REVIEW ARTICLE

Radiographic and CT Features of Viral Pneumonia. A brief overview with emphasis on coronavirus.

Julio Manuel Díaz Riverol

Abstract
Viruses are the most common causes of respiratory infection, and causative agents of lower respiratory tract infections that vary according to patient age and immunity. The imaging findings of viral pneumonia are diverse and overlap with those of other non-viral infections and inflammatory conditions. Computed tomographic findings of viral pneumonia are diverse and may be affected by the immune status of the host and the underlying pathophysiology of the viral pathogen. Coinfection with bacteria is common and identification of the underlying viral pathogens may not always be easy. There are a number of indicators for identifying viral pathogens on the basis of imaging patterns. While not all cases manifest with typical patterns, most viral pneumonia patterns exhibit similarity on the basis of the virus family. Even though a definite diagnosis cannot be achieved on the basis of imaging features alone, recognition of viral pneumonia patterns may aid in differentiating viral pathogens. The objective of this review was to describe differential imaging diagnoses of pathogens in early stages of the infection based on the imaging patterns of pneumonia and suggest the possible prognosis. Early diagnosis of pneumonia as viral, using tests such as radiologic studies and blood or serology tests, would reduce unnecessary use of antibiotics and may improve the clinical course. Moreover, rapid diagnosis can lead to early control of potential transmission, thus decreasing overall treatment costs

Key words
Viral pneumonia, coronaviridae, imaging techniques

■ INTRODUCTION

Viruses are the most common causes of respiratory infection, and causative agents of lower respiratory tract infections that vary according to patient age and immunity. The imaging findings of viral pneumonia are diverse and overlap with those of other non-viral infections and inflammatory conditions. Computed tomographic (CT) findings of viral pneumonia are diverse and may be affected by the immune status of the host and the underlying pathophysiology of the viral pathogen. Moreover, coinfection with bacteria is common, however, identification of the underlying viral pathogens may not always be easy. There are a number of indicators for identifying viral pathogens on the basis of imaging patterns, which are associated with the pathogenesis of viral infections. Viruses in the same viral family share a similar pathogenesis of pneumonia, and the imaging patterns have distinguishable characteristics. Although not all cases manifest with typical patterns, most typical imaging patterns of viral pneumonia can be classified according to viral families. Although a definite diagnosis cannot be achieved on the basis of imaging features alone, recognition of viral pneumonia patterns may aid in differentiating viral pathogens, thus reducing the use of antibiotics.(1)

The clinical and CT findings of numerous respiratory viral pathogens such as influenza, human parainfluenza virus (HPIV), respiratory syncytial virus (RSV), rhinovirus, and adenovirus have been described.(2,3)

RSV shows an airway-centric pattern of disease with "tree-in-bud" opacity and bronchial wall thickening. Adenovirus appears as multifocal consolidation or ground-glass opacity (GGO), and GGO was more frequently noticed in patients with adenovirus pneumonia than in those with other viral infections or bacterial infections. A diffuse airspace pattern was seen more frequently in patients with bacterial infections. On the basis of the imaging patterns of pneumonia, we can suggest a differential diagnosis of the pathogen during early stages of the infection. Diagnostic tests including radiologic studies and blood or serologic tests that could help establish the cause of pneumonia would reduce the use of antibiotics and may improve the clinical course. Moreover, rapid diagnosis can lead to early control of potential transmission, thus decreasing overall treatment costs.

With the recent advancement in molecular biology and the

MD, Radiologist, Belize Healthcare Partners, Belmopan Medical Imaging Center.

Corresponding author: Dr. Julio Díaz Email: diazriverol@hotmail.com

ability to amplify multiple viral genomes by using multiplex reverse-transcription polymerase chain reaction assays, several new human respiratory viruses, such as human metapneumovirus (HMPV), human coronaviruses, and bocavirus have been discovered.(4,5) A number of these new viruses, including severe acute respiratory syndrome (SARS) coronavirus and Middle East respiratory syndrome (MERS) coronavirus, have been associated with regional outbreaks in the past and could reemerge to produce outbreaks in the future.(6)

■ PATHOGENESIS OF VIRAL PNEUMONIA

CT patterns of viral pneumonia are related to the pathogenesis of pulmonary viral infection. Although not all cases demonstrate typical imaging patterns, most viral pneumonia patterns exhibit similarity on the basis of the virus family. For example, RSV and HPIV replicate in the nasopharyngeal epithelium, spread to the lungs, and induce bronchiolitis with sloughing of epithelial cells of the small airways.(7) HMPV also infects the lung epithelium and induces an inflammatory cascade.(8)

