scan of a 65-year-old man with severe chest pain and a history of pneumonia.

Table 1. Uncertain Findings of New COVID-19

Numbers	Uncertain Findings	Percentage of Prevalence, %	Description
1	Tree-in-bud opacity	Rarely	In CT scans, multiple fading-like nudes follow a linear branching pattern (model), and this is more common in Tuberculosis (TB) patients.
2	Centriloubular distribution only	11	Distributed only in the center of the lobes
3	Peribronchovascular	Rarely	It occurs along with the peribronchovascular package. If it is poor in chest radiography in some cases, it is a sign of thickening of the peribronchovascular. If it expands, it tends to be distributed in larger masses.
4	Perdominanatly nodular opacities	Regularly	Small lung nodes 5-10mm, which are anatomically located in the center of the pulmonary lobes of the second. (Glass condition is weak)
5	Cavitation	Rarely	In this situation, rapid changes occur in the pressure of the liquid, which leads to the formation of small vapor-filled cavities in places where the pressure is relatively low.
6	Lymphadenopathy	4 - 35	Inflammation of the lymph nodes that is caused by an infection with the virus.
7	Pleural effusion	4 - 39	It is the excessive accumulation of fluid in the adjacent space that surrounds the lungs. This extra liquid makes breathing difficult.
8	Air bronchogram	14 - 23	Air-filled (dark) bronchioles that are visible by foaming around the alveolus (gray or white), and in addition to the air, other materials fill the alveolus and block the airway.
9	Pneumothoram	1	The overlap with a part or all of the lungs due to the leak of air into the open area between the chest and lungs

of COVID-19. Such clinical signs are symptoms of COVID-19 infection. However, for those who only have one of these two signs, clinical symptoms should be examined and a PCR test is necessary because these symptoms may be related to another disease. In the first days of the involvement, these two views mostly occur at lower and posterior parts of the lungs in the 5 pulmonary lobes. Concerning the experiences from the SARS epidemic, a follow-up CT scan is recommended for those affected by COVID-19 after recovery to observe the long-term effects of the disease on the lungs.
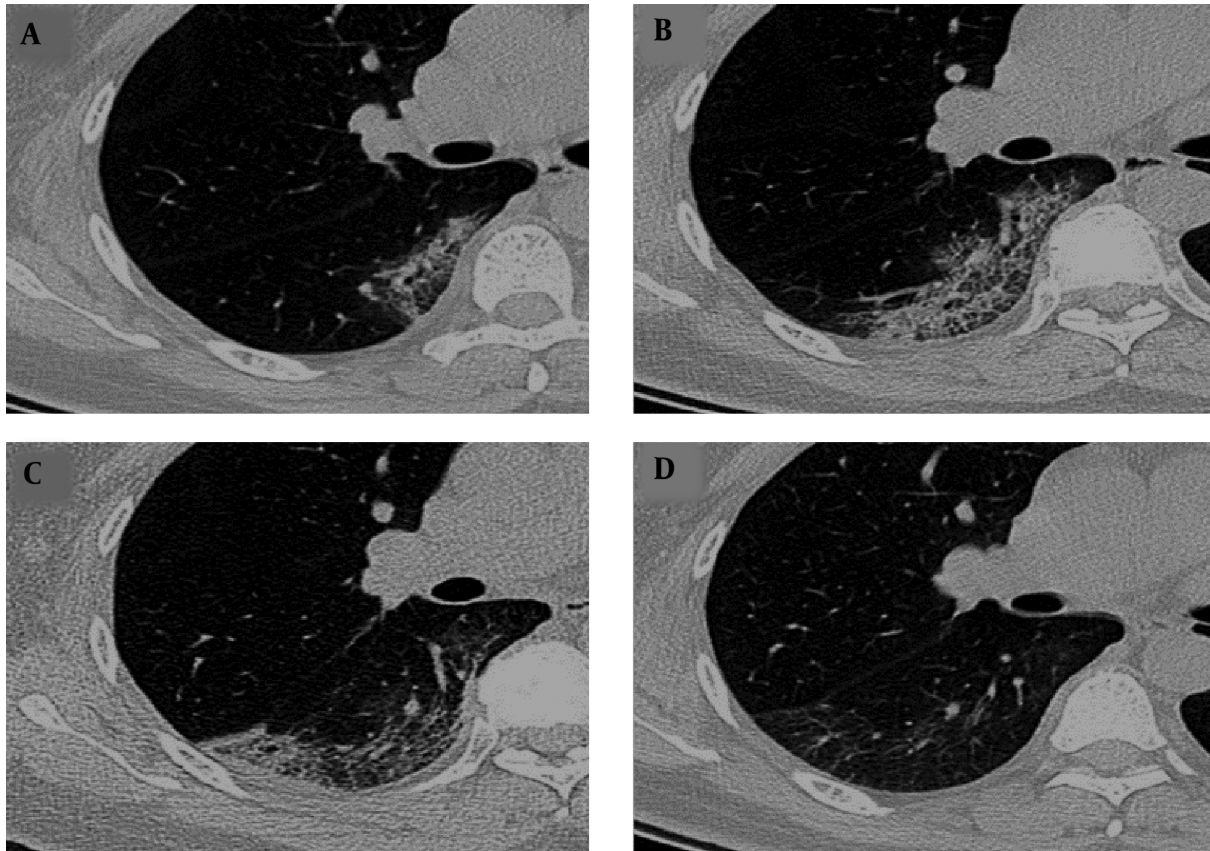
Supplementary Material

