Chest CT findings in COVID-19

Tomografia komputerowa w diagnostyce COVID-19

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KEYWORDS:

- COVID-19
- computed tomography
- diagnostic imaging

ABSTRACT

RT-PCR is the gold standard in the diagnosis of COVID-19 infections, due to its high specificity. However, there are clinical situations in which chest CT may prove vital, for example in patients with high clinical and epidemiologic suspicion towards COVID-19 before positive RT-PCR conversion or in detecting complications. Researchers have developed scales that, based on the findings in chest CT, help predict the severity of the disease.

There are three main pathologic patterns of lung injury that correlate with the duration of COVID-19 symptoms. Epithelial pattern with diffuse alveolar damage and desquamation /reactive hyperplasia of pneumocytes; vascular pattern with capillary congestion and (micro) thrombi and fibrotic pattern with interstitial fibrous changes. The epithelial pattern and vascular pattern appear early, even before the symptoms of the disease, whereas the fibrous pattern appears approximately three weeks after the onset of the disease.

Typical findings on chest CT in COVID-19 infection are: GGO, consolidation, GGO mixed with consolidation, interlobular septal thickening, air bronchogram sign, crazy paving, bronchial wall thickening and vascular enlargement.

Findings that may suggest a different etiology include multiple nodules, tree-in-bud opacities, bronchiectasis, pleural and pericardial effusion, extensive consolidations.

SŁOWA KLUCZOWE:

- COVID-19
- tomografia komputerowa
- diagnostyka obrazowa

STRESZCZENIE

RT-PCR, dzięki wysokiej swoistości, jest złotym standardem w diagnostyce zakażenia SARS-CoV-2, jednakże w części sytuacji klinicznych, niezbędne pozostaje wykorzystanie tomografii komputerowej, szczególnie u pacjentów z wysokim prawdopodobieństwem zakażenia przed uzyskaniem konwersji serologicznej oraz w ocenie powikłań choroby. Opracowano skale, które pozwalają na podstawie wyników tomografii komputerowej oszacować prawdopodobieństwo ciężkości przebiegu choroby.

Występują 3 główne histologiczne wzory uszkodzenia płuc, które korelują z czasem trwania COVID-19. Wzór nabłonkowy z rozsianym uszkodzeniem pęcherzyków płucnych i złuszczeniem/reaktywnym przerostem pneumocytów, naczyniowy z przekrwieniem naczyń włosowatych i mikrozatorami oraz włóknisty ze zmianami śródmiąższowymi. Zmiany o charakterze nabłonkowym i naczyniowym stwierdzane są wcześnie, nawet przed wystąpieniem objawów choroby, a zmiany o charakterze włóknistym pojawiają się po około 3 tygodniach od zakażenia.

Typowe nieprawidłowości stwierdzane w badaniach tomografii komputerowej u chorych na COVID-19 to zagęszczenia typu „matowej szyby", konsolidacje, zagęszczenia typu „matowej szyby" w połączeniu z konsolidacjami, pogrubienie przegród międzyzarazikowych, obraz bronchogramu powietrznego, obraz „kostki brukowej", pogrubienie ścian oskrzeli oraz pogrubienie naczyń.

Objawy radiologiczne, które sugerują inną niż zakażenie SARS-CoV-2 etiologię zapalenia płuc to obecność licznych guzków, rozstrzeni oskrzeli, płynu w jamie opłucnej lub w osierdziu oraz rozległych konsolidacji.

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Introduction

In December 2019 a novel virus emerged, causing severe respiratory disease, later named coronavirus disease 2019 (COVID-19) by WHO (1).

RT-PCR of samples taken from the upper and lower respiratory tract remains a reference method in the diagnosis of SARS-CoV-2 virus infection. Although RT-PCR is a highly specific diagnostic method, its lately estimated sensitivity is at 30-60% and even lower in the early stage of the disease (5). An important disadvantage of RT-PCR is the fact, that it takes time to be performed, while fast recognition and isolation of highly infectious patients is an absolute condition for the spread of the disease to be limited (5). Therefore, chest computed tomography, which is characterized by high sensitivity, is very helpful in some clinical situations, especially in cases highly suspicious of COVID-19 infection with negative initial RT-PCR.

