REVIEW ARTICLE

Diagnostic role of chest computed tomography in coronavirus disease 2019

Piotr Jędrusik[1], Zbigniew Gaciong[1], Katarzyna Sklinda[2], Radosław Sierpiński[3,4], Jerzy Walecki[2,5], Mariusz Gujski[6]

1 Department of Internal Medicine, Hypertension and Vascular Diseases, Medical University of Warsaw, Warsaw, Poland
2 Department of Radiology and Diagnostic Imaging, Centre of Postgraduate Medical Education, Professor Adam Gruca Clinical Hospital, Otwock, Poland
3 National Institute of Cardiology, Warsaw, Poland
4 Collegium Medicum, Cardinal Stefan Wyszyński University, Warsaw, Poland
5 Diagnostic Radiology Department, Central Clinical Hospital of the Ministry of the Interior and Administration, Warsaw, Poland
6 Department of Public and Environmental Health, Medical University of Warsaw, Warsaw, Poland

KEY WORDS

chest computed tomography, coronavirus disease 2019, imaging, severe acute respiratory syndrome coronavirus 2, viral pneumonia

ABSTRACT

Coronavirus disease 2019 (COVID-19) is an infectious disease caused by a novel strain of coronavirus, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), that appeared in China in December 2019 and spread globally, evolving into the currently observed pandemic. The laboratory diagnosis of SARS-CoV-2 infection is currently based on real-time reverse transcriptase–polymerase chain reaction (RT-PCR) testing, and imaging cannot replace genetic testing in patients with suspected COVID-19. However, with predominant respiratory manifestations of COVID-19, particularly in more severe cases, chest imaging using computed tomography (CT) plays a major role in detecting viral lung infection, evaluating the nature and extent of pulmonary lesions, and monitoring the disease activity. The role of chest CT as a diagnostic tool may be increased when the laboratory testing capacities using RT-PCR prove inaccurate or insufficient during a major outbreak of the disease. In these settings, a rapid presumptive diagnosis of COVID-19 potentially offered by CT might be an advantage, in addition to obvious benefits of delineating the nature and extent of pulmonary lesions. In the present paper, we reviewed the diagnostic role of chest CT in patients with COVID-19.

Correspondence to:
Piotr Jędrusik, MD, PhD, Department of Internal Medicine, Hypertension and Vascular Diseases, Medical University of Warsaw, ul. Banacha 1a, 02-097 Warszawa, Poland, phone: +48 22 599 12 07, email: pjedrusik@wum.edu.pl
Received: April 9, 2020.
Revision accepted: April 29, 2020.
Published online: May 9, 2020.
Pol Arch Intern Med. 2020; 130 (6): 520-528
doi:10.20452/pamw.15348

Introduction Coronavirus disease 2019 (COVID-19) is an infectious disease caused by a novel strain of coronavirus, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), that appeared in Wuhan, China in December 2019,[1,2] with first cases tracked back to November 2019,[3] and spread globally, evolving into the currently observed pandemic.

The etiology of COVID-19, its manifestations, clinical course, and radiologic findings are similar to 2 other recent coronavirus diseases, severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS), but also show some important differences.

The laboratory diagnosis of SARS-CoV-2 infection is based on the nucleic acid amplification test using the real-time reverse transcriptase-polymerase chain reaction (RT-PCR). However, with predominant respiratory manifestations of COVID-19, particularly in more severe cases, chest imaging, mostly with computed tomography (CT), plays a major role in detecting viral lung infection, evaluating the nature and extent of pulmonary lesions, and monitoring the disease activity. However, the role of chest CT has not been clearly defined, particularly when the laboratory testing capacities using RT-PCR prove inaccurate or insufficient during a major outbreak of the disease, with a high number of new and suspected cases to be tested over a short period of time, as it was observed in Wuhan.

Taking into account the major challenges of the current COVID-19 pandemic, with a rapidly growing number of affected people in many countries and regions, laboratory testing capacities may again prove to be insufficient, similarly as it was observed in China. Thus, attempts to curb the epidemic by detecting symptomatic cases

TABLE 1 Clinical severity of confirmed coronavirus disease 2019 pneumonia[a]

Type	Findings
Mild	Mild clinical symptoms (fever <38 °C, with or without cough, no dyspnea)
	No imaging findings of pneumonia
Moderate	Fever ≥ 38 °C with respiratory symptoms
	Imaging findings of pneumonia
Severe	Any of the following: • Respiratory distress, respiratory rate ≥ 30/min • SaO_2 $<93\%$ at rest • PaO_2/FiO_2 ≤ 300 mm Hg • Rapid progression ($>50\%$) on CT imaging within 24–48 hours[b]
Critical	Respiratory failure, need for ventilatory support
	Shock
	Extrapulmonary organ failure

a Modified from Zu et al[11]

b Added in the sixth version of the Chinese classification criteria (published on February 18, 2020).

Abbreviations: CT, computed tomography; FiO_2, fraction of inspired oxygen; PaO_2, partial pressure of oxygen; SaO_2, oxygen saturation

and known contacts may fail, especially without widespread lockdown and quarantine measures and with surveillance methods and diagnostic capacities varying between countries. In addition, this may lead to a large number of undiagnosed asymptomatic or presymptomatic carriers who have been proven to be the source of spread of this highly contagious virus.

As a result, it may be expected that some or many patients will present with respiratory symptoms or as severely or critically ill cases without a prior diagnosis or even suspicion of COVID-19. In an uncurbed, full-blown epidemic, the burden of such patients may become overwhelming, and waiting times for the results of RT-PCR testing may be excessively long. In such patients, a rapid presumptive diagnosis of COVID-19 potentially offered by CT might be an advantage, in addition to obvious benefits of delineating the nature and extent of pulmonary lesions. The purpose of the present study is to review the diagnostic role of chest CT in patients with COVID-19.