Supplementary material(s) is available here [To read supplementary materials, please refer to the journal website and open PDF/HTML].

Footnotes

Authors' Contribution: All authors had contributed to the study design, data collection, writing, and preparing this article.

Conflict of Interests: The authors declare no conflict of interest.

Figure 9. The CT scan image of a 47-year-old woman with a fever higher than 38°C for three days. Images are taken on different days. A, It is taken three days before the onset of the symptoms; B, it's related to the CT scan on the seventh day; C, CT scan of the patient on the eleventh day of infection; D, it's related to the patient's CT scan on the twentieth day.

References

1. Cui J, Li F, Shi ZL. Origin and evolution of pathogenic coronaviruses. *Nat Rev Microbiol*. 2019;**17**(3):181–92. doi: 10.1038/s41579-018-0118-9. [PubMed: 30531947]. [PubMed Central: PMC7097006].

2. Pan F, Ye T, Sun P, Gui S, Liang B, Li L, et al. Time course of lung changes at chest CT during recovery from coronavirus disease 2019 (COVID-19). *Radiology*. 2020;**295**(3):715–21. doi: 10.1148/radiol.2020200370. [PubMed: 32053470]. [PubMed Central: PMC7233367].

3. Ai T, Yang Z, Hou H, Zhan C, Chen C, Lv W, et al. Correlation of chest CT and RT-PCR testing for coronavirus disease 2019 (COVID-19) in China: A report of 1014 cases. *Radiology*. 2020;**296**(2):E32–40. doi: 10.1148/radiol.2020200642. [PubMed: 32101510]. [PubMed Central: PMC7233399].

4. Xie X, Zhong Z, Zhao W, Zheng C, Wang F, Liu J. Chest CT for typical coronavirus disease 2019 (COVID-19) Pneumonia: Relationship to negative RT-PCR testing. *Radiology*. 2020;**296**(2):E41–5. doi: 10.1148/radiol.2020200343. [PubMed: 32049601]. [PubMed Central: PMC7233363].

5. Lee EYP, Ng MY, Khong PL. COVID-19 pneumonia: what has CT taught us? *Lancet Infect Dis*. 2020;**20**(4):384–5. doi: 10.1016/S1473-3099(20)30134-1. [PubMed: 32105641]. [PubMed Central: PMC7128449].

6. Chung M, Bernheim A, Mei X, Zhang N, Huang M, Zeng X, et al. CT imaging features of 2019 novel coronavirus (2019-nCoV). *Radiology*. 2020;**295**(1):202–7. doi: 10.1148/radiol.2020200230. [PubMed: 32017661]. [PubMed Central: PMC7194022].

7. *RSNA*. 2020. Available from: https://rsna.org.

8. Shi H, Han X, Jiang N, Cao Y, Alwalid O, Gu J, et al. Radiological findings from 81 patients with COVID-19 pneumonia in Wuhan, China: A descriptive study. *Lancet Infect Dis*. 2020;**20**(4):425–34. doi: 10.1016/s1473-3099(20)30086-4.