The CT findings of RSV pneumonia, HPIV pneumonia, and HMPV pneumonia are similar. The viruses usually appear as multifocal patchy consolidation with GGO, and centrilobular nodules with bronchial wall thickening are also noticed. Influenza virus diffusely invades the respiratory epithelium, resulting in necrotizing bronchitis and diffuse alveolar damage, which manifest as consolidation.(1, 9)

Adenovirus affects the terminal bronchioles and causes bronchiolitis, which may be accompanied by necrotizing bronchopneumonia. Herpes simplex virus (HSV) has cytopathic effects in both the airways and alveoli; these manifest as a multifocal scattered airspace pattern of opacity and predominant areas of peribronchial consolidation. Intranuclear inclusions can be observed in lung biopsy tissue or at cytologic examination of bronchoalveolar lavage fluid. In a patient with HSV pneumonia who underwent open lung biopsy, areas of GGO on CT images corresponded to pathologic diffuse alveolar damage.(10)

The presence of mononuclear or multinuclear epithelial cells containing an intranuclear inclusion suggests the diagnosis of HSV pneumonia. Similarly, cytomegalovirus (CMV) exhibits acute interstitial pneumonia with diffuse alveolar edema with fibrinous exudate. Multifocal nodular infiltration represents infected areas of cells with cytoplasmic CMV inclusion. In a murine model of CMV pneumonia, interstitial fibrocytes, alveolar epithelial cells, and endothelial cells were target cells of CMV infection.(11)

Coronaviridae

Human coronaviruses are considered as important pathogens that cause infections in pediatric, geriatric, and immunocompromised patients and include upper and lower respiratory tract infections (pneumonia and bronchiolitis) and even acute respiratory distress syndrome.(12)

SARS coronavirus was identified as a member of the Coronaviridae family in late 2003 after a world-wide epidemic. In 2012, another coronavirus-related epidemic occurred in the Middle East that was identified as MERS. (13)

Seven coronaviruses are known to cause human disease. Three are zoonoses: the severe acute respiratory syndrome coronavirus (SARS-CoV), the Middle East respiratory syndrome coronavirus (MERS-CoV) and the recently discovered SARS-Co V-2, all of which may sometimes be fatal. There are not vaccines or specific treatments for them. The remaining four viruses cause common cold.(13)

Angiotensin-converting enzyme 2 is a potential receptor for SARS viruses and is a negative regulator of the renin-angiotensin system that affects vascular permeability. Angiotensin-converting enzyme 2 is expressed in the lungs and kidneys, and the SARS virus induces direct lung injury by involving angiotensin-converting enzyme, which contributes to diffuse alveolar damage. Also, SARS coronavirus-encoded proteins induce cell apoptosis, including that of the lungs, kidneys, and liver. MERS coronavirus can evade immune response and cause a severe dysregulation of the host cellular transcriptome, resulting in cell apoptosis.(14,15)

SARS Coronavirus

A worldwide outbreak of SARS coronavirus, which was first identified in Guangdong Province, China, occurred during 2002–2003. There were more than 8000 cases of identified infection, with 21% occurring in health care workers. SARS mortality in 2003 was estimated at 6.8%–13.2% for patients younger than 60 years and 43%–50% for patients older than 60 years. Patients with comorbidities such as diabetes or chronic hepatitis exhibited increased mortality. The animal hosts of SARS coronavirus appear to include the masked palm civet, raccoon dogs, and the Chinese ferret-badger.(16)

After a 2–10-day incubation period, patients present with flu-like symptoms, dyspnea, and recurrent or persistent fever. Patients typically have a history of exposure and new infiltration of pneumonia on a chest radiograph. A diagnosis is made on the basis of one or more positive tests for SARS coronavirus.(16)

The radiologic features of SARS are similar to those of other community-acquired types of pneumonia. Initial chest radiographs are normal but soon progress to show multifocal airspace consolidation, predominantly in the lower lung zone. In most patients, peripheral lung involvement is common. Unifocal involvement is more common than multifocal or bilateral involvement. On CT

images, GGOs with consolidations are main findings, and reticulation is noted after the 2nd week.(17) Cavitation, lymphadenopathy, or pleural effusions are not common findings.(18)

MERS Coronavirus

MERS coronavirus is a new member of the β-coronaviruses and is different from SARS and other endemic human β-coronaviruses (e.g. OC43, HKU1). The first case was identified in September 2012, in Riyadh, Saudi Arabia. Bats and dromedary camels are considered to be reservoirs of MERS coronavirus. The virus was named SARS-like coronavirus, novel coronavirus, or human coronavirus Erasmus Medical Center (EMC) when it was first discovered. During 2012–2014, the number of cases of MERS coronavirus infection increased in Saudi Arabia, with overall mortality of 35%–44%.(19) MERS was reported in at least 10 other countries in Europe and Asia and in the United States and was associated with travel to the Middle East.(20) In May 2015, a large outbreak of MERS coronavirus infection occurred in South Korea, with 186 identified patients and 38 deaths.(21)