Clinical presentation, complications, and classification of the clinical severity of COVID-19 pneumonia The typical clinical presentation of COVID-19 includes systemic and respiratory manifestations.[4] Common symptoms and signs include fever, fatigue, cough, and dyspnea. Subjects infected with SARS-CoV-2 may also be asymptomatic carriers of the infection.[5] Also gastrointestinal or cardiovascular symptoms may occur; however, less commonly.[6,7]

In a large study including 1099 patients from China, 6% of patients required invasive or noninvasive ventilation and 5% were admitted to the intensive care unit.[4] More severely ill patients tend to be older and have more comorbidities.[4,8] Common sequelae include acute respiratory distress syndrome (ARDS), acute cardiac injury (as manifested by elevated troponin levels), secondary infections, sepsis, acute kidney injury, multiorgan failure, and death.[9]

Available data indicate that a high percentage of SARS-CoV-2 carriers may be asymptomatic. In a study that assessed the clinical characteristics of SARS-CoV-2–positive close contacts of patients with COVID-19, approximately 30% of these SARS-CoV-2–positive subjects never developed any clinical symptoms or lesions on chest CT. The remainder showed lesions on CT, and about 20% of them developed symptoms during their hospital stay but did not develop severe disease.[10]

Patients with confirmed COVID-19 can be categorized into 4 groups depending on their clinical manifestations, that is, with mild, moderate, severe, or critical disease[11] (TABLE 1). Patients with mild disease have no imaging findings of pneumonia, those with moderate disease show imaging findings of pneumonia, and those with severe or critical disease present with respiratory distress or failure. According to the Chinese classification system, patients showing rapid progression (>50%) on CT imaging within 24 to 48 hours should also be considered and managed as severe cases.[11]

Laboratory diagnostic methods The current definitive test for SARS-CoV-2 is the nucleic acid amplification test using RT-PCR. Its specificity is high but the reported sensitivity ranges from between 60% and 70% to between 95% and 97%.[12,13] These differences may reflect sampling errors and different diagnostic yield of various sampling sites (eg, pharyngeal swab vs bronchoalveolar lavage) but also various timing of testing during the course of the infection, with low viral titers in the early phase leading to false-negative results.[14] As a result, false-negative results may be a clinical challenge and several negative results during serial testing may be required to exclude the disease. The biological material for virological testing includes upper and lower respiratory tract samples and blood samples.

Other limitations of RT-PCR testing include time required for test performance, varying quality and reliability of available SARS-CoV-2 nucleic acid detection kits, limited number and throughput of laboratories performing these tests, and the fact that RT-PCR testing detects the presence of a virus but has a limited utility for monitoring the disease progression / regression.

Tests detecting anti-SARS-CoV-2 immunoglobulin (Ig) M and IgG antibodies and SARS-CoV-2 antigens, including rapid tests, are under development and some have already entered the clinical practice but their diagnostic precision has not been established yet. Based on the information available on the United States Food and Drug Administration (FDA) website,[15] as of April 16, 2020, there are no FDA-approved diagnostic tests for COVID-19. The FDA has only issued an emergency use authorization for one serological test.[16]

Other abnormalities seen in laboratory test results of patients with COVID-19 include leukopenia and lymphopenia, low procalcitonin level, increased prothrombin time, elevated levels of lactate dehydrogenase, creatine kinase, and D-dimer as well as elevated inflammatory markers (C-reactive protein [CRP] and erythrocyte sedimentation rate).[8,17] Guan et al[4] reported admission laboratory data of 1099 patients with COVID-19. Lymphocytopenia (<1500/μl) was present in 83.2% of these patients, thrombocytopenia (<150 000/μl) in 36.2%, and leukopenia (<4000/μl) in 33.7%. Most of the patients had an elevated CRP level (≥10 mg/l; 60.7%), and less common abnormalities included elevated levels of lactate dehydrogenase (41%), alanine aminotransferase (21%), aspartate aminotransferase (22%), creatine kinase (14%), and D-dimer (46%). Patients with severe disease (n = 173) had more prominent laboratory abnormalities than those with nonsevere disease (n = 926), namely, lymphocytopenia was present in 96% of patients with severe disease as compared with 80% in those with nonsevere disease, leukopenia in 61% as compared with 28%, elevated CRP level in 81% as compared with 56%, and elevated D-dimer level 60% as compared with 43%.

Shi et al[18] in a study of 81 patients, compared those who had their first CT scan performed early after symptom onset (≤1 week) and those who had it performed later, at the time that corresponded to the usual peak disease severity on CT images (1–2 weeks). Laboratory findings, including the mean leukocyte, lymphocyte, and platelet counts, the proportion of patients with lymphocytopenia (<1000/μl), and increased levels of CRP, liver enzymes, and bilirubin did not vary significantly between the 2 groups.

Imaging findings Chest imaging plays a major role in detecting viral lung infection, evaluating the nature and extent of pulmonary lesions, and monitoring progression / regression of the disease. Plain chest radiograph and CT in patients with COVID-19 usually show atypical or organizing pneumonia, often with bilateral, peripheral, basal, and / or multilobar involvement.[12,19-21] In mild and / or early cases, chest imaging has limited sensitivity for COVID-19, as normal chest X-ray or CT was noted in as many as 18% of patients with mild / early disease but this proportion is reduced to 3% in more severe cases.[4,22]

Obviously, CT may also detect alternative lung pathologies and / or complications of COVID-19, such as pulmonary embolism and bacterial pneumonia, which is another role of CT in these patients. It seems, however, that the approach to diagnosing pulmonary embolism and bacterial pneumonia in this population is generally the same as in patients without COVID-19 and this issue is beyond the scope of the present review.