Role of CT imaging

CT imaging, being a fast and broadly available method of examination, in the beginning of the pandemic was considered as the leading method for COVID-19 diagnosis and exclusion (19). Nowadays it is considered a method complementary to RT-PCR. Even though different studies confirm high sensitivity of chest CT estimated at 94-97%, (3, 9) the main disadvantage of CT imaging in COVID-19 infection is poor specificity, estimated at 37-60%. This is because COVID-19 CT findings share similarities with findings in other viral pneumonia caused by influenza and parainfluenza viruses, adenoviruses, CMV, RSV, rhinoviruses and other viruses (5). In some cases findings similar to those in COVID-19 may be found in patients with hypersensitivity pneumonitis, acute eosinophilic pneumonia, diffuse alveolar hemorrhage, pulmonary edema, transfusion-related acute lung injury and many others. Low specificity remains the main reason CT imaging cannot replace RT-PCR. However, CT imaging proved to be very useful in many situations, among them: early detection in patients with high clinical and epidemiologic suspicion towards COVID-19 before positive RT-PCR conversion, monitoring and predicting the course of the disease, detecting complications and providing possible alternative diagnoses (7, 9).

According to a Multinational Consensus Statement from the Fleischner Society, CT imaging should not be routinely used in patients suspected of having COVID-19 and mild clinical course except in those at risk for disease progression.

Indications for CT imaging comprise of worsening respiratory status in a patient with COVID-19, assessment of comorbidities and, in case no other methods are available, triage of patients with the high epidemiological probability of COVID-19 infection, who demonstrate moderate to severe signs and symptoms.

The great advantage of chest CT is its reliability as a diagnostic method (16, 17).

Typical CT findings

As for imaging protocol, slices thinner than 3 mm are preferred, most favorably in deep inspiration and with volumetric acquisitions, with the patient lying supine (5). Prone position acquisition may be used to distinguish posteriorly located abnormalities from position-dependent atelectasis (9). Expiratory acquisition may help to differentiate between hypovascular mosaic attenuation and air-trapping (9). Additional acquisitions are usually withdrawn from protocol, as it might be challenging for the patients with severe disease. Obtained images are often not optimal due to artifacts caused by tachypnea and body movement.

Its been established that lesions in the lungs can be found in CT before the onset of symptoms (6) and can suggest COVID-19 infection in patients examined because of other medical conditions.

Studies show that the most common lesion distribution pattern in patients with COVID-19 was bilateral, peripheral lung affection with three or more lobes involved, most commonly right lower lobe and left upper lobe (1).

The most typical lesion pattern is GGO, defined as areas of increased lung attenuation, with bronchi and vessels distinguishable from parenchyma, found in up to 83% of cases of COVID-19 infections (1). Other common lesion patterns are consolidation and GGO mixed with consolidation (mainly in the elderly), interlobular septal thickening and air bronchogram sign (1, 6) (Figures 1-4). Slightly less common findings comprise crazy paving, bronchial wall thickening and vascular enlargement (1, 8).

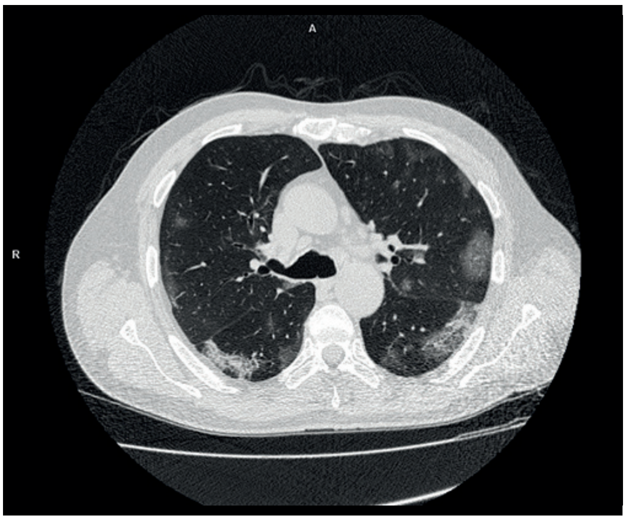

Figure 1. Peripheral, predominantly posterior, ground-glass opacification and crazy paving pattern areas.