Clinical symptoms resemble other lower respiratory tract diseases involving fever, cough, dyspnea, and pneumonia. The infection may progress rapidly to acute respiratory distress syndrome, multiorgan failure, and death. MERS progresses more rapidly to respiratory failure than does SARS and induces acute kidney injury. Approximately 20% of all virus cases were identified in health care workers and persons who come into close contact with camels.(19) MERS pneumonia appears on CT images as subpleural and basilar airspace lesions, with extensive GGO and consolidation.(22) Cavitation is uncommon.

Pleural effusion and pneumothorax are more common in patients who died than in those who recovered (23). After recovery, these abnormalities show marked improvement, but fibrotic changes remain.(24)

SARS-CoV-2 (coronavirus disease 2019)

COVID-19 (coronavirus disease 2019) is an infectious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), previously known as 2019 novel coronavirus (2019-nCoV), a strain of coronavirus. The first cases were documented in Wuhan, China, in December 2019 before spreading globally.(25) The current outbreak was officially recognized as a pandemic on March 11, 2020.(26) No effective treatment or vaccine exists currently.

The non-specific imaging findings are most commonly of atypical or organizing pneumonia, often with a bilateral, peripheral, and basal predominant distribution.(27)

The World Health Organization (WHO) originally called this illness "novel coronavirus-infected pneumonia (NCIP)", and the virus itself had been provisionally named "2019 novel coronavirus (2019-nCoV)". On February 11, 2020, the WHO officially renamed the clinical condition as COVID-19 (a shortening of CoronaVIrus Disease-19). Coincidentally, on the same day, the Coronavirus Study Group of the International Committee on Taxonomy of Viruses renamed the virus "severe acute respiratory syndrome coronavirus 2" (SARS-CoV-2).(28) The names of both the disease and the virus should be fully capitalized, except for the 'o' in the viral name, which is in lowercase

The official virus name is similar to SARS-CoV, the virus strain that caused epidemic severe acute respiratory syndrome (SARS) in 2002–2004, potentially causing confusion. The WHO has stated it will use "COVID-19 virus" or the "virus that causes COVID-19" instead of its official name, SARS-CoV-2, when communicating with the public.(28)

On March 23, 2020, the number of cases of confirmed COVID-19 infection globally was over three hundred thousand. COVID-19 has now been diagnosed in 185 territories, in six continents (29) according to the WHO. As of March 23, 2020, there are 7 countries with >10,000 to >50,000 cases, 16 countries with 1,000 to 10,000 confirmed cases and the remaining countries have from 1 to ≈ 900 confirmed cases. The death total was 14,502.(29)

NB: surveillance methods and capacity vary dramatically between countries, and there is reason to suspect that there may be a significant number of undiagnosed asymptomatic carriers in many territories.

The R0 (basic reproduction number) of SARS-CoV-2 has been estimated between 2.2 and 3.28, that is, each infected individual, on average, causes between 2–3 new infections. (30)

The incubation period for COVID-19 was initially calculated to be ~5 days, based on 181 patients. An American group performed an epidemiological analysis of these cases, for which days of exposure and symptom onset could be estimated accurately. They calculated a median incubation period of 5.1 days, that 97.5% became symptomatic within 11.5 days (CI, 8.2 to 15.6 days) of being infected, and that extending the cohort to the 99th percentile results in almost all cases developing symptoms in 14 days after exposure to SARS-CoV-2.(31)

The case fatality rate is ~3–4%. It is speculated that the true case fatality rate is lower than this because many mild cases are not being tested, which thus skews the apparent death rate upwards. Several other factors can restrict obtaining an accurate estimate of the CFR. The virus and its clinical course are new, the availability of healthcare workers, resources, facilities, and preparedness. In Singapore, where quarantine and isolation of infected or suspected cases have been implemented, the CFR of 631 cases (as of March 25, 2020) is 0·3%. Although highly

transmissible, the CFR of COVID-19 appears to be lower than that of SARS (9·5%) and Middle East respiratory syndrome (34·4%),(8) but higher than that of influenza (0·1%).(32)

A paper published by the Chinese Center for Disease Control and Prevention (CCDC) analyzed all 44,672 cases diagnosed up to February 11, 2020. Of these, ~1% were asymptomatic, and ~80% were classed as "mild".(33)