Chest radiography and lung ultrasound Plain chest radiograph in patients with COVID-19 may show a patchy or diffuse air space opacities,[22] but it was shown to have much lower sensitivity compared with CT,[23] reported as 69% and 91%, respectively, in one study.[24]

As indicated by initial experience from China and later also from Italy, lung ultrasonography may also be of use when evaluating critically ill patients with COVID-19, especially when CT imaging is not feasible.[25] Lesions seen on ultrasound tend to be predominantly bilateral and posterobasal. They include multiple B-lines ranging from focal to diffuse with spared areas, irregular thickened pleural line with scattered discontinuities (subpleural consolidations), and pneumonic consolidations typically associated with preservation of flow or hyperemia.[26-29] Although lung ultrasound was found to be superior in the diagnostic workup of pneumonia and ARDS compared with chest X-ray and it may be performed repeatedly without exposure to radiation, its limitations include the need for an ultrasonographer with an adequate expertise in interpreting images in patients with COVID-19.

Computed tomography findings Typical findings reported in adults with COVID-19[8,18,30,31] include ground-glass opacities, crazy paving appearance, that is, appearance of ground-glass opacity with superimposed interlobular and intralobular septal thickening, consolidations, bronchovascular thickening in lesions, and traction bronchiectases. The ground-glass opacities and consolidations are usually located bilaterally, they are diffuse and they show peripheral and basal distribution.[12,32]

In a large study that reported CT findings on hospital admission of 975 patients, positive findings were reported in 840 patients (86.2%), including ground-glass opacities in 505 (56.4%), local patchy shadowing in 409 (41.9%), bilateral patchy shadowing in 505 (51.8%), and interstitial lesions, mainly interlobular and intralobular septal thickening, in 143 (14.7%). All these types of abnormalities were more common in severe compared with nonsevere patients.[4]

In a review of imaging findings that included 919 patients, ground-glass opacities were found in 88% of patients, bilateral involvement in 87.5% of patients, peripheral distribution in 76% of patients, and multilobar involvement in 78.8% of patients. The most common CT findings included isolated ground-glass opacities or a combination of ground-glass opacities and consolidative opacities.[33]

With regard to the diagnostic value of chest CT findings, peripheral distribution of the lesions, ground-glass opacities, and bronchovascular thickening in the lesions were found to have the highest value for differentiating between COVID-19 and other viral pneumonias.[34]

Other CT findings have been absent or seen in a small proportion of patients and thus could be considered as suggestive of other diagnoses including bacterial pneumonia.[12,22] These findings include mediastinal lymphadenopathy, pleural

TABLE 2 Typical chest computed tomography imaging findings in coronavirus disease 2019 pneumonia[a]

CT abnormalities	Prevalence (%)[b]	Temporal trends on serial CT imaging
GGO with or without consolidations	+ + + (GGO usually 80–95, including 50–60 with consolidations)	Early sign, but later growing and often evolving into crazy-paving pattern, but GGO may persist longer than other lesions (Wang et al[44])
Only consolidations	+ (<10)	More lesions develop later with disease progression (at peak intensity of CT lesions), then resolve
Multiple lesions	+ + + (70–85)	–
Bilateral involvement	+ + + (75–90)	–
Lower lobe predilection	+ + + (67–75)	–
Peripheral/subpleural distribution	+ + + (75–90)	–
Crazy-paving pattern	+ + (40–75)	Generally seen later (at peak intensity of CT lesions)
Bronchovascular thickening in the lesions	+ + (15–80)	–
Traction bronchiectases	+ + (50)	–
Air bronchogram	+ + (50–80)	–
Reverse halo sign	+ (5–60)	Generally seen later
Linear opacities/fibrotic streaks	+ (10–15)	Generally seen later
Mediastinal lymphadenopathy, pleural effusion, multiple small pulmonary nodules, tree-in-bud sign, pneumothorax, cavitations, calcifications	Rare or absent (usually <10)	In some series pleural effusion more common later, perhaps as a complication (10%–20%)

+ – Low prevalence

++ – Moderate prevalence

+++ – High prevalence

a Modified from Zu et al.[11] Data derived from Huang et al,[2] Wang et al,[8] Chung et al,[20] Ng et al,[23] Pan et al,[30] Zhao et al,[31] Lee et al,[35] Pan et al,[39] Bernheim et al,[40] Li and Xia,[43] and Wang et al[44]

b Numbers are approximate rounded values and generally refer to the prevalence rates seen in early computed tomography imaging (ie, ≤1 week from symptom onset, generally on hospital admission).

Abbreviations: GGO, ground-glass opacities

effusion, multiple small discrete pulmonary nodules (in contrast to many other viral pneumonias), the tree-in-bud sign, pneumothorax, and cavitations.[29,35]

The diagnosis of COVID-19 based on chest CT findings may be enhanced by artificial intelligence systems that facilitate differentiation from other etiologies of community-acquired pneumonia and other nonpneumonic lung diseases.[36,37] Chest CT imaging findings in COVID-19 pneumonia are summarized in TABLE 2, and typical CT images are shown in FIGURE 1A–1D. Typical CT findings were also recently reported in this journal by Sabri et al.[38]