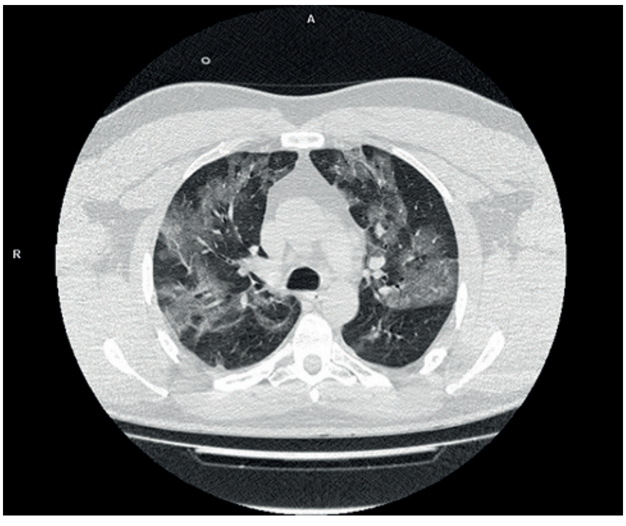

Figure 2. Diffuse, bilateral areas of ground-glass opacification.

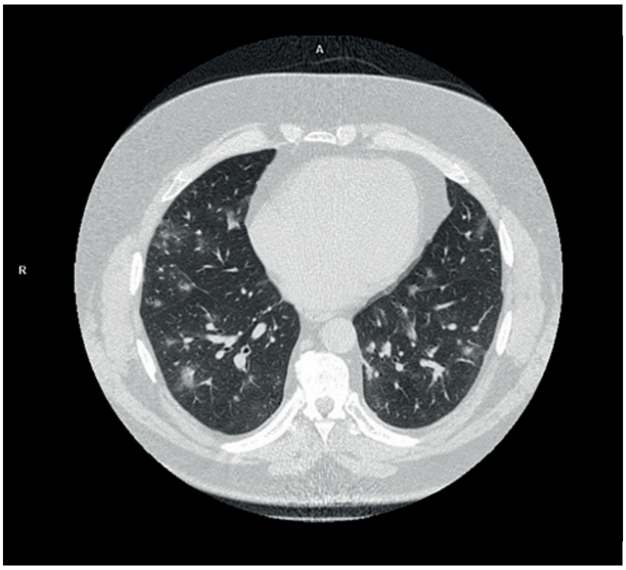

Figure 3. Bilateral, scattered ground-glass opacification.

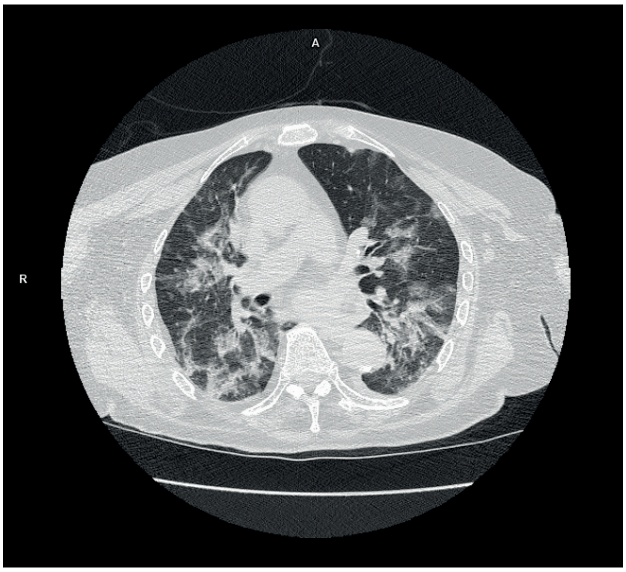

Figure 4. Bilateral areas of ground-glass opacification with crazy paving.

Pathologic patterns of lung injury are based on histologic changes and correlate with the duration of COVID-19 symptoms. The epithelial pattern is the first to appear, often before the beginning of infection signs. In this stage inflammatory cells are attracted to infected type-II pneumocytes and processes of apoptosis and necroptosis begin, causing diffuse alveolar damage and desquamation with reactive hyperplasia of pneumocytes. Epithelial debris and exudate start to fill the alveoli. Simultaneously, microvascular changes, with capillary congestion and microthrombi appear. In diagnostic imaging filling of airspaces, interstitial thickening, inflammation and edema translate into GGO, consolidations and nodules, whereas cellular infiltration and deposits within the septal space, filling of the airspaces at the periphery of the lobules and venous congestion are seen as interlobular septal thickening. Crazy-paving appears in the superposition of interstitial septal thickening on ground-glass opacity (12).