Another study looked at clinical characteristics in COVID-19 positive close contacts of COVID-19 patients. Approximately 30% of those COVID-19 positive close contacts never developed any symptoms or changes on chest CT scans. The remainder showed changes on CT, but ~20% reportedly developed symptoms during their hospital course, none of them developed severe disease. This suggests that a high percentage of COVID-19 carriers are asymptomatic.(34)

In the Chinese population, the median age of the COVID-19 patients was 47 years; 41.9% of the patients were female. (35)

Children seem to be relatively unaffected by this virus, or indeed other closely-related coronaviruses, with large cohort studies reporting that 1–2% of COVID-19 patients are children. However, there have been cases of critically-ill children with infants under 12 months likely to be more seriously affected. A very low number of pediatric deaths has been reported. In children, male gender does not seem to be a risk factor. The incubation period has been reported to be shorter than in adults, at about two days.(36)

NB: it is important to appreciate that the known epidemiological parameters of any new disease are likely to change as larger cohorts of infected people are studied, although this will only to some extent reflect a true change in the underlying reality of disease activity (as a disease is studied and understood humans will be simultaneously changing their behaviors to alter transmission or prevalence patterns).

History and etymology

The first mention in the medical press about the emerging infection was in the British Medical Journal (BMJ) on January 8, 2020 in a news article, which reported "outbreak of pneumonia of unknown cause in Wuhan, China, has prompted authorities in neighboring Hong Kong, Macau, and Taiwan to step up border surveillance, amid fears that it could signal the emergence of a new and serious threat to public health".(37) On January 9, 2020, the World Health Organization confirmed that SARS-CoV-2 was the cause of the new disease.(38)

The first scientific article about the new disease, initially termed 2019–new coronavirus (2019–nCoV) by the World Health Organization (WHO), was published in the Journal of Medical Virology on January 16, 2020.(39)

On January 13, 2020, the first confirmed case outside China was diagnosed, a Chinese tourist in Thailand.(40) On January 20, the first infected person in the United States was confirmed to be a man who had recently returned from Wuhan.(41) The infection was declared a Public Health Emergency of International Concern (PHEIC) on January 30, 2020 by the WHO.(42) On February 28, 2020, the WHO increased the global risk assessment of COVID-19 to "very high".(43) On March 11, 2020, COVID-19 was declared a pandemic by the WHO.(26)

On March 27, 2020, the USA surpassed China as the country with the most confirmed cases.(44) The number of confirmed cases globally exceeded one million on April 3, 2020. The number of global deaths surpassed 56,000.(45)

Clinical presentation

COVID-19 typically presents with systemic and/or respiratory manifestations. Some individuals infected with SARS-CoV-2 are asymptomatic and can act as carriers.(34) Some also experience mild gastrointestinal or cardiovascular symptoms, although these are much less common. The full spectrum of clinical manifestation of COVID-19 remains to be determined. Symptoms and signs are non-specific:(46,47)

- Common: fever (85–90%), cough (65–70%), fatigue (35–40%), sputum production (30–35%) and shortness of breath (15–20%);
- Less common: myalgia/arthralgia (10–15%), headaches (10–15%), sore throat (10–15%), chills (10–12%) and pleuritic pain,
- Rare: nausea, vomiting, nasal congestion (<10%), diarrhea (<5%), palpitations and chest tightness.(48)

COVID-19 sufferers have reported high rates of disturbances of smell and taste, including anosmia, hyposmia, ageusia and dysgeusia. The numbers of patients affected vary and current evidence points more towards a non-neurological cause of the olfactory dysfunction.(49)

Various reports suggest patients with the disease may have symptoms of conjunctivitis, and those affected, may have positive viral PCR in their conjunctival fluid.(50,51)

A recent report suggests that cutaneous lesions may also be seen, similar to many other viral infections. In a cohort of 88 patients, 20% developed skin disease, most commonly an erythematous rash. Most of the skin abnormalities were self-limited, resolving in a few days.(52)

The clinical presentation in children with COVID-19 is milder than in adults. Symptoms are similar to any acute chest infection, encompassing most commonly pyrexia, dry cough, sore throat, sneezing, myalgia and lethargy. Wheezing has also been noted. Other less common (<10%) symptoms in children included diarrhea, lethargy, rhinorrhea and vomiting,(53)

Risk factors for severe illness or poor outcome:(54)[4]
• General: old age, people in a long-term care facility or nursing home. male gender;
• Comorbidities: cardiovascular disease, diabetes mellitus, hypertension, chronic respiratory disease, e.g. COPD, cancer and immunosuppression
• Patient condition and laboratory values at hospital admission: high sequential organ failure assessment (SOFA) score, D-dimer levels greater than 1µg/mL, elevated levels of IL-6, troponin I, lactate dehydrogenase and lymphopenia.