Evolution of computed tomography lesions In general, 4 stages of the evolution of CT lesions have been described in patients with COVID-19.[12,29,30,39] During the initial stage (0–4 days), CT scan is normal or only ground-glass opacities can be seen, which are usually focal or multifocal and are usually located peripherally (in about 50%–75% of patients). Normal CT scans have been reported in up to half of patients within 2 days of flu-like symptoms onset. During the progressive stage (5–8 days), increased ground-glass opacities and crazy-paving appearance are seen. At the peak stage (9–13 days), the predominant abnormalities are crazy paving appearance and consolidations, with the peak lesions at about 10 days. During the absorption stage (>14 days), fibrotic streaks appear along with the clinical improvement but resolution of the abnormalities may take 1 month or longer.[12] Thus, ground-glass opacities are the predominant abnormality in the early disease, followed by the development of crazy paving pattern, and then increasing consolidation later in the disease course.[40] Progression of pulmonary lesions has been associated with poor outcomes.[29]

It was also shown that serial chest CT imaging may provide precise data on the disease progression and may be used to monitor treatment effects. Some authors[41] found that greater consolidations that generally develop later in the course of the disease indicated disease progression, while a smaller size, extent, and absorption of these lesions (developing organizing pneumonia pattern in what was pure consolidation) indicated improvement. This, however, is based on follow-up CT performed in only 13 patients, of whom 7 (54%) showed improvement and 4 (31%) showed

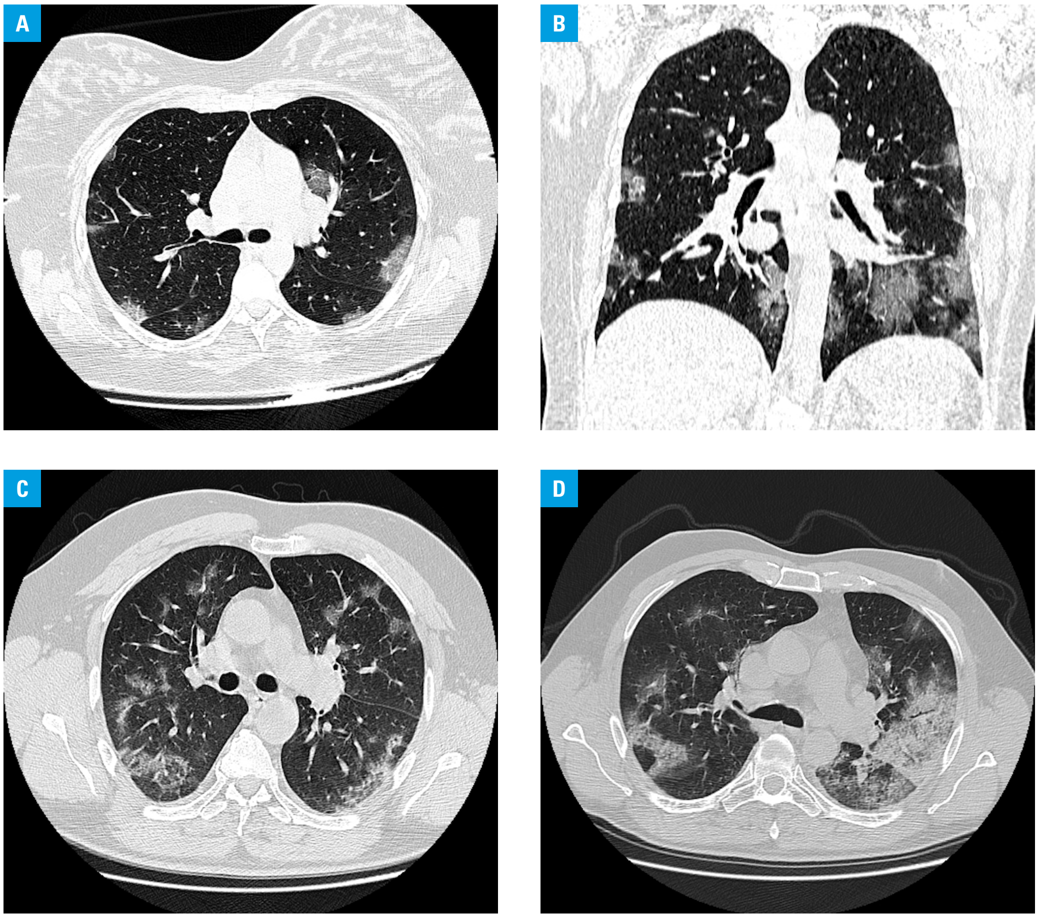

FIGURE 1 Typical chest computed tomography (CT) images in coronavirus disease 2019: **A**, **B** – noncontrast axial and coronal plane chest CT images of a 20-year-old man with mild COVID-19 pneumonia. CT scans show ground-glass opacities in multiple lung segments. **C** – a 49-year-old man with COVID-19 presenting with fever lasting for 8 days. CT scan in the axial plane shows consolidation in the left lobe subpleural area and bilateral ground-glass opacities. **D** – a 66-year-old man with COVID-19 presenting with cough and myalgia lasting for 7 days. CT scan shows a reticular pattern superimposed on the background of ground-glass opacities (crazy paving appearance).

disease progression. Of note, lung CT findings showing improvement have been listed among the Chinese criteria for hospital discharge or discontinuation of quarantine.[42] In one study, 42% of patients showed improvement on follow-up chest CT before the RT-PCR results turned negative.[21]

Timing of repeated computed tomography scanning and postdischarge follow-up computed tomography

