International Journal of Advanced Research and Multidisciplinary Trends (IJARMT)
An International Open Access, Peer-Reviewed Refereed Journal
Impact Factor: 6.4 Website: https://ijarmt.com ISSN No.: 3048-9458

Low-Dose Chest CT in COVID-19: Diagnostic Performance, Radiation Safety, and Inter-Observer Variability—A Comprehensive Review

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Abstract

Background: The use of chest computed tomography (CT) for lung involvement monitoring, disease diagnosis, and severity assessment has expanded dramatically as a result of the COVID-19 epidemic. The need of optimizing radiation doses is highlighted by growing worries about the hazards associated with cumulative radiation exposure, even though chest CT is renowned for its great sensitivity in identifying lung abnormalities related to COVID-19. Although low-dose chest CT (LDCT) has become a viable substitute, further research is needed to fully understand its efficacy, radiation safety, and interpretation variability.

Aim : The goal of this review is to bring together the latest evidence on how well low-dose chest CT performs in diagnosing COVID-19, explore strategies for reducing radiation doses and ensuring safety, and examine how consistently different observers interpret LDCT results.

Methods: In order to do this, we used major medical databases to perform a thorough assessment of the literature, focusing on studies that examined low-dose and ultra-low-dose chest CT in COVID-19 patients. Imaging methods, radiation dose measurements, diagnostic accuracy, observer agreement, and standardized reporting systems were all covered in the articles we included. The results of observational research, comparative analyses, and consensus guidelines were all rigorously examined.

Results: Our findings demonstrate that utilizing radiation doses far lower than those of standard-dose CT, LDCT maintains a high degree of diagnostic accuracy for identifying frequent COVID-19 lung abnormalities, such as ground-glass opacities, consolidation, and bilateral peripheral involvement. Additionally, sophisticated reconstruction methods lower noise and enhance image quality. While there is modest agreement for more subtle findings such interlobular septal thickness and early fibrotic alterations, the majority of studies show excellent agreement among observers regarding significant CT features. To reduce interpretation variability, radiologists' experience and the use of standardized reporting systems, including CO-RADS and RSNA recommendations, are crucial.

Conclusion: Low-dose chest CT strikes a remarkable balance between radiation safety and diagnostic accuracy, making it a safe and useful imaging technique for evaluating COVID-19. We can further increase the trustworthiness of interpretations by regularly implementing dose-optimized protocols, organized reporting, and targeted training. These observations support the broader use of LDCT in routine clinical practice, particularly in high-volume and follow-up imaging scenarios.

Keywords: COVID-19; Low-dose chest CT; Radiation dose optimization; Diagnostic performance; Inter-observer variability; CO-RADS; RSNA guidelines

Introduction

Global diagnostic imaging practices have been significantly impacted by the COVID-19 epidemic. The gold standard for verifying SARS-CoV-2 infections is still reverse transcription polymerase chain reaction (RT-PCR), however difficulties with test availability, turnaround times, and the possibility of false negatives have brought attention to the necessity of imaging as a supplementary diagnostic technique. For patient triage, severity assessment, and illness progression tracking, chest computed tomography (CT) has demonstrated exceptionally high sensitivity in detecting lung involvement.

The COVID-19 pandemic has had a major impact on diagnostic imaging techniques worldwide. Reverse transcription polymerase chain reaction (RT-PCR) is still the gold standard for confirming SARS-CoV-2 infections, but issues with test availability, turnaround times, and the potential for false negatives have highlighted the need for imaging as an additional diagnostic method. Chest computed tomography (CT) has shown remarkably high sensitivity in identifying lung involvement for patient triage, severity evaluation, and illness progression tracking.

Low-dose chest CT (LDCT) techniques have become popular as a way to reduce radiation hazards. We can drastically lower radiation doses while maintaining high diagnostic picture quality thanks to technological developments like automatic tube current regulation, iterative reconstruction methods, and deep learning-based image reconstruction. Several studies have demonstrated that LDCT may identify common lung abnormalities linked to COVID-19 on par with standard-dose CT.

