

Most commonly used imaging methods for the detection of COVID-19. Literature review

Métodos de diagnóstico Imagenológico más empleados para la detección de la COVID-19. Una revisión de la literatura

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ABSTRACT

The aim of this study is to comprehensively review the literature on the imaging techniques most commonly used to diagnose COVID-19. In the present work, a literature review was conducted, performing a reflexive critical analysis of the theoretical content of different updated scientific articles, obtained from PubMed, Cochrane databases. Different inclusion criteria were determined as year of publication between 2017 and 2023, scientific articles in English and Spanish, whose content had to be related to the pre-established topic. The findings show that chest computed tomography, thoracic radiography and lung ultrasound are the most commonly used imaging methods for the detection of coronavirus disease. It is concluded that three imaging techniques frequently used for the detection of COVID-19 were analyzed. Among them are thoracic radiography, whose devices are easy to

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handle and disinfect; its price is accessible and stands out for its careful emission of X-rays in the part of the body to be examined; computed tomography, which allows an early diagnosis by evaluating pulmonary involvement and an assessment of the response to treatment, is sophisticated and provides detailed images to improve the results; and finally, pulmonary ultrasound, which stands out for its versatility.

Keywords: COVID-19, Diagnosis, Imaging, Tomography, Radiography, Ultrasonography.

RESUMEN

El estudio tiene como objetivo examinar exhaustivamente la literatura sobre las técnicas de diagnóstico por imágenes más utilizadas para diagnosticar la COVID-19. En el presente trabajo se realizó una revisión bibliográfica, efectuando un análisis crítico reflexivo del contenido teórico de diferentes artículos científicos actualizados, obtenidos en bases de datos PubMed, Cochrane. Se determinaron distintos criterios de inclusión como año de publicación entre el 2017 y 2023, artículos científicos en inglés y español, cuyo contenido debían tener relación con la temática preestablecida. Los hallazgos permiten evidenciar que la tomografía computarizada de tórax, la radiografía torácica y la ecografía pulmonar son los métodos imagenológicos más utilizados para la detección de la enfermedad por coronavirus. Se concluye que tres técnicas imagenológicas frecuentemente son utilizadas para la detección de COVID-19 fueron analizadas. Entre ellas se encuentra la radiografía torácica, cuyos aparatos son fácil de manejo y desinfectar; su precio es accesible y se destaca por su emisión cuidadosa de rayos X en la parte del cuerpo han de examinar; la tomografía computarizada, que permite un diagnóstico temprano al evaluar la afectación pulmonar y una valoración de la respuesta al tratamiento, es sofisticada y proporcionando imágenes detalladas para mejorar los resultados; y finalmente, la ecografía pulmonar, que se destaca por su versatilidad.

Palabras Clave: COVID-19, Diagnóstico, Imagenología, Tomografía, Radiografía, Ecografía.

INTRODUCTION

Since December 2019, there have been documented cases of a new form of pneumonia that emerged in Wuhan, Hubei Province, China. Subsequent investigations identified a new strain of coronavirus, classified as COVID-19, derived from “corona + virus + disease”. This virus, which belongs to the beta-coronavirus group, was also given the name severe acute respiratory syndrome (SARS-CoV-2) by the International Committee on Taxonomy of Viruses (ICTV). The isolated virus belongs to the subfamily Coronavirinae, which comprises four genera: Alphacoronavirinae, Betacoronavirinae and Deltacoronavirinae (Aragón-Nogales et al., 2019).

The virus causes a mutation process due to its intrinsic nature and host factors, leading to symptomatic or asymptomatic symptomatology, which represents a diagnostic challenge for health professionals (Delgado et al., 2020; Rosón et al., 2020). The spread of the virus has been facilitated by its easy transmission through Flugge aerosols or microdroplets, which are expelled when coughing, talking, sneezing or breathing, and which initially affected Asian countries and subsequently spread to Europe and worldwide, with an estimated 2 million deaths. It is worth noting that this virus differs from SARS and MERS, which caused significant mortality rates in the past (Escamilla Llano et al., 2020; Aragón-Nogales et al., 2019; Sánchez-Oro et al., 2020).