Regarding the timing of repeated CT scanning, it should generally depend on the clinical condition of the patient. A repeat CT scan may be performed even as early as after 24 hours if the patient's condition worsens significantly.[30] In the available literature, CT was usually repeated as deemed necessary on the clinical grounds. Thus, CT was usually repeated early in severe / clinically progressing patients and for this reason, progression was mostly seen with early repeated CT imaging (at the mean interval of 2.5–5 days) in some of the reported small series. For example, in a study by Li and Xia,[43] the mean time between the initial and follow-up CT studies was 5 days (range, 2–15 days), and follow-up CT showed mild or marked disease progression in 18 of 24 patients (75%). In a study by Chung et al[20] which included 8 patients, the mean time between the initial chest CT and follow-up scanning was 2.5 days (range, 1–4 days), and 7 of 8 patients showed progression. In some studies that provided the above data on the temporal evolution of CT lesions, CT has been repeated more systematically over the course of hospitalization, at the average interval of about 4 days (82 scans in 21 patients who all recovered and were discharged)[30] or 6 days (366 scans in 90 patients, of which 70 survived and were discharged),[44] with the average duration of hospitalization of 16 to 18 days. Of note, in a study by Wang et al,[44] 66 of the 70 discharged patients (94%) had residual disease on final CT scans, with ground-glass opacities being the most common pattern. Thus, ground-glass opacities may be the most common initial finding, followed by other lesions (consolidations, crazy paving appearance) but ground-glass opacities may persist for a longer time (as noted by Wang et al,[44] the percentage of pure ground-glass opacities showed a trend of "first falling then rising" in their study).

No data are yet available on the value of postdischarge CT in COVID-19 during long-term follow-up to evaluate for possible late fibrotic complications of ARDS and other long-term complications.

Case reports from China are also being published regarding postdischarge follow-up CT to evaluate patients who retested positive on RT-PCR after they had had negative test results and had been discharged from hospital.[42,45]

Computed tomography in asymptomatic patients including healthcare workers In a retrospective study of 112 cases from the Diamond Princess cruise ship, 54% of asymptomatic patients were found to have had pneumonic lesions on CT.[46] Of these 112 cases, 82 (73%) were asymptomatic (44 [54%] of which had lung opacities on CT) and the other 30 (27%) cases were symptomatic (24 [80%] of which had abnormal CT findings). Asymptomatic patients presented with ground-glass opacities more frequently than with consolidations, while symptomatic patients presented with consolidations more frequently than with ground-glass opacities. The CT severity score was higher in symptomatic cases than asymptomatic cases, particularly in the lower lobes.

In another study, chest CT was performed in 15 healthcare workers exposed to SARS-CoV-2 before they developed clinical symptoms. Ground-glass opacities were found in 14 of them.[18]

Overall, these studies indicate that chest CT may identify asymptomatic and / or presymptomatic COVID-19 patients with pneumonic lesions.

Role of chest computed tomography in an epidemic COVID-19 outbreak An early diagnosis is of key importance in the management of patients with COVID-19 and to control the epidemic. It has been reported, mainly based on the Chinese experience with the COVID-19 epidemic outbreak in Wuhan, that in some healthcare settings, chest CT may be a more available, reliable, and rapid diagnostic tool compared with RT-PCR testing.

For example, one study reported that with limitations of sample collection, transportation and kit performance, the total positive rate of RT-PCR for throat swab samples in patients with COVID-19 was only about 30% to 60% at initial presentation.[47] In addition, with a high number of new cases during the outbreak in Wuhan, the number of people awaiting RT-PCR for the detection of SARS-CoV-2 greatly exceeded the capacity of medical institutions, RT-PCR diagnostic kits could not be provided in sufficient amounts to keep up with the demand, and laboratories were not able to return the results within a reasonable time frame.

On the other hand, chest CT may detect COVID-19 more rapidly by showing lung lesions typical for SARS-CoV-2 infection, which are different from lesions observed in other viral and nonviral pneumonias. Indeed, abnormal CT findings with initial false-negative RT-PCR results were reported.[48,49] For example, Fang et al[49] compared the detection rate by initial chest CT and RT-PCR, both performed within 3 days from the disease onset, and reported a higher detection rate for the initial CT (50/51 patients [98%]) compared with the first RT-PCR (36/51 patients [71%]) ($P < 0.001$). Ai et al[21] reported the results of chest CT in comparison with the initial and serial RT-PCR results in a large series of 1014 patients with suspected COVID-19. Out of 308 patients with negative RT-PCR results but positive chest CT scans, 147 (48%) patients were reconsidered as highly likely cases, and 103 (33%) as probable cases by a comprehensive evaluation. In the analysis of serial RT-PCR assays and CT scans, 60% to 93% of patients had initial positive chest CT consistent with COVID-19 before the initial positive RT-PCR results.

Chest CT has been shown to be highly sensitive for the diagnosis of COVID-19 pneumonia, and it has been useful for the diagnostic purposes. In addition, the value of chest CT lies in the fact that it does not only detect the disease but also provides information on the location and extent of lung lesions, and when performed serially, may be used to monitor the progression and / or regression of the disease.[14] The information provided by chest CT may again precede that provided by follow-up RT-PCR testing. In one study, 42% of patients showed improvement on follow-up chest CT scans before the RT-PCR results turned negative.[21]

As a result, a number of Chinese authors suggested that chest CT may be considered a primary tool for COVID-19 detection in epidemic areas.[14,21,43,50] When reviewing triage strategies for COVID-19 in fever clinics established for triaging patients in Wuhan, Zhang et al[51] recommended performing chest CT in all patients with dyspnea or hypoxia (oxygen saturation <93%), fever of 37.3 °C or higher, or absolute lymphocyte count less than 1100/μl.

In summary, it should be emphasized that CT cannot replace RT-PCR as a diagnostic method for COVID-19, but in some settings, RT-PCR, even if widely available, may return the diagnostic result with a delay, and / or may give a false-negative result for reasons discussed above, and thus repeat testing may be required, yielding a positive result with an even longer delay.