While there are clear benefits, there are still worries about image noise, the potential loss of fine details, and the variability in interpretation that comes with reducing doses. One major concern is inter-observer variability, which significantly affects how reliable and consistent CT readings are, especially in low-dose imaging scenarios. Differences in the experience and training of radiologists, along with how standardized reporting systems are used, can add to the inconsistencies in diagnoses. This thorough review aims to assess how well low-dose chest CT performs in diagnosing COVID-19, look into radiation safety and strategies for optimizing doses, and explore the variability in how different observers interpret LDCT results. By bringing together the latest evidence, this review hopes to offer practical insights for improving imaging protocols while ensuring that diagnostic accuracy and patient safety remain a top priority

Role of Chest CT in COVID-19

During the initial phases of the COVID-19 pandemic when testing capacity for viral detection and reverse transcription-polymerase chain reaction (RT-PCR) was limited or often yielded either delayed results or falsely negative results in some cases, CT of the chest played an important role in managing COVID-19 due to its high sensitivity to the pulmonary manifestations of this disease prior to RT-PCR confirmation of the infection.

Bilateral, multifocal patches of ground-glass opacity, mainly in the peripheral and posterior lungs with or without areas of consolidation, were common chest CT findings in the early stages of COVID-19 pneumonia. Other common features, such as organized pneumonia, thickening of interlobular septae, and crazy paving, emerged as the illness progressed. The usefulness of chest CT for early detection of COVID-19 pneumonia has been reinforced by the consistent validation of these results across various populations and clinical settings.

Chest CT has been routinely used not only for diagnosis but also to evaluate and predict the severity of COVID-19 pneumonia. Clinical presentation, the patient's requirement for additional oxygen, and overall survival rates have all been shown to positively correlate with the degree of lung involvement as indicated by chest CT findings. In order to help clinicians prioritize and treat COVID-19 pneumonia patients according to the severity of the illness, track the disease's progression, and assess treatment responses, semi-quantitative chest CT severity score systems have been created. Chest computed tomography (CT) has been essential in managing COVID-19, especially during the early days of the pandemic when lab testing was limited and RT-PCR results were often delayed or inaccurate. Numerous studies have shown that chest CT is highly sensitive in spotting lung issues related to COVID-19, often detecting abnormalities even before RT-PCR tests confirm the diagnosis [1–3].

Common CT findings in COVID-19 pneumonia include bilateral, multifocal ground-glass opacities, typically found in the peripheral and posterior areas of the lungs, sometimes accompanied by consolidation. As the illness advances, other signs like crazy-paving patterns, thickening of the interlobular septa, and organizing pneumonia patterns may emerge [4–6]. These imaging traits have been consistently observed across various populations and clinical environments, highlighting the diagnostic importance of chest CT. In addition to diagnosis, chest CT has been extensively utilized for assessing severity and predicting outcomes. The degree of lung involvement seen on CT scans has been linked to clinical severity, oxygen needs, and patient outcomes [7]. To assist in patient triage, track disease progression, and evaluate treatment responses, semi-quantitative CT severity scoring systems have been suggested. However, despite its clinical benefits, the routine use of chest CT for COVID-19 has sparked debate due to concerns about radiation exposure, particularly for patients needing multiple follow-up scans [8, 9]. This concern is especially pertinent during large outbreaks when CT imaging might be done repeatedly in a short time frame. As a result, professional organizations have stressed the careful use of CT, advising that imaging should primarily be reserved for patients with moderate to severe disease or those whose clinical condition is worsening [18].

Radiation Dose Considerations and Optimization Strategies

The widespread use of chest computed tomography (CT) during the COVID-19 pandemic has sparked significant concerns about patient radiation exposure, especially in cases where multiple scans are needed to monitor the disease. Unlike chest radiography, conventional chest CT exposes patients to a much higher dose of radiation, and undergoing these scans repeatedly can lead to a greater cumulative exposure, which in turn raises the long-term risk of developing radiation-induced cancers [8, 9]

To tackle this issue, radiation dose optimization follows the As Low As Reasonably Achievable (ALARA) principle, which focuses on minimizing radiation exposure while still ensuring that the image quality is good enough for accurate diagnoses. Thanks to advancements in CT technology, we can now significantly reduce radiation doses using various strategies, such as lowering the tube voltage and current, employing automatic exposure control, increasing pitch, and utilizing advanced reconstruction algorithms [10-12].