With the progression of the disease, when a greater volume of parenchyma is affected and more debris and fluid fill the alveoli, more extensive GGO and consolidations with air bronchograms start to show (Figures 5, 6). Last of all, the fibrotic pattern of lung injury predominates, about three weeks after starting of symptoms, with interstitial fibrous changes, that are seen in CT as interlobular septal thickening, reticulation and architectural distortion of parenchyma as well as thickening of bronchial walls (12) (Figure 7).

Typical findings in chest CT can be divided into 5 groups according to the stage of disease, as described in the study by Jin et al. (6). In the "ultra-early" stage, corresponding to the asymptomatic period within one to two weeks after exposure to the virus, uni- and multifocal GGO, consolidations and nodules may be shown (6). In the "early stage", the stage of early clinical signs and symptoms, the imaging signs are similar to those in the "ultra-early" stage, but with superimposed interlobular septal thickening (6). Later, in the "rapid-progression" stage, which corresponds to approximately days three to seven after the onset of the clinical symptoms, consolidations with air bronchograms start

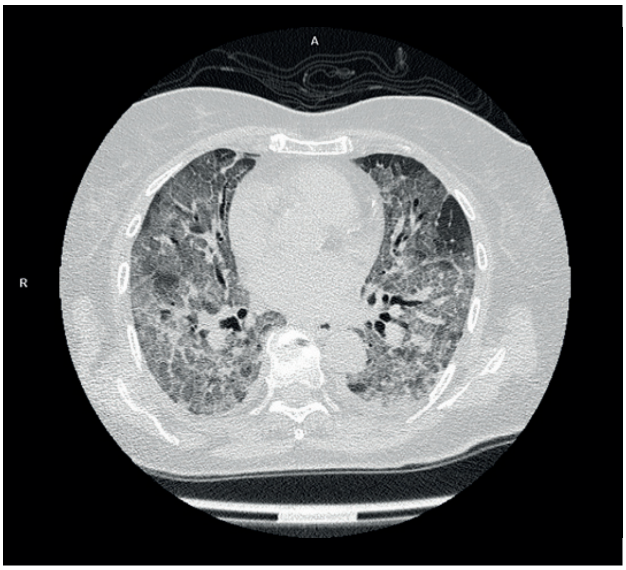

Figure 5. Ground-glass opacification, crazy paving pattern and consolidation in 90% of lung parenchyma.

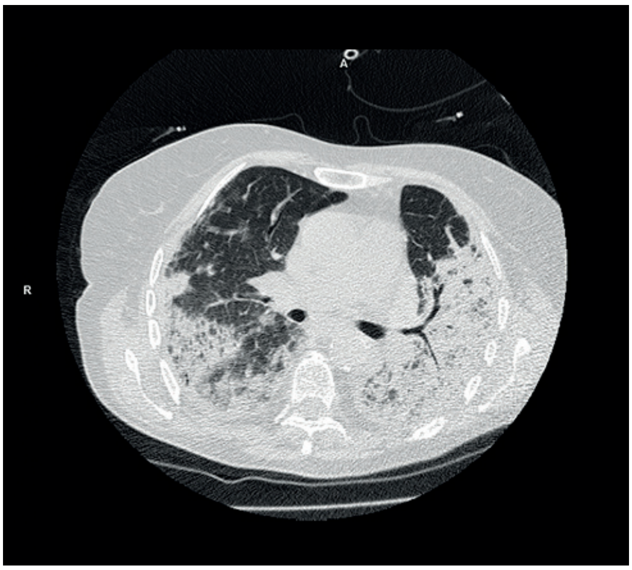

Figure 6. Bilateral, diffuse consolidation with air bronchogram sign.