Expert position statements regarding the role of chest computed tomography as a primary diagnostic or screening tool for COVID-19 Some authors have suggested that the sensitivity of chest CT and rapid availability of its findings may justify its use as an early diagnostic tool in the acute setting in selected cases. Indeed, CT findings have been used as a surrogate diagnostic test by some authors.[12,22]

However, many radiological organizations including the American College of Radiology (ACR), The Royal College of Radiologists in the United Kingdom, and the Canadian Association of Radiologists have stated that chest CT should not be considered a primary diagnostic or screening tool when investigating for COVID-19.[52-54] One

TABLE 3 Pros and cons for a widespread use of chest computed tomography in coronavirus disease 2019

Pros	Cons
• Evaluates the nature and extent of pulmonary lesions • May be used to monitor disease progression/regression • Rapid presumptive diagnosis of COVID-19 when typical findings are seen on CT • Diagnostic result may be more rapidly available compared with RT-PCR, particularly in the settings of an epidemic disease outbreak with a shortage of RT-PCR tests and a limited capacity of diagnostic laboratories • May detect disease in asymptomatic and/or presymptomatic subjects	• CT findings not specific for COVID-19 (only suggestive but not definitive) • Normal CT findings do not exclude infection • Cost • Availability • Exposure to radiation • Need for stringent infection control measures in CT laboratories • Possible need for allocating dedicated diagnostic units only for the purpose of imaging of patients suspected for COVID-19

Abbreviations: COVID-19, coronavirus disease 2019; RT-PCR, real-time reverse transcriptase–polymerase chain reaction; others, see TABLE 1

argument that has been raised is that the abovementioned studies tended to suffer from a selection bias.[29] For example, ACR stated that CT should not be used to screen for COVID-19 or as a first-line test to diagnose the disease. According to ACR, CT should be used sparingly and reserved for hospitalized, symptomatic patients with specific clinical indications for CT, with appropriate infection control procedures followed before scanning subsequent patients.[52]

On the other hand, the Radiological Society of North America stated that due to the current shortage of nucleic acid testing kits used to confirm the presence of SARS-CoV-2, CT scans have become the first line of defense in the diagnostic workup of a suspected infection. The Radiological Society of North America is currently in the process of preparing a free diagnostic resource for the global radiology community.[55]

In February 2020, confirmed cases in the Hubei province, China, could be defined based on not only the laboratory criteria but also the clinical criteria that included CT evidence of a viral infection.[56] The sixth edition of the Chinese criteria published on February 18, 2020 no longer included the CT findings without confirmation by RT-PCR.[57] CT findings also were not included among the diagnostic criteria for COVID-19 which were published in March 2020 by a group of American and Singaporean experts.[13]

Finally, it should be noted that CT devices are frequently located in multi-specialist hospitals where patients with cancer and other immunocompromised patients are often examined, for whom contact with those with COVID-19 poses a very serious threat. A widespread use of chest CT in patients suspected for COVID-19 requires solving a number of biohazard and logistic issues related, for example, to the need for facility and equipment decontamination from SARS-CoV-2, adequate protection of radiology unit personnel from exposure to a highly contagious agent, providing/purchasing an adequate number of CT imaging systems, and perhaps even allocating dedicated diagnostic units only for the purpose of imaging in patients suspected for COVID-19.

Summary and conclusions Chest CT without administration of an intravenous contrast agent is a precise diagnostic tool for the detection of COVID-19 pneumonia and the assessment of the extent of pulmonary lesions, with a demonstrated advantage over plain chest radiography. Chest CT is a noninvasive and safe examination modality, as the radiation dose used is not high. It has been shown to be highly sensitive at detecting inflammatory lesions. CT findings are not specific for the SARS-CoV-2 pathogen but their typical patterns have been well described and the rates of false-positive results were low in the reported patient groups.[43] Thus, imaging cannot replace genetic testing in patients suspected for COVID-19. However, chest CT is a very important tool for assessing the extent of COVID-19, monitoring the disease progression/regression, and planning the therapeutic management and patient care. CT findings of a viral lung infection may precede a positive RT-PCR test result, particularly in the settings of an epidemic disease outbreak with a shortage of RT-PCR tests and a limited capacity of diagnostic laboratories. Thus, some authors suggested that due to difficulties with providing a sufficient number of nucleic acid detection test kits used to confirm the presence of SARS-CoV-2, the sensitivity of chest CT and rapid availability of its findings may justify its use as an early diagnostic tool in the acute setting. However, many radiological organizations stated that chest CT should not be relied upon as a primary diagnostic or screening tool for COVID-19 but rather reserved for hospitalized, symptomatic patients with specific clinical indications for CT, with appropriate infection control measures when scanning subsequent patients. However, CT devices are often located in multi-specialist hospitals where patients with cancer and other immunocompromised patients are often examined, for whom contact with those with COVID-19 poses a very serious threat. Thus, there is a possible need for allocating dedicated diagnostic units only for the purpose of imaging patients suspected for COVID-19. Notwithstanding these limitations, an easy access to CT scanning might facilitate identification of patients with COVID-19 and contribute to reducing the burden of the epidemic in some healthcare settings. Pros and cons for a widespread use of chest CT in COVID-19 are summarized in TABLE 3.

ARTICLE INFORMATION

CONFLICT OF INTEREST None declared.

HOW TO CITE Jędrusik P, Gaciong Z, Sklinda K, et al. Diagnostic role of chest computed tomography in coronavirus disease 2019. Pol Arch Intern Med. 2020; 130: 520-528. doi:10.20452/pamw.15348

REFERENCES

1 Zhu N, Zhang D, Wang W, et al. A novel coronavirus from patients with pneumonia in China, 2019. N Engl J Med. 2020; 382: 727-733.

2 Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet. 2020; 395: 497-506.