Innovative techniques like iterative reconstruction and, more recently, deep learning-based methods have been crucial in enhancing image quality in low-dose CT (LDCT). These approaches help reduce image noise while maintaining important anatomical details. As a result, we can achieve considerable dose reductions without losing the ability to clearly see critical COVID-19-related lung issues, such as ground-glass opacities and consolidations. Research has shown that effective radiation doses in LDCT protocols can be brought down to levels below one millisievert, which is comparable to those of traditional chest radiography [13-15].

Optimizing COVID-19 dosages is particularly crucial for younger patients, those with mild symptoms, and those who require multiple follow-up exams. Low-dose computed tomography (LDCT) can detect common COVID-19 signs just as well as standard-dose CT, according to research, supporting its routine use in appropriate clinical settings [14, 15]. In order to achieve a balance between radiation safety and diagnostic value during the pandemic, dose-optimized protocols have also been pushed for by international guidelines and expert opinions [18]. Chest CT is now a safer method for assessing COVID-19 thanks to techniques for maximizing radiation doses. The successful application of LDCT protocols emphasizes the necessity of combining clinical knowledge, standardized imaging procedures, and technology developments to put patient safety first while preserving diagnostic accuracy.

Diagnostic Performance of Low-Dose Chest CT in COVID-19

The effectiveness of low-dose chest CT (LDCT) in diagnosing COVID-19 has been thoroughly examined alongside standard-dose CT and RT-PCR testing. Numerous studies have shown that LDCT maintains a high sensitivity for spotting the typical lung issues associated with COVID-19, such as ground-glass opacities, consolidation, and bilateral peripheral lung involvement, which are essential for early diagnosis and evaluating the disease [1–3,13].

When comparing low-dose and standard-dose CT protocols, researchers found no significant differences in identifying the usual imaging features of COVID-19. For instance, Dangis et al. noted that submillisievert LDCT achieved diagnostic accuracy on par with standard-dose CT, providing excellent visualization of crucial lung abnormalities [13]. Likewise, Zali et al. found that LDCT preserved high sensitivity and specificity while significantly reducing radiation exposure, reinforcing its clinical usefulness [15]. The reliability of LDCT as a diagnostic tool is further boosted by advancements in reconstruction techniques that help reduce the image noise that often comes with lower doses. Techniques like iterative and deep learning-based reconstruction algorithms have been effective in maintaining image contrast and detail, allowing for accurate detection of COVID-19-related lung changes, even at much lower radiation levels [11,12]. These technological strides have proven especially beneficial during

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times of high patient volume, facilitating quick and safe imaging processes. Beyond just diagnosis, LDCT has also shown its value in evaluating the extent and severity of the disease. Semi-quantitative CT severity scores derived from LDCT images have been found to correlate well with clinical severity and inflammatory markers, much like those from standard-dose CT scans [7]. This indicates that LDCT can be reliably utilized not only for diagnosing but also for tracking disease progression and response to treatment. However, in patients with early or resolving disease, the diagnostic efficacy of LDCT may be diminished for subtle findings like early interstitial changes and mild fibrotic alterations. In order to guarantee consistent and accurate diagnosis, these limitations highlight the significance of reader experience and standardized interpretation frameworks. Despite these difficulties, the available data clearly shows that LDCT is a successful imaging technique that strikes a balance between radiation safety and excellent diagnostic performance.