Diagnosis

The definitive test for SARS-CoV-2 is the real-time reverse transcriptase-polymerase chain reaction (RT-PCR) test. It is believed to be highly specific, but with sensitivity reported as low as 60–70% and as high as 95–97%.(55,56) Thus, false negatives are a real clinical problem, and several negative tests might be required in a single case to be confident about excluding the disease.(57)
Multiple radiological organizations and learned societies have stated that CT should not be relied upon as a diagnostic/screening tool for COVID-19. On March 16, 2020, an American-Singaporean panel published that CT findings were not part of the diagnostic criteria for COVID-19. However, CT findings have been used as a surrogate diagnostic test by some.(56)

Markers

The most common ancillary laboratory findings in a study of 138 hospitalized patients were the following: lymphopenia (70.3%), prolonged prothrombin time (58%), and elevated lactate dehydrogenase (39.9%).(58)
Mild elevations of inflammatory markers (CRP and ESR) and D-dimer are also seen

Complications

In one of the largest studies of hospitalized patients, reviewing 1,099 individuals across China, the admission rate to the intensive care unit (ICU) was 5%. In this same study, 6% of all patients required ventilation, whether invasive or non-invasive. ICU patients tend to be older with more comorbidities.(59)
Commonly reported sequelae are: acute respiratory distress syndrome (ARDS) ~22.5% (range 17–29%); acute cardiac injury (elevated troponin levels, myocardial ischemia.); secondary infections, e.g. bacterial pneumonia; sepsis; acute kidney injury (AKI); multiorgan failure.(27)
In a small subgroup of severe ICU cases, a secondary hemophagocytic lymphohistiocytosis (a cytokine storm syndrome) was observed.(60)

Etiology

On 9 January 2020, the World Health Organization (WHO) confirmed that SARS-CoV-2 was the cause of COVID-19 (2019-nCoV was the name of the virus at that time).(38) It is a member of the Betacoronavirus genus, one of the genera of the Coronaviridae family of viruses. Coronaviruses are enveloped single-stranded RNA viruses that are found in humans, mammals and birds. These viruses are responsible for pulmonary, hepatic, CNS, and intestinal disease.(13)

As with many human infections, SARS-CoV-2 is zoonotic. The closest animal coronavirus by genetic sequence is a bat coronavirus, and this is the likely ultimate origin of the virus. The disease was thought to be transmitted by snakes and pangolins are also considered possible intermediate hosts.(61)

Pathophysiology

The SARS-CoV-2 virus, like the closely-related MERS and SARS coronaviruses, carries out its cellular entry via attachment of its virion spike protein (a.k.a. S protein) to the angiotensin-converting enzyme 2 (ACE 2) receptor. This receptor is commonly found on alveolar cells of the lung epithelium, underlying the development of respiratory symptoms as the commonest presentation of COVID-19. It is thought that the mediation of the less common cardiovascular effects is also via the same ACE-2 receptor, which is also commonly expressed on the cells of the cardiovascular system.(62)

Transmission

Although originating from animals, COVID-19 is not considered a direct zoonosis as its transmission is now primarily human-to-human. It is primarily transmitted in a similar way to the common cold, via contact with droplets of infected individuals' upper respiratory tract secretions, e.g. from sneezing or coughing.

A recent Bayesian regression model has found that aerosol and fomite transmission are plausible. Orofecal spread was seen with the SARS epidemic, and although it remains unclear if SARS-CoV-2 can be transmitted in this way, there is some evidence for it.(63)
A recently published cohort study (March 26, 2020) could not rule out the possibility of vertical transmission with 9% of neonates (n=3/33) developing an early onset SARS-CoV-2 infection despite strict infection control measures during delivery.(64) However, a retrospective study of nine pregnant patients infected by SARS-CoV-2 did not show any evidence of vertical/intrauterine transmission.(65) A recently published (March 20, 2020) guidance from a joint Chinese-American consensus panel stated that it remains unclear if vertical transmission can occur.(66)

Imaging indications

The threshold for the imaging of patients with potential/confirmed COVID-19 demonstrates a degree of variation globally due to local resources, the published guidelines of individual learned bodies and sociocultural approaches to imaging.
According to a Fleischner Society consensus statement published on April 7, 2020:(67)

• Imaging is not indicated in patients with suspected COVID-19 and mild clinical features unless they are at risk for disease progression.
• Imaging is indicated in a patient with COVID-19 and worsening respiratory status.
• In a resource-constrained environment, imaging is indicated for medical triage of patients with suspected COVID-19 who present with moderate-severe clinical features and a high pretest probability of the disease.