3 Scher I. The first COVID-19 case originated on November 17, according to Chinese officials searching for 'patient zero'. The Business Insider website. https://www.businessinsider.com/coronavirus-patients-zero-contracted-case-november-2020-3?IR=T. Published March 13, 2020. Accessed March 29, 2020.

4 Guan WJ, Ni ZY, Hu Y, et al. Clinical characteristics of coronavirus disease 2019 in China. N Engl J Med. 2020; 382: 1708-1720.

5 Hu Z, Song C, Xu C, et al. Clinical characteristics of 24 asymptomatic infections with COVID-19 screened among close contacts in Nanjing, China. Sci China Life Sci. 2020; 63: 706-711.

6 Velavan TP, Meyer CG. The Covid-19 epidemic. Trop Med Int Health. 2020; 25: 278-280.

7 Zheng YY, Ma YT, Zhang JY, Xie X. COVID-19 and the cardiovascular system. Nat Rev Cardiol. 2020; 17: 259-260.

8 Wang D, Hu B, Hu C, et al. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China. JAMA. 2020; 323: 1061-1069.

9 Cao B, Wang Y, Wen D, et al. A trial of lopinavir-ritonavir in adults hospitalized with severe Covid-19. N Engl J Med. 2020; 382: 1787-1799.

10 Hu Z, Song C, Xu C, et al. Clinical characteristics of 24 asymptomatic infections with COVID-19 screened among close contacts in Nanjing, China. Sci China Life Sci. 2020; 63: 706-711.

11 Zu ZY, Jiang MD, Xu PP, et al. Coronavirus disease 2019 (COVID-19): a perspective from China. Radiology. 2020 Feb 21. [Epub ahead of print].

12 Kanne JP, Little BP, Chung JH, et al. Essentials for radiologists on COVID-19: An update—Radiology Scientific Expert Panel. Radiology. 2020 Feb 27. [Epub ahead of print].

13 Mossa-Basha M, Meltzer CC, Kim DC, et al. Radiology department preparedness for COVID-19: Radiology Scientific Expert Panel. Radiology. 2020 Mar 16. [Epub ahead of print].

14 Dai WC, Zhang HW, Yu J, et al. CT imaging and differential diagnosis of COVID-19. Can Assoc Radiol J. 2020; 71: 195-200.

15 U.S. Food and Drug Administration. Coronavirus Disease 2019 (COVID-19). https://www.fda.gov/emergency-preparedness-and-response/counterterrorism-and-emerging-threats/coronavirus-disease-2019-covid-19. Accessed April 16, 2020.

16 U.S. Food and Drug Administration. Coronavirus (COVID-19) Update: Serological Tests. https://www.fda.gov/news-events/press-announcements/coronavirus-covid-19-update-serological-tests. Accessed April 16, 2020.

17 Zhou F, Yu T, Du R, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. Lancet. 2020; 395: 1054-1062.

18 Shi H, Han X, Jiang N, et al. Radiological findings from 81 patients with COVID-19 pneumonia in Wuhan, China: a descriptive study. Lancet Infect Dis. 2020; 20: 425-434.

19 Chen N, Zhou M, Dong X, et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. Lancet. 2020; 395: 507-513.

20 Chung M, Bernheim A, Mei X, et al. CT imaging features of 2019 novel coronavirus (2019-nCoV). Radiology. 2020; 295: 202-207.

21 Ai T, Yang Z, Hou H, et al. Correlation of chest CT and RT-PCR testing in coronavirus disease 2019 (COVID-19) in China: a report of 1014 cases. Radiology. 2020 Feb 26. [Epub ahead of print].

22 Rodrigues JCL, Hare SS, Edey A, et al. An update on COVID-19 for the radiologist – a British Society of Thoracic Imaging statement. Clin Radiol. 2020; 75: 323-325.

23 Ng M, Lee EYP, Yang J, et al. Imaging profile of the COVID-19 infection: radiologic findings and literature review. Radiol Cardiothorac Imaging. 2020; 2: e200034.

24 Wong HYF, Lam HYS, Fong AH, et al. Frequency and distribution of chest radiographic findings in COVID-19 positive patients. Radiology. 2020 Mar 27. [Epub ahead of print].

25 Peng QY, Wang XT, Zhang LN. Findings of lung ultrasonography of novel corona virus pneumonia during the 2019-2020 epidemic. Intensive Care Med. 2020; 46: 849-850.

26 Huang Y, Wang S, Liu Y, et al. A preliminary study on the ultrasonic manifestations of peripulmonary lesions of non-critical novel coronavirus pneumonia (COVID-19). Research Square. 2020 Feb 26. [Epub ahead of print].

27 Poggiali E, Dacrema A, Bastoni D, et al. Can lung US help critical care clinicians in the early diagnosis of novel coronavirus (COVID-19) pneumonia? Radiology. 2020; 295: E6.

28 Ianniello S, Piccolo CL, Buquicchio GL, et al. First-line diagnosis of paediatric pneumonia in emergency: lung ultrasound (LUS) in addition to chest-X-ray (CXR) and its role in follow-up. Br J Radiol. 2016; 89: 20150998.

29 Bell DJ. COVID-19. Radiopaedia website. https://radiopaedia.org/articles/covid-19-3. Accessed March 28, 2020.

30 Pan F, Ye T, Sun P, et al. Time course of lung changes on chest CT during recovery from 2019 novel coronavirus (COVID-19) pneumonia. Radiology. 2020; 295: 715-721.

31 Zhao W, Zhong Z, Xie X, et al. Relation between chest CT findings and clinical conditions of coronavirus disease (COVID-19) pneumonia: a multicenter study. AJR Am J Roentgenol. 2020; 214: 1072-1077.

