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Research Article

Imaging the Impact: Computed Tomography Thorax in COVID-19 - A Comprehensive Review and Clinical Analysis

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Abstract

This comprehensive review and clinical analysis explore the pivotal role of thorax computed tomography (CT) in the context of COVID-19. As the world grapples with the ongoing pandemic, the need for effective diagnostic tools and management strategies remains paramount. This review meticulously examines the impact of thorax CT imaging on the understanding, diagnosis, and clinical management of COVID-19. The review encompasses an extensive analysis of the existing literature, shedding light on the nuances of thorax CT findings in COVID-19 patients. It explores the characteristic imaging features, such as ground-glass opacities, consolidations, and other pulmonary abnormalities, providing insights into the pathophysiology of the disease. Furthermore, the clinical analysis component synthesizes data from diverse studies to elucidate the diagnostic accuracy and sensitivity of thorax CT, particularly in cases where molecular testing may present challenges. The review also delves into the role of thorax CT in early detection, risk stratification, and longitudinal monitoring of patients with COVID-19, offering valuable perspectives for healthcare professionals. Importantly, considerations of radiation exposure and ethical use of thorax CT are addressed, emphasizing the judicious integration of imaging into clinical practice. The article concludes with practical recommendations for optimizing the utility of thorax CT in the broader context of COVID-19 diagnosis and patient care.

Keywords

Thorax Computed Tomography Imaging, SARS-CoV-2, COVID-19, Diagnostic Imaging, Ground-Glass Opacities GGO

1. Introduction

The infectious ailment known as Coronavirus Disease 2019 (COVID-19) is induced by the virus named Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2 [1, 2]. The novel coronavirus was named as the severe acute respiratory syndrome coronavirus-2 (SARS-CoV- 2, 2019-nCoV) due to its high homology (~80%) to SARS- CoV, which caused acute respiratory distress syndrome (ARDS) and high mortality during 2002–2003 [3, 4]. This manuscript focuses on the significance of an integrated Computed Tomography (CT) approach in diagnosing, monitoring, and predicting outcomes for COVID-19 patients. The initial instances of COVID-19 in humans were initially disclosed by authorities in Wuhan, China, in December of 2019 [5-7]. The virus was transmittable between humans and the disease rapidly spread throughout the world and was declared a pandemic by the World Health Organization (WHO) on March 12, 2020 [8-10]. As of May 2022, it had caused more than 500 million infections and more than 6 million deaths worldwide [11, 12]. There were no specific treatments or vaccines for COVID-19. However, numerous ongoing clinical trials were evaluating

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potential treatments, and various efforts were underway to develop vaccines [13, 14]. The pandemic, fueled by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), poses an unparalleled challenge in the search for effective preventive measures and treatments. Worldwide, the impact of the disease varies, with patients exhibiting a range of symptoms such as fever, cough, sore throat, breathlessness, fatigue, and malaise. Managing the illness involves general and symptomatic treatments, antiviral drugs, oxygen therapy, and harnessing the immune system. SARS-CoV-2 virus primarily affects the respiratory system, although other organ systems are also involved. Lower respiratory tract infection related symptoms including fever, dry cough and dyspnea were reported in the initial case series from Wuhan, China [15, 16]. Early recognition of potential cases was paramount to promptly isolating suspected individuals from confirmed COVID-19 cases, mitigating the risk of further transmission to both patients and healthcare personnel. The rising death toll had prompted numerous countries to implement social distancing measures and lockdowns. Computed Tomography (CT) had emerged as the primary imaging modality for suspected cases of COVID-19 pneumonia. In instances where there was high suspicion of the virus, CT scans have proven to be effective, even in cases where Reverse Transcription Polymerase Chain Reaction (RT-PCR) results were negative. The versatility of CT extends beyond initial diagnosis; it was also valuable for monitoring patients throughout the course of treatment. This highlights the critical role of CT in providing a comprehensive and reliable assessment in the context of COVID-19, aiding in both diagnosis and ongoing patient management [17, 18]. Although reverse transcription polymerase chain reaction (RT-PCR) was the required laboratory test to confirm the diagnosis of COVID-19, non-contrast chest CT was considered a valid tool in the initial assessment of this patient population. Nevertheless, at that time, there was no consensus on its role within the major Professional Scientific Societies. For example, in China, during the early phase of the outbreak, CT was widely used as a supporting tool in the diagnosis of COVID-19 [19]. Early in the outbreak, especially in regions like China, CT scans played a crucial role as a complementary diagnostic tool alongside the standard reverse transcription polymerase chain reaction (RT- PCR) test. CT scans were instrumental in detecting characteristic pulmonary abnormalities associated with COVID-19, such as ground-glass opacities, consolidations, and bilateral involvement of the lungs. Computed Tomography (CT) played various roles in the context of COVID-19. It served a pivotal role in diagnosing and assessing the severity of the disease by detecting characteristic pneumonia patterns and providing insights into the extent of lung involvement. Additionally, CT scans were utilized for triaging and prioritizing patients, especially in high-volume situations, aiding in the rapid identification of severe cases requiring immediate attention. They also played a role in follow-up and monitoring, enabling healthcare professionals to track disease progression and assess recovery post-treatment. Furthermore, CT imaging significantly contributed to enhancing our understanding of COVID-19's pathophysiology and typical radiological features. Despite these contributions, it's essential to acknowledge the limitations, such as CT not being a definitive diagnostic test, with the gold standard being the RT-PCR test. Moreover, the associated radiation exposure necessitated caution, and the interpretation of CT findings should consider the broader clinical context, recognizing that asymptomatic or mild cases may not have warranted a CT scan.