Radiographic features

The primary findings of COVID-19 on chest radiograph and CT are those of atypical pneumonia (68) or organizing pneumonia.(69)

Imaging has limited sensitivity for COVID-19, as up to 18% demonstrate normal chest radiographs or CT when mild or early in the disease course, but this decreases to 3% in severe disease.(59) Bilateral and/or multilobar involvement is common.(70)

Plain radiograph

Although less sensitive than chest CT, chest radiography is typically the first-line imaging modality used for patients with suspected COVID-19.(71) For ease of decontamination, use of portable radiography units is preferred.(72)
Chest radiographs may be normal in early or mild disease. Of patients with COVID-19 requiring hospitalization, 69% had an abnormal chest radiograph at the initial time of admission, and 80% had radiographic abnormalities sometime during hospitalization. Findings are most extensive about 10–12 days after symptom onset.(71)
The most frequent findings are airspace opacities, whether described as consolidation or, less commonly, GGO.(71,73) The distribution is most often bilateral, peripheral, and lower zone predominant. In contrast to parenchymal abnormalities, pleural effusion is rare (3%).(73)

Tomography

The primary findings on CT in adult patients have been reported as: ground-glass opacities (GGO), bilateral, subpleural, peripheral; crazy paving appearance (GGOs and inter-/intra-lobular septal thickening); air space consolidation; bronchovascular thickening in the lesion; traction bronchiectasis.(74)
The ground-glass and/or consolidative opacities are usually bilateral, peripheral, and basal in distribution.
A retrospective study of 112 patients found 54% of asymptomatic patients had pneumonic changes on CT.(75)
Some papers suggest that CT has a sensitivity that could justify its use in early imaging in the acute setting in select cases. Yet its use as a primary screening tool is currently discouraged, not least because these studies tended to suffer from selection bias. In a recent investigation, these chest CT findings had the highest discriminatory value ($p<0.001$): peripheral distribution, bronchovascular thickening (in lesions).(76). (Figures 3 and 4)

Atypical CT findings(73)
These findings only seen in a small minority of patients should raise concern for superadded bacterial pneumonia or other diagnoses: mediastinal lymphadenopathy, pleural effusions: may occur as a complication of COVID-19, multiple tiny pulmonary nodules (unlike many other types of viral pneumonia), tree-in-bud, pneumothorax cavitation.

Temporal CT changes(77)
Four stages have been described on CT: *1-early/initial stage* (0–4 days), normal CT or GGO, only up to half of patients have normal CT scans within two days of symptom onset; *2- progressive stage* (5–8 days), increased GGO and crazy paving appearance; *3- peak stage* (9–13 days), and *4- consolidation; absorption stage* (>14 days, with an improvement in the disease course, "fibrous stripes" appear and the abnormalities resolve at one month and beyond,

Pediatric CT
In a small study of five children that had been admitted to

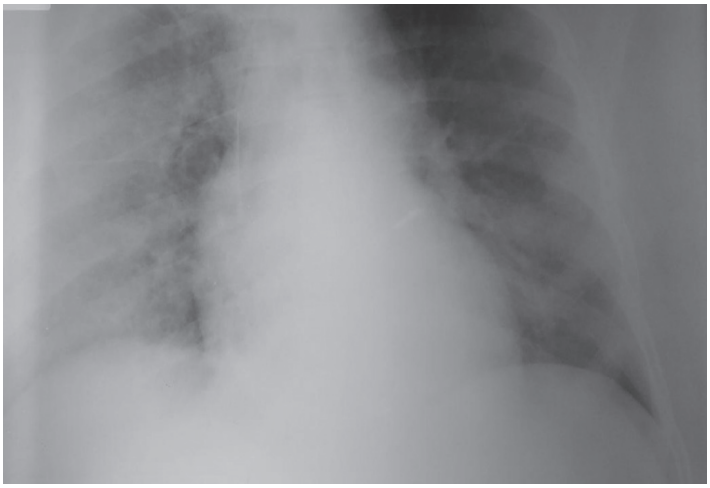

Figure 1. Belizean patient. Portable x ray. Extensive air space opacities affecting the right lung and scattered patchy areas in the left lower pulmonary lobe.