32 Lee EYP, Ng MY, Khong PL. COVID-19 pneumonia: what has CT taught us? Lancet Infect Dis. 2020; 20: 384-385.

33 Salehi S, Abedi A, Balakrishnan S, Gholamrezanezhad A. Coronavirus disease 2019 (COVID-19): a systematic review of imaging findings in 919 patients. AJR Am J Roentgenol. 2020 Mar 14. [Epub ahead of print].

34 Bai HX, Hsieh B, Xiong Z, et al. Performance of radiologists in differentiating COVID-19 from viral pneumonia on chest CT. Radiology. 2020 Mar 10. [Epub ahead of print].

35 Lee KS. Pneumonia associated with 2019 novel coronavirus: can computed tomographic findings help predict the prognosis of the disease? Korean J Radiol. 2020; 21: 257-258.

36 Li L, Qin L, Xu Z, et al. Artificial intelligence distinguishes COVID-19 from community acquired pneumonia on chest CT. Radiology. 2020 March 19. [Epub ahead of print].

37 Liu J. Artificial Intelligence Assisted Radiology Technologies Aid COVID-19 Fight in China. Imaging Technology News website. https://www.itnonline.com/article/artificial-intelligence-assisted-radiology-technologies-aid-covid-19-fight-china. Accessed April 2, 2020.

38 Sabri A, Taheri MS, Mahdavi A, Dobranowski J. A 63-year-old man treated for coronavirus disease 2019. Pol Arch Inter Med. 2020; 130: 324-325.

39 Pan Y, Guan H, Zhou S, et al. Initial CT findings and temporal changes in patients with the novel coronavirus pneumonia (2019-nCoV): a study of 63 patients in Wuhan, China. Eur Radiol. 2020; 30: 3306-3309.

40 Bernheim A, Mei X, Huang M. Chest CT findings in coronavirus disease-19 (COVID-19): relationship to duration of infection. Radiology. 2020; 295: 200463.

41 Song F, Shi N, Shan F, et al. Emerging coronavirus 2019-nCoV pneumonia. Radiology. 2020; 295: 210-217.

42 Lan L, Xu D, Guangming Y, et al. Positive RT-PCR test results in patients recovered from COVID-19. JAMA. 2020; 323: 1502-1503.

43 Li Y, Xia L. Coronavirus disease 2019 (COVID-19): role of chest CT in diagnosis and management. AJR Am J Roentgenol. 2020; 214: 1280-1286.

44 Wang Y, Dong C, Hu Y, et al. Temporal changes of CT findings in 90 patients with COVID-19 pneumonia: a longitudinal study. Radiology. 2020 Mar 19. [Epub ahead of print].

45 Dou P, Zhang S, Wang C, et al. Serial CT features in discharged COVID-19 patients with positive RT-PCR re-test. Eur J Radiol. 2020; 127: 109010.

46 Shohei I, Fujikawa A, Jitsu M, et al. Chest CT findings in cases from the cruise ship "Diamond Princess" with coronavirus disease 2019 (COVID-19). Radiol Cardiothorac Imaging. 2020; 2: e200110.

47 Yang Y, Yang M, Shen C, et al. Evaluating the accuracy of different respiratory specimens in the laboratory diagnosis and monitoring the viral shedding of 2019-nCoV infections. medRxiv. Preprint posted online February 17, 2020.

48 Xie X, Zhong Z, Zhao W, et al. Chest CT for typical 2019-nCoV pneumonia: relationship to negative RT-PCR testing. Radiology. 2020 Feb 12. [Epub ahead of print].

49 Fang Y, Zhang H, Xie J, et al. Sensitivity of chest CT for COVID-19: comparison to RT-PCR. Radiology. 2020 Feb 19. [Epub ahead of print].

50 Wan Y, Shang J, Graham R, et al. Receptor recognition by the novel coronavirus from Wuhan: an analysis based on decade-long structural studies of SARS coronavirus. J Virol. 2020; 94: e00127-20.

51 Zhang J, Zhou L, Yang Y, et al. Therapeutic and triage strategies for 2019 novel coronavirus disease in fever clinics. Lancet Respir Med. 2020; 8: e11-e12.

52 American College of Radiology. ACR Recommendations for the use of chest radiography and computed tomography (CT) for suspected COVID-19 infection. https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Recommendations-for-Chest-Radiography-and-CT-for-Suspected-COVID19-Infection. Published March 11, 2020. Accessed April 5, 2020.

53 The Royal College of Radiologists. The role of CT in patients suspected with COVID-19 infection. https://www.rcr.ac.uk/college/coronavirus-covid-19-what-rcr-doing/rcr-position-role-ct-patients-suspected-covid-19. Published March 12, 2020. Accessed April 5, 2020.

54 Canadian Society of Thoracic Radiology and Canadian Association of Radiologists' Statement on COVID-19. Canadian Association of Radiologists website. https://car.ca/cstr/. Accessed April 5, 2020.

55 Radiological Society of North America. https://cases.rsna.org/coronavirus. Accessed April 5, 2020.

56 General Office of National Health Committee. Office of state administration of traditional Chinese medicine. Notice on the issuance of a programme for the diagnosis and treatment of novel coronavirus (2019-nCoV) infected pneumonia (trial fifth edition) (2020-02-26)[EB/OL]. http://bgs.satcm.gov.cn/zhengcewenjian/2020-02-06/12847.html. Accessed April 5, 2020.

57 National Health Commission of the People's Republic of China website. Diagnosis and treatment of novel coronavirus infection (trial version6). www.nhc.gov.cn/yzygj/s7653p/202002/8334a8326dd94d329df351d7da8aefc2.shtml. Accessed April 5, 2020.