Classification of COVID-19 Patients: A classification table is provided, categorizing COVID-19 patients into asymptomatic, mild, moderate, severe, and critical, based on clinical symptoms and imaging findings. This classification aids in understanding the spectrum of disease severity and guides clinical management.

Table 1. *Classification of COVID-19 patients.*

Asymptomatic	**COVID nucleic acid test positive. Without any clinical symptoms and signs and the chest imaging is normal**
Mild	Mild symptoms of an acute upper respiratory tract infection include fever, fatigue, myalgia, cough, sore throat, runny nose, and sneezing. Alternatively, individuals may experience digestive symptoms such as nausea, vomiting, abdominal pain, and diarrhoea.
Moderate	characterized by recurring fever and cough, without evident hypoxemia, as confirmed by chest CT scans revealing lesions
Severe	Pneumonia a accompanied by low oxygen levels ($SpO_2 < 92\%$)
Critical	Acute respiratory distress syndrome (ARDS), may have shock, encephalopathy, myocardial injury, heart failure, coagulation dysfunction and acute kidney injury.

2. Pathophysiology of COVID-19

The genome of coronaviruses consists of a positive-sense single-stranded RNA of approximately 30 kb. [20]. COVID-19, caused by the SARS-CoV-2 virus, primarily affects the respiratory system, but it can also have systemic effects. The pathophysiology of COVID-19 involves a complex interplay of viral invasion, immune response, and inflammatory processes. Here's an overview:

Viral Entry and Replication:

The SARS-CoV-2 virus primarily enters the body through respiratory droplets when an infected person coughs, sneezes, or talks. It can also spread by touching a surface with the virus and then touching the face.

The virus primarily targets cells with angiotensin- converting enzyme 2 (ACE2) receptors, which are found in the respiratory tract, especially in the alveoli of the lungs.

Respiratory Tract Infection:

1. After entering the respiratory tract, the virus infects and damages epithelial cells lining the airways and alveoli, leading to inflammation.
2. The viral replication cycle causes cell death and shedding, contributing to airway obstruction.

Immune Response:

1. The immune system responds to the infection by activating both innate and adaptive immune responses.
2. Innate immune cells such as macrophages and neutrophils are recruited to the site of infection to eliminate the virus.
3. In some cases, an exaggerated immune response can lead to a cytokine storm, where the body produces excessive amounts of inflammatory cytokines, causing widespread inflammation and tissue damage.

Inflammatory Response:

The release of cytokines, particularly interleukin-6 (IL-6), can lead to an inflammatory cascade and contribute to the symptoms of COVID-19, such as fever, fatigue, and muscle aches.

In severe cases, the inflammatory response can lead to acute respiratory distress syndrome (ARDS), a condition characterized by severe lung inflammation and difficulty breathing.

Vascular and Coagulation Effects:

COVID-19 has been associated with vascular complications, including endothelial dysfunction and blood clot formation.

The virus can directly infect endothelial cells, leading to inflammation and a prothrombotic state, increasing the risk of blood clot formation.

Multi-organ Involvement:

While the respiratory system is the primary target, COVID-19 can affect multiple organs, including the heart, kidneys, liver, and nervous system.

Organ dysfunction may result from direct viral invasion, immune response, or secondary effects of inflammation and clot formation.

Long COVID:

Some individuals experience persistent symptoms long after the acute infection has resolved, a condition known as "long COVID" or post-acute sequelae of SARS-CoV-2 infection (PASC). The exact mechanisms behind long COVID are not fully understood and may involve a combination of immune dysregulation and lingering viral particles

CT features in COVID-19 pneumonia:

The CT scans of individuals with COVID-19 pneumonia often reveal signs of acute damage to the interstitial lung tissue, along with corresponding changes in the lung parenchyma. These alterations are a consequence of the cytokine storm induced by the virus's internalization into the pneumocystis' [21-23].