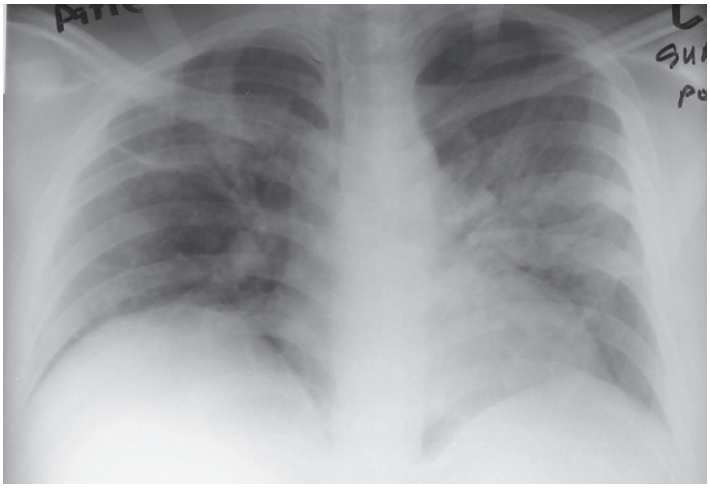

Figure 2. Belizean patient. Bilateral diffuse air space consolidation with predominance on the left lung. Laminar atelectasis centered in the right upper lobe.

hospital with positive COVID-19 RT-PCR tests and who had CT chest performed, only three children had abnormalities. The main abnormality was bilateral patchy ground-glass opacities, similar to the appearances in adults, but less florid, and in all three cases the opacities resolved as they clinically recovered.(78)

On 18 March 2020, the details of a much larger cohort of 171 children with confirmed COVID-19, and evaluated in a hospital setting was published as a letter in the New England Journal of Medicine. Ground-glass opacities were seen in one-third of the total, whereas almost 16% of children had no imaging features of pneumonia.(79)

Treatment

No specific treatment or vaccine exists for COVID-19 (April 2020). Therefore, resources have been concentrated on public health measures to prevent further interhuman transmission of the virus. This has required a multipronged approach and for individuals includes meticulous personal hygiene, the avoidance of large crowds/crowded environments and where necessary, self-isolation.(80)

In healthcare facilities, concerted efforts are required to effect rapid diagnosis, quarantine infected cases and provide effective supportive therapies. This will encompass empirical treatments with antibiotics, antivirals, and supportive measures. Mechanical ventilation and extracorporeal membrane oxygenation (ECMO) have also been used where clinically necessary.

Antiviral therapy

Whilst specific antiviral therapies for SARS-2-CoV do not currently exist, the combination of the protease inhibitors, ritonavir, and lopinavir, or a triple combination of these antiviral agents with the addition of ribavirin, showed some success in the treatment of SARS, and early reports suggested similar efficacy in the treatment of COVID-19. However, a more recent randomized, controlled open-label trial failed to demonstrate any added benefit of lopinavir-ritonavir combination therapy.(81)

Remdesivir, a drug originally developed to treat Ebola virus and shown to be effective against MERS-CoV and SARS-CoV, showed promising in vitro results against SARS-CoV-2 and is undergoing phase III trials. Other antivirals in phase III trials include oseltamivir, ASC09F (HIV protease inhibitor), lopinavir, ritonavir, darunavir, and cobicistat.(82)

Early reports demonstrated that treatment with two antimalarial drugs, chloroquine, and its close chemical derivative, hydroxychloroquine, have a beneficial effect on the clinical outcome, and it was also shown that they demonstrate anti-SARS CoV-2 activity in vitro. This was further corroborated by a recent open-label, randomized clinical trial, which demonstrated a significant reduction of viral carriage, and a lower average carrying duration in patients treated with hydroxychloroquine. Furthermore, a combination with the antibiotic azithromycin resulted in a synergistic effect.(83)

Vaccines

The primary target in developing coronavirus vaccines has been the spike protein (S protein) which is on the surface of the virion particle, and in vivo is the most important antigen for triggering an immune response.(84)
Vaccines for the coronaviruses have been under development since the SARS outbreak, but none are yet available for humans. A phase I trial in humans of a potential vaccine against MERS-CoV has already been performed in the UK.(85)

NSAIDs

Emerging expert opinion is that non-steroidal anti-inflammatory drugs (NSAIDs) are relatively contraindicated in those with COVID-19. This is based upon several strands of "evidence":(86)