Transmission occurs presymptomatically, with an incubation period of 14 days, although the mortality rate is lower compared to SARS-CoV or MERS-CoV. The virus has a relatively low mutation rate, but has evolved to enhance person-to-person transmission and replication rates. Therefore, efforts are directed to explore complementary methods, particularly imaging, to assess the impact of this disease on affected individuals (J. Antonio et al., 2020; Aragón-Nogales et al., 2019; Delgado et al., 2020). This review aims to comprehensively examine the literature on the imaging techniques most commonly used to diagnose COVID-19.

Coronaviruses represent a diverse family of viruses capable of causing disease in both humans and animals. Structurally, they exhibit a pleomorphic spherical shape ranging from 80 to 120 nanometers, with spike-like membrane glycoproteins forming a corona-shaped envelope on the surface and a nucleoprotein that protects the viral RNA from internal degradation. Viral replication is facilitated by nonstructural proteins such as helicase and RNA-dependent RNA polymerase, with key structural components including the spike glycoprotein (S), envelope (E), membrane (M), and nucleocapsid (N) (Bravo et al., 2018).

Virus replication is initiated by the activity of non-structural proteins such as helicase and RNA-dependent RNA polymerase, while at the structural level, notable components include the spike glycoprotein (S), envelope (E), membrane (M) and nucleocapsid (N). Through genetic analysis, several human coronaviruses, such as

HKU1, NL63, 229E and OC43, have been identified as causing mild respiratory disease. In contrast, some coronaviruses enter cells via endosomal or alternative routes and, after binding to specific host cell protein receptors (angiotensin-converting enzyme, dipeptidyl peptidase 4, aminopeptidase N and O-acetylsialic acid), release RNA and nucleocapsid into the cytoplasm, allowing viral transcription and replication, resulting in the production of new virions. These virions are then released, causing systemic alterations ranging from pneumonia to death in patients due to elevated levels of proinflammatory cytokines that aggravate the disease in different organs and systems (Chen et al., 2020; Kompatscher et al., 2021).

Clinical manifestations

The clinical presentation of COVID-19 is predominantly nonspecific and often resembles that of other conditions, making definitive diagnosis difficult. In particular, mortality and adverse outcomes are more common among persons with underlying comorbidities (50% to 75% of severe cases) and the elderly, with hospital mortality rates ranging from 4% to 11% and case fatality rates between 2% and 3%. The virus is spread mainly through aerosols and saliva droplets, which are generated during daily activities, resulting in a pathology characterized by specific features. According to Ibarra et al. (2020); Jin et al. (2020); Rosón et al. (2020) these characteristics are:

- Cough: approximately 59% of infected persons present a dry, irritating cough, with or without sputum production.
- Fever: about 90% of patients present fever; however, the severity may vary and some cases are asymptomatic.
- Fatigue: weakness and fatigue are observed in up to 69% of infected persons.
- Shortness of breath: 31% of patients report chest tightness and dyspnea.

It is important to note that COVID-19 can manifest asymptotically or with severe symptoms, including neurological manifestations such as headache, vomiting, nausea, diarrhea and abdominal pain. In addition, cardiovascular symptoms such as chest tightness, palpitations and mild pain in the extremities have been documented, as well as loss of smell and taste, ophthalmic symptoms such as conjunctivitis and skin rashes on hands and feet (Ibarra et al., 2020; Rosón et al., 2020).

Importance of imaging in the detection of COVID-19
In the midst of the COVID-19 pandemic, the importance of imaging analysis, which allows professionals to assess the evolution of internal changes due to this disease, has been highlighted. Imaging plays a crucial role in identifying patient complications such as pneumonia, lesions and lung damage. The worldwide application of imaging aims at diagnosing, monitoring various health abnormalities and supporting treatment efforts, leading to the establishment and maintenance of radiological services in several countries (Delgado et al., 2020; Jawerth, 2020).
Imaging methods used for the detection of COVID-19.