Inter-Observer Variability and Standardized Reporting Systems

Inter-observer variability is a key factor in how reliable chest CT interpretations are, especially when it comes to COVID-19. This is crucial because the imaging results can sometimes look similar to those of other viral pneumonias and noninfectious lung diseases. Differences in how images are interpreted can stem from various sources, such as the radiologist's experience, their training, the quality of the images, and how they subjectively assess the imaging features. These issues can be even more pronounced in low-dose chest CT (LDCT) due to the increased image noise and changes in lung texture [16-,17] Numerous studies have looked into how consistently different observers agree on COVID-19 CT findings. They found a strong consensus on typical features like ground-glass opacities, consolidation, bilateral involvement, and peripheral distribution. However, when it comes to more subtle or evolving signs—like interlobular septal thickening, crazy-paving patterns, and early fibrotic changes—the agreement is only moderate. This pattern holds true for both standard-dose CT and LDCT, indicating that the variability in interpretation is more about how obvious the features are and the experience of the reader rather than just the radiation dose. The experience of the radiologist is crucial in minimizing inter-observer variability [22]. Senior radiologists and specialists in thoracic imaging tend to show higher levels of agreement, especially when it comes to atypical or subtle CT findings [21, 23]. This underscores the need for focused training and experience to enhance diagnostic consistency, particularly in high-pressure situations like a pandemic, where quick and accurate interpretations are vital. When it comes to LDCT, having standardized reporting is even more crucial because subtle image noise can really impact how we perceive visuals. By combining dose-optimized imaging protocols with structured interpretation frameworks and ongoing training for radiologists, we can greatly improve the consistency of diagnoses. Plus, the rise of AI-driven decision support tools could help minimize differences in interpretation by offering quantitative assessments and objective pattern recognition.

Clinical Implications and Future Direction

The evidence we've looked at really emphasizes how crucial low-dose chest CT (LDCT) is as a safe and effective imaging tool in managing COVID-19. LDCT's ability to accurately spot key lung issues while significantly cutting down on radiation exposure is a game-changer for everyday clinical practice, especially in areas with high infection rates and during major disease outbreaks.

From a clinical perspective, LDCT is a great option for the initial evaluation of patients showing moderate to severe symptoms, tracking disease progression, and monitoring post-COVID lung changes. It's particularly beneficial for those who need multiple scans, younger patients, and anyone who is more sensitive to radiation. The proven reliability of LDCT makes it a solid choice to include in standard imaging protocols without hindering clinical decisions.

The variability seen among different observers highlights the need for structured reporting systems and standardized interpretation methods. Sticking to RSNA guidelines and CO-RADS can boost diagnostic confidence and minimize differences in interpretation among radiologists with varying levels of experience. By incorporating these systems into everyday practice, we can improve communication between radiologists and clinicians, leading to more consistent patient management. Looking ahead, future research should aim for large multicenter studies to further confirm the diagnostic effectiveness of LDCT across various populations and healthcare environments. The use of AI-based tools for automated detection, quantification, and severity scoring of COVID-19 lung involvement is an exciting direction that could help reduce reliance on individual observers and improve diagnostic consistency. Moreover, long-term studies examining the role of LDCT in tracking the lasting lung effects of COVID-19 are definitely needed.

Conclusion

Low-dose chest CT has become a go-to imaging technique for assessing and managing COVID-19, proving to be safe, effective, and reliable. Research shows that these optimized CT protocols can accurately identify key lung issues associated with COVID-19, like ground-glass opacities, consolidation, and bilateral peripheral lung involvement, all while significantly cutting down on radiation exposure. Thanks to advancements in CT technology and reconstruction methods, we can now achieve a notable reduction in dose without sacrificing image quality, making low-dose protocols a regular part of clinical practice. While most radiologists tend to agree on typical COVID-19 findings, there can still be some differences in interpreting subtle or changing abnormalities. This variability underscores the importance of a radiologist's experience and the need for standardized reporting systems, such as the RSNA guidelines and CO-RADS. Incorporating low-dose chest CT into everyday clinical use strikes a great balance between diagnostic accuracy and radiation safety. By continuing to adopt structured interpretation frameworks, providing ongoing training for radiologists, and utilizing emerging AI tools, we can improve diagnostic consistency and enhance patient care. The insights gained from imaging during the COVID-19 pandemic highlight the broader potential of low-dose CT strategies for managing future respiratory pandemics and other conditions that require repeated thoracic imaging.

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