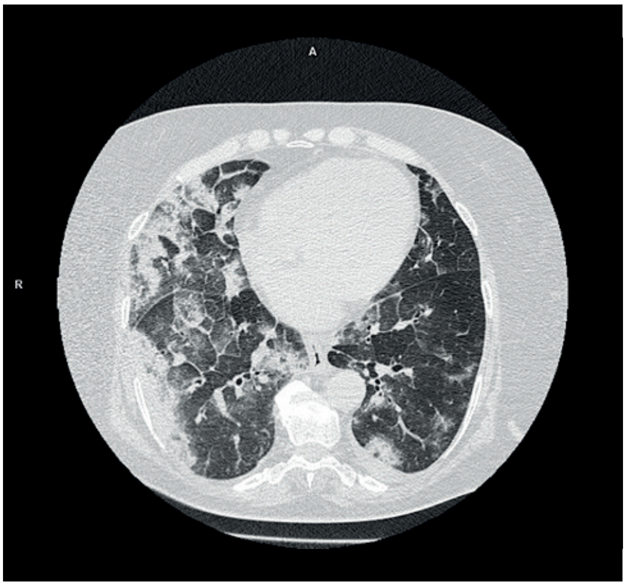

Figure 7. Areas of consolidation and ground-glass opacification, with fibrotic streaks.

to show (6). Regression of formerly mentioned CT signs can be seen in the fourth, "consolidation stage", usually starting from day eighth after symptoms start (6). Ultimately, in the last stage, two to three weeks after symptoms beginning, thickening of interlobular septa and bronchial walls is seen (6).

Mediastinal lymphadenopathy is reported in around 6% of patients admitted to the hospital for COVID-19. Some authors suggest, that there may be a correlation of lymphadenopathy to the severity of the disease (15).

Atypical findings in COVID-19 include multiple nodules, tree-in-bud opacities, bronchiectasis, pleural and pericardial effusion, extensive consolidations and they may suggest different etiology (9). There are reports of halo sign and reverse halo sign (atoll sign) in patients with COVID-19. Halo sign represents the focus of pulmonary infarction surrounded by alveolar hemorrhage, while reverse halo sign is caused by alveolar septal inflammation with cellular debris in alveolar spaces, surrounded by granulomatous tissue within the distal air spaces (13, 14).

The ratio of affected lung parenchyma volume to total lung parenchyma volume, lesion pattern and lesion distribution pattern correlate with disease stage, patients' clinical status, forthcoming disease course and complications probability.

The complexity of CT imaging findings in monitored patients can cause assessment of the exam in relation to previous exams of the same patient challenging. To support intra- and inter-observer consistency many scales have been developed (11). When describing chest CT, the three scales are most often used: chest CT severity score (proposed by Yang et al.), total severity score (proposed by Kunwei et al.) and chest CT score (proposed by Li et al.) (11). One of the studies summarized the clinical condition of patients measured using the Modified Early Warning Score with the degree of lung involvement in the chest CT assessed in one of the three above scales. The results show that the Chest CT Severity Score has the best correlation with the patient's clinical condition (17). In the same research it was demonstrated that the agreement between the assessments of the two radiologists was greatest using the Total Severity Score (17). In our radiology department, we use the modified Total Severity Score to evaluate the CT of COVID-19 patients. The modification is based on emphasizing the dominant type of changes in the pulmonary parenchyma (16). This is highly useful in assessing the course of the disease as higher mortality has been observed in patients with predominant consolidations (16).

It is very important to highlight that chest x-rays are not sensitive in the detection of ground-glass opacities and often demonstrate normal findings in COVID-19 infection, especially in the early stage of the disease (1), and should be reserved for assessment of complications of the disease.

Conclusions

There are no pathognomonic findings in CT imaging in patients with COVID-19 and diagnostic imaging cannot replace RT-PCR as the fundamental method of disease diagnosis. Nevertheless, our review of the studies listed in the references, as well as our clinical experience strongly enforce the importance of CT imaging (especially using thin-slice protocols) in patients suspected of COVID-19 as well as in those already diagnosed, monitored and treated.

In the first aforementioned group, the most common findings, which are posteriorly and peripherally distributed bilateral, multilobar GGO with a predilection for lower lobes are suspicious for changes in COVID-19 and can suggest this etiology to radiologists and clinicians, even in early stages, when the RT-PCR results remain negative. In patients already diagnosed with COVID-19, CT imaging helps to assess the stage of the disease, monitor its course and to some extent predict the outcome. It plays a fundamental role in the assessment of complications of COVID-19 pneumonia and the assessment of comorbidities. Moreover, it was confirmed that this method is reliable and shows prognostic value.

To sum up, CT imaging, being a fast and broadly available method of examination, should be considered complementary to RT-PCT, however, because of its limited specificity, applied in certain, yet numerous conditions.

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