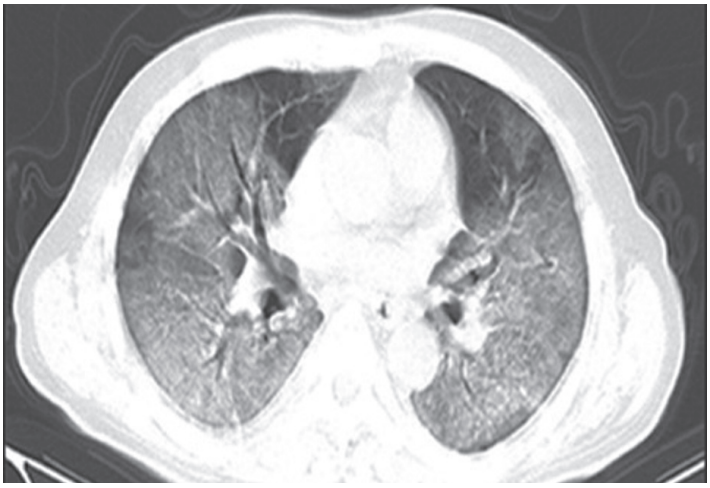

Figure 3. Belizean patient confirmed with COVID-19. Axial CT image. Extensive bilateral basilar ground glass opacity (GGO) associated with bronchovascular thickening.

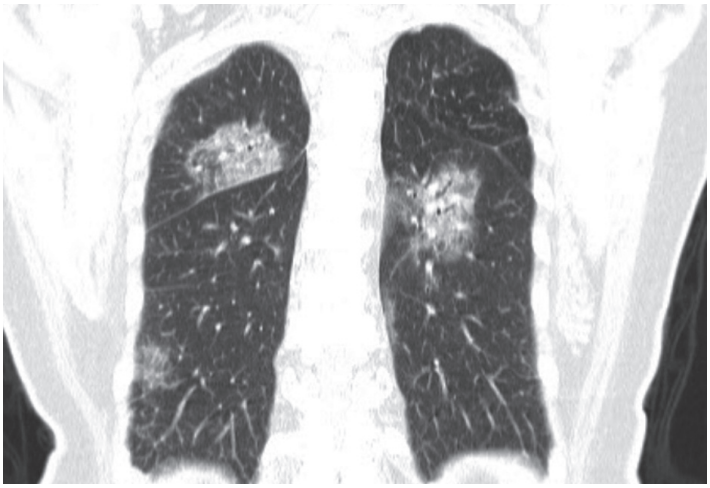

Figure 4. Belizean patient confirmed with COVID-19. Coronal reformatted CT image. Bilateral patchy areas of ground glass opacity (GGO) with bronchovascular thickening within the lesions.

• Since 2019 the French government National Agency for the Safety of Medicines and Health Products has advised against the routine use of NSAIDs as antipyretic;
• Previous research has shown that NSAIDs may suppress the immune system;
• anecdotal reports from France suggest that young patients on NSAIDs, otherwise previously fit and well, developed more severe COVID-19 symptoms.
However, it is important to note that there is currently (March 2020) no published scientific evidence showing that NSAIDs increase the risk of developing COVID-19 or worsen established disease. Also, at least one report shows antiviral activity by indomethacin (an NSAID) against SARS-CoV.(87)

Características radiográficas y de tomografía computarizada de la neumonía viral. Una breve descripción con énfasis en el coronavirus.

Resumen

Los virus son las causas más comunes de infección respiratoria y los agentes causantes de infecciones del tracto respiratorio inferior, que varían según la edad y la inmunidad del paciente. Los hallazgos por imagenología en neumonía viral son diversos y se superponen con los de otras infecciones no virales y afecciones inflamatorias. Los resultados tomográficos de la neumonía viral son variados y pueden verse afectados por el estado inmune del huésped y la fisiopatología subyacente del patógeno viral. La coinfección con bacterias es frecuente y la identificación de los patógenos virales subyacentes no siempre es fácil. Hay una serie de indicadores para identificar patógenos virales sobre la base de patrones de imágenes. Si bien no todos los casos se manifiestan con patrones típicos, la mayoría de los patrones de neumonía viral presentan similitudes en función de la familia viral. Aunque no se pueda lograr un diagnóstico definitivo sobre la base de las características de las imágenes solamente, el reconocimiento de los patrones de neumonía viral puede ayudar a diferenciar los patógenos virales.
El objetivo de esta revisión fue describir los diagnósticos diferenciales por imagenología de los patógenos en las primeras etapas de la infección en función de los patrones de imagen de la neumonía y sugerir el pronóstico posible.
El diagnóstico precoz de una neumonía como viral, utilizando pruebas como los estudios radiológicos y los análisis de sangre o serológicos, reduciría el uso innecesario de antibióticos y podría mejorar el curso clínico. Además, el diagnóstico rápido puede conducir a un control temprano de la transmisión potencial, disminuyendo así los costos generales del tratamiento.

Palabras clave

Neumonía viral, coronaviridae, técnicas de imagenología.

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