3. Conclusion

The ongoing COVID-19 pandemic had been a pressing global concern, impacting people across the world. In the absence of definitive therapeutic interventions, the approach at that time had focused on mitigating the spread of the virus and offering supportive care to affected individuals. There had been a critical demand for the development of specific therapies. The examination of variations in how pediatric and adult populations had responded to the virus could have guided the design of immune-based treatments. Common chest CT features in COVID-19 had included ground-glass opacities, vascular enlargement, bilateral abnormalities, lower lobe involvement, and a posterior preference. The appearance of COVID-19 on chest CT had evolved predictably over time. Asymptomatic individuals with SARS-CoV-2 infection had often had normal chest CT results, and a notable proportion of symptomatic COVID-19 patients had also had normal chest CT scans. However, lung abnormalities observed on chest CT had not been specific to COVID-19. Therefore, chest CT alone should not have been used to definitively diagnose or rule out COVID-19; RT-PCR test results had remained the diagnostic standard.

Despite its limitations, chest CT could have served as a rapid triaging tool in resource-limited settings with a high prevalence of COVID-19, particularly for patients with moderate to severe respiratory symptoms. Additionally, chest CT could have been considered if an alternative diagnosis had been suspected. Incidental findings of typical or indeterminate features of COVID-19 during CT scans for other reasons should have been promptly communicated to the referring physician using standardized reporting guidelines.

Furthermore, chest CT could have been valuable in evaluating patients with clinical deterioration for COVID-19 progression or secondary cardiopulmonary complications such as acute respiratory distress syndrome (ARDS), pulmonary embolism (PE), superimposed pneumonia, or heart failure. The prognostic role of chest CT in COVID-19 would have required further investigation through future studies.

Panel a - Frontal chest X-ray demonstrating subtle, bilateral opacities mainly involving the mid and lower zones of the lungs. Panels b, c - Non-contrast chest CT scan showing multiple ground glass opacities and “crazy-paving” pattern (arrow - panel b) in the right middle and lower lobes. Panels d, e, f - Non-contrast chest CT scan documenting increased extent of GGOs mixed with new areas of consolidation in the lower pulmonary lobes. An air Bronchogram is visible in the right lower lobe (arrow - panel e). Panels g, h, i - Contrast CT scan showing a lung abscess containing an air-fluid level in the superior segment of the left upper lobe (arrow - panel h). GGOs and consolidative areas are significantly decreased compared to the previous CT scan. Panels j, k - 3D reconstructions of the lung abscess. Panels l, m, n - Non-contrast chest CT demonstrating the lung abscess (arrow - panel m) and the near resolution of the parenchymal abnormalities.

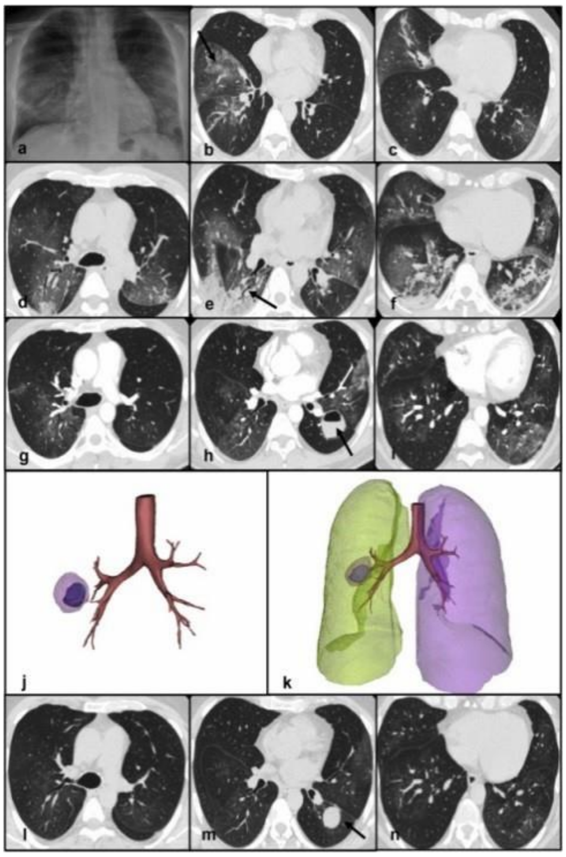

Figure 1. *COVID 19 Cases.*

Abbreviations

COVID-19	Coronavirus Disease
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus-2
PCR	Polymerase Chain Reaction
RT-PCR	Real-Time Polymerase Chain Reaction
WHO	World Health Organization
ARDS	Acute Respiratory Distress Syndrome
ACS	Acute Coronary Syndrome
CT	Computed Tomography
PPE	Personal Protective Equipment
GGO	Ground Glass Opacities
CDC	Centers for Disease Control and Prevention
mRNA	Messenger RNA
MERS	Middle East Respiratory Syndrome

Author Contributions

Yasmeena Maqbool is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

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