9. Ye Z, Zhang Y, Wang Y, Huang Z, Song B. Chest CT manifestations of new coronavirus disease 2019 (COVID-19): A pictorial review. *Eur Radiol*. 2020;**30**(8):4381–9. doi: 10.1007/s00330-020-06801-0. [PubMed: 32193638]. [PubMed Central: PMC7088323].

10. Fang Y, Zhang H, Xie J, Lin M, Ying L, Pang P, et al. Sensitivity of chest CT for COVID-19: Comparison to RT-PCR. *Radiology*. 2020;**296**(2):E115–7. doi: 10.1148/radiol.2020200432. [PubMed: 32073353]. [PubMed Central: PMC7233365].

11. Nikpour M, Behmanesh F, Darzipoor M, Zavareh MSH. Pregnancy outcomes and clinical manifestations of Covid-19 in pregnant women: A narrative review. *J Mil Med*. 2020;**22**(2):177–83.

12. Keshavarzi E, Ghaeb Y, Rouhani SF. *The magnetic properties of Fe3O4 nanoparticale with different Coats and hydrodynamic diameters.*

2010. Available from: http://www.civilica.com/Paper-ISPTC12-ISPTC12_121.html.

13. Rampinelli C, Origgi D, Bellomi M. Low-dose CT: Technique, reading methods and image interpretation. *Cancer Imaging*. 2013;**12**:548–56. doi: 10.1102/1470-7330.2012.0049. [PubMed: 23400217]. [PubMed Central: PMC3569671].

14. Kalender WA. Principles and applications of spiral CT. *Nucl Med Biol*. 1994;**21**(5):693–9. doi: 10.1016/0969-8051(94)90039-6.

15. Silverman PM, Kalender WA, Hazle JD. Common terminology for single and multislice helical CT. *AJR Am J Roentgenol*. 2001;**176**(5):1135–6. doi: 10.2214/ajr.176.5.1761135. [PubMed: 11312166].

16. *Iranian society of radiology COVID-19 consultants (ISRCC)*. Iran; 2020.

17. [No author listed]. Radiology (HRCT) reports template for COVID-19 by iranian society of radiology COVID-19 consultants (ISRCCR). *J Clin Microbiol*. 2020.

18. Groome MJ, Page N, Cortese MM, Moyes J, Zar HJ, Kapongo CN, et al. Effectiveness of monovalent human rotavirus vaccine against admission to hospital for acute rotavirus diarrhoea in South African children: A case-control study. *Lancet Infect Dis*. 2014;**14**(11):1096–104. doi: 10.1016/S1473-3099(14)70940-5. [PubMed: 25303843].

19. Kanne JP. Chest CT findings in 2019 novel coronavirus (2019-nCoV) in-

fections from Wuhan, China: Key points for the radiologist. *Radiology*. 2020;**295**(1):16–7. doi: 10.1148/radiol.2020200241. [PubMed: 32017662]. [PubMed Central: PMC7233362].

20. Johkoh T, Itoh H, Muller NL, Ichikado K, Nakamura H, Ikezoe J, et al. Crazy-paving appearance at thin-section CT: Spectrum of disease and pathologic findings. *Radiology*. 1999;**211**(1):155–60. doi: 10.1148/radiology.211.1.r99ap10155. [PubMed: 10189465].

21. Martínez-Jiménez S, Rosado-de-Christenson ML, Carter BW. *Specialty imaging: HRCT of the lung e-book*. USA: Elsevier Health Sciences; 2017.

22. Koo HJ, Lim S, Choe J, Choi SH, Sung H, Do KH. Radiographic and CT features of viral pneumonia. *Radiographics*. 2018;**38**(3):719–39. doi: 10.1148/rg.2018170048. [PubMed: 29757717].

23. *Multi-centre collaborative network: Laboratories testing for SARS*. 2003. Available from: https://www.who.int/csr/sars/testing/en/.

24. Tavakoli A, Karbalaie Niya MH, Keshavarz M, Safarnezhad Tameshkel F, Monavari SH. Middle East respiratory syndrome coronavirus (MERS-CoV). *Iran J Med Microbiol*. 2017;**11**(1):1–8.

25. [No author listed]. Radiological diagnosis in novel coronavirous pneumonia: Expert recommendation from the Chinese Society of Radiology. *Chin Soc Radiol*. 2020.