Thoracic Radiography

Currently, the prioritization of imaging modalities to diagnose COVID-19 depends on laboratory tests, clinical conditions of patients and availability of radiological equipment in healthcare facilities. Chest radiography (CXR), in particular, is noted for reducing the risk of infection among healthcare workers when caring for COVID-19-positive patients, especially in emergency situations. Chest radiography is critical in assessing lung tissue in patients with respiratory symptoms, as it aids in treatment decisions and disease management, especially in acute respiratory cases. In particular, chest radiographs offer advantages over computed tomography, such as lower radiation dose, accessibility, ease of use and portability, which improves the understanding of the characteristics of SARS.COV-2 infection (Jawerth, 2020; Navarro, 2020; Ortega Garcia, 2020).

Thoracic Computed Tomography

In the case of thoracic computed tomography, the equipment rotates around the patient and emits X-rays from different body angles. Specialized detectors capture the X-ray patterns, which are then processed by a computer to generate detailed 3D images of the thoracic region. Although more expensive and sophisticated than computed radiographs, chest CT machines provide comprehensive and valuable information. This imaging method is recognized for its accessibility and rapidity in detecting COVID-19, and offers high sensitivity in identifying pulmonary changes during the presymptomatic and early symptomatic stages.

Research has demonstrated the reliability and reproducibility of chest CT in detecting COVID-19-related lung disorders, positioning it as the leading imaging tool in current medical practice (Escamilla Llano et al., 2020; Gonzalez and Pieri, 2017; Jin et al., 2020; Mayanga-Sausa et al., 2020).

It has been observed that CT scans can yield negative results in the early symptomatic phase of COVID-19, so it is recommended that a negative CT scan should not be used to rule out the disease, especially in early stages.

Abnormal pulmonary findings have been observed in asymptomatic individuals, establishing a correlation between radiological findings and duration since symptom onset. The evolution of COVID-19-related lung abnormalities is classified into four distinct stages (Mayanga-Sausa et al., 2020; Rodriguez-Gonzalez, M Espinoza-Rosales, 2016; Yuan et al., 2020):

- Early stage (0-4 days after symptom onset): tarnished glass pattern predominates, with uni- or bilateral and multifocal involvement. It may show a rounded morphology.
- Progression phase (5-8 days): ground-glass involvement progresses rapidly in extent and becomes diffuse, diffuse, with multilobar involvement.

- Peak phase (9-13 days): maximum involvement is observed, with areas of ground glass that transform into consolidation.
- Resolution phase (>14 days): reabsorption of the consolidations manifests again as ground glass opacities that may be associated with bronchial dilatations with subpleural distortion.

Pulmonary Ultrasonography

In the context of COVID-19, lung ultrasound uses high-frequency sound waves interacting with an ultrasound device, emitting and receiving billions of sound waves per second to examine the lungs. These waves generate an echo when they come in contact with fluid, soft tissue or bone. The device can determine the distance and intensity of the echo, translating this data into real-time images.

Lung ultrasounds are described as cost-effective, easily accessible, portable, compact, easy to disinfect, deployable in ambulances, patient rooms or triage centers, and offer immediate dynamic visualization on a screen, facilitating rapid patient assessment by healthcare professionals (Accinelli et al., 2020; Wangüemert Pérez, 2021). Lung ultrasound represents a valuable modality for evaluating individuals with respiratory manifestations, as it allows effective visualization of pathology in the resulting images. This diagnostic approach involves ultrasound capture using a probe that penetrates to a specific depth, depending on the frequency of the probe and the target anatomical region.

It takes advantage of discrepancies in tissue propagation velocities to translate these variations into electrical signals that are displayed in varying shades of grayscale on a screen (Accinelli et al., 2020; Gutierrez et al., 2020). Although lung ultrasound (PE) has historically been considered inadequate due to poor air conduction of ultrasound, it has gained prominence over time. Especially in the context of COVID-19, PE has become a crucial diagnostic tool, allowing bedside evaluations to be performed with minimal delay.

This non-ionizing technique provides rapid insight into the state of the lung parenchyma, often within minutes, which contributes significantly to patient care during the pandemic (Jin et al., 2020; Wangüemert Pérez, 2021).

In addition, lung ultrasound is a vital tool for the accurate diagnosis and detection of lung diseases, facilitating informed decision making about patients' health status. Individuals with mild lung involvement or normal results can be discharged, while those with elevated lung risk should be hospitalized for appropriate intervention. Ultrasonographic observations include pleural line irregularities (100%), presence of B-lines and consolidation (64%) (Bravo et al., 2018; Stang, 2020).

MATERIALS AND METHODS

The study was qualitative, supported by a critical and reflective review of the literature. The literature search was non-systematic using specific keywords in databases such as PubMed/Medline and the Cochrane Library to identify relevant studies on COVID-19 imaging.

Priority was given to high-quality systematic reviews and critical analyses from authoritative sources, covering primary articles, reviews, randomized controlled trials, and research studies published in English and Spanish.

RESULTS

Dr. Elver Leguía clarifies that the identification of COVID 19 goes beyond mere symptoms such as cough, fever, headache and respiratory distress, which are discernible only through specific tests, such as RNA tests that analyze the genetic material of the virus. In addition, CT scans of the chest, by thoroughly evaluating the thoracic region, can more accurately identify pulmonary manifestations of coronavirus. Although accessible, rapid and highly sensitive, this diagnostic method may not yield optimal results during the early stages of symptom manifestation, which could lead to unexpected results.

Imaging techniques are time-consuming and require strict infection control protocols to mitigate the risks of viral transmission among healthcare workers. Accordingly, he advocates the initial use of ultrasound and radiography, noting that while radiographs may lack sensitivity for detecting disease markers, their portability facilitates disease diagnosis and follow-up. After highlighting the cost-effectiveness and ease of disinfection of electromagnetic devices, their ability to measure distances, calculate echo intensities, and translate data into descriptive images, all without ionizing radiation, is emphasized. However, Ying Hui argues that premature ejaculation is not universally recognized as a primary diagnostic tool due to air interference that impedes the clarity of ultrasound images (Mayanga, 2020).

In addition, Dr. Sayan Manna highlights the valuable insights provided by echocardiography and lung ultrasound, which can complement CT findings; however, caution should be exercised to safeguard patient welfare (Manna et al., 2020).

Regarding imaging technologies, Antonio et al. (2005) state that computed tomography and chest radiography are among the most prevalent modalities, with CT scans surpassing rXT in sensitivity. Despite its cost-effectiveness, accessibility and minimal health risks, rXt reveals alveolar, interstitial and alveolar interstitial opacities, whereas CT scans reveal a variety of findings, such as ground-glass opacities, reticular patterns, consolidations, halo signs, bronchial wall thickening and pulmonary fibrosis.

DISCUSSION

The Spanish Society of Emergency Radiology (SERAU) stresses the importance and use of the computed tomography diagnostic technique for the detection of COVID, particularly in hospitalized patients and when RT-PCR tests are not available. In contrast, the American College of Radiology (ACR) points out the high potential risk of contamination in imaging facilities associated with this method, and stresses the importance of taking precautionary measures to avoid shared and continuous use that could lead to harm. In contrast, the Spanish Society of Medical Radiology (SERAM) recommends minimizing the movement of patients with COVID-19 whenever possible, emphasizing the use of portable equipment. Finally, the Chilean Society of Radiology (SOCHRADI) suggests the application of CT scans to resolve uncertainties in cases of severe pneumonia, hospitalization, slow progression and cases of respiratory distress.

Jawerth (2020) the three techniques examined serve as complementary tests that allow systemic analysis of the impact of COVID-19 in the pulmonary and thoracic regions. While laboratory tests are accurate diagnostic tools for virus detection, imaging plays a crucial role not only in identifying and assessing pathology, but also in understanding its behavior. Consequently, X-ray devices are indispensable during this pandemic because of their light weight, ease of use, portability and simple decontamination procedures, which facilitate a thorough examination of lung tissue.

While alternative diagnostic approaches exist, such as molecular and serological tests for antigen detection, imaging modalities have proven to be essential in monitoring disease progression in infected individuals. Among these, chest radiography stands out as a viable option due to its affordability and availability and the efficacy of disinfecting equipment after use, while chest CT scanning is recommended for patients diagnosed with pneumonia by COVID-19 (Varadarajan et al., 2021).

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