J Bionic Mem 2023; 3(1): 15-22 DOI: 10.53545/jbm.2023.25

Journal of Bionic Memory Original article

Assessment of the effectiveness of low-dose chest computed tomography in the diagnosis of COVID-19 pneumonia

Melike Elif Kalfaoglu, Emine Dagistan

Department of Radiology, Bolu Abant Izzet Baysal University, Medical Faculty, Bolu, Türkiye

ABSTRACT

Aim: To determine whether low-dose chest computed tomography (CT) imaging protocol is appropriate in terms of technical success and radiation safety, by comparing it with standard protocols in terms of reaching diagnosis and X-ray exposure. Additionally, to investigate radiation dose criteria in patients undergoing CT scan for COVID-19.

Method: CT scans of 149 patients diagnosed with COVID-19 between April 2020 and June 2021 were analyzed. Patients were randomly assigned to either a standard protocol or a low-dose protocol. Factors such as technical success, diagnostic accuracy, exposure dose and side effects were analyzed.

Results: A statistically significant difference was found between low-dose and standard-dose CT scans for tube current-time product (p<0.001), CTDI (p<0.001), DLP (p<0.001), effective dose (p<0.001). , and cancer risk (p<0.001).

Conclusion: The low-dose CT protocol in COVID-19 patients yields similar results to standard protocols in terms of technical success and diagnostic accuracy, while significantly reducing exposure dose. Therefore, the use of low-dose protocol can be considered as an option to reduce the radiation dose that patients are exposed to.

Keywords: COVID-19, pneumonia, radiation safety, low-dose CT.

Dr. Melike Elif Kalfaoglu,
Department of Radiology, Bolu Abant Izzet Baysal University, Medical Faculty, Bolu, Türkiye
E-mail: m.elifkalfaoglu@gmail.com
Received: 2023-05-01
Accepted: 2023-05-17 / Published: 2023-05-21

Introduction

The outbreak of Coronavirus Disease 19 (COVID-19) was first reported in Wuhan, China, in December 2019. As of April 28, 2023, the COVID-19 pandemic has been confirmed in almost every country in the world, with almost 764 million people infected and roughly 6.9 million deaths reported globally [1]. The real-time reverse transcriptase polymerase chain reaction (RT-PCR) test is the current gold standard for diagnosing COVID-19, but it has some limitations, such as a high false-negative rate, limited availability, and delay in confirmation [2]. False-negative RT-PCR tests have been reported in patients with CT findings of COVID-19 who eventually tested positive with serial sampling [3]. Thorax CT was found to have a higher sensitivity in detecting the infection compared to RT-PCR, as reported in one study [4]. Due to the unprecedented public health challenge presented by the COVID-19 pandemic, there has been an increased focus on the use of radiologic imaging to evaluate ongoing lung abnormalities associated with the disease [5]. Despite not being recommended as a screening tool in current guidelines (American College of Radiology. Available via https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Recommendations-for-Chest-Radiography-and-CT-for-Suspected-COVID19-Infection), the broad availability, quick turnaround time for results, and high sensitivity of thorax CT imply that individuals with doubtful laboratory findings or clinical symptoms should consider undergoing a chest CT scan for the detection of COVID-19 pneumonia, especially in areas where RT-PCR testing is restricted or not readily available [6]. Although CT imaging has been proven to be a great aid in the diagnosis of COVID-19, its increased use has raised concerns about potential radiation exposure for both patients and healthcare workers [7]. It is widely accepted that ionizing radiation, including x-rays emitted by CT scanners, is a carcinogen capable of damaging DNA and increasing the risk of cancer over a person's lifetime. The level of radiation dose and the age at which a person is exposed are two important factors that influence the risk of developing cancer from ionizing radiation [8].

Previous studies have reported that obtaining a low-dose chest CT scan by applying a reduced tube current results in reliable sensitivity compared to standard-dose CT protocols in detecting intrathoracic pathologies such as pulmonary nodules, lung masses, or parenchymal abnormalities [9]. Due to the increased use of chest CT scans during the Covid-19 pandemic, new protocols with reduced doses and maintained diagnostic accuracy have been developed, particularly for patients under 40 years of age [10]. The low-dose scanning protocol provides sufficient image quality and diagnostic accuracy, while reducing the radiation dose and associated cancer risk for the patient compared to the standard dose protocol [11]. Tofighi et al. have stated that the low-dose CT protocol provides adequate image quality and diagnostic accuracy in the intermediate and advanced stages of the disease since the CT scan, along with other clinical findings, can help with the diagnosis of COVID-19 [12].

Although low-dose radiation studies have been reported in Covid-19 pneumonia in the literature, our evaluations reveal differences in the imaging parameters we applied in our Low Dose CT protocol, as well as in our objective and subjective evaluation methods.

In our study, we aimed to determine whether the low-dose chest CT imaging protocol is appropriate in terms of technical success and radiation safety, by comparing it with standard protocols in terms of reaching a diagnosis and exposure to X-ray dose criteria in patients undergoing CT scans due to COVID-19.

Materials and methods

In the present retrospective study, we analyzed the thorax CT images of the subjects with COVID-19 pneumonia. This retrospective study was approved by the Institutional Ethics Committee (approval number: 2023-20). Patients with incomplete or inadequate data and those diagnosed with cancer were excluded from the study (n=23). Between April 2020 and June 2021, a total of 149 patients who had symptoms and tested positive for SARS-CoV-2 on RT-PCR underwent both low-dose and standard-dose chest CT scans to evaluate for possible COVID-19 pneumonia and were included in the study. Patients were evaluated in terms of age, gender, hospitalization duration, type of medical care (either as in-patient or out-patient), mortality, accompanied comorbidities, RT-PCR results (either as negative or positive), and pulmonary involvement.

Thorax CT examination was performed with a 64-slice CT device (General Electric Revolution EVO, 64slices). The scanning range was from the apex to the base of the lung. Acquisitions were performed during a deep inspiration, breath-hold, without contrast administration. We implemented a low-dose scanning protocol with the following parameters: tube voltage, 80 kVp; tube current, 10–90 mA; rotation time, 0.75 s; pitch, 1.5; slice thickness, 3 mm; and detector width, 1.5 mm. In addition to the above-mentioned reduction dose strategy, we used iterative reconstruction algorithms. The dose length product and effective dose were 33.72 mGy.cm and 0,476mSv, compared with 307 mGy.cm and 4,19mSv in a standard dose protocol.

All CT images were evaluated by two radiologists with 14 and 12 years of experience, respectively. The image quality was assessed using a 5-point scale (1: poor, 2: borderline, 3: moderate, 4: adequate-good, 5: excellent) to record the visibility and clarity of COVID-19 pneumonia findings on the CT scans. The chest CT images were classified according to the Radiological Society of North America Expert Consensus Statement as Typical, Indeterminate, Atypical, and negative in terms of COVID-19 pneumonia findings. The signal and noise values of the images were calculated from the measurements obtained using ROI drawn around a circle with approximately 1 cm diameter in lung, pectoral muscle, and axillary fat tissue in all patients. The SNR and CNR ratios of the parenchyma and vertebral body in the parenchymal window and the pectoral muscle and axillary fat in the mediastinal window were measured. The volume computed tomography dose index (CTDIvol) and dose length product (DLP), which are radiation dose descriptors automatically calculated by the CT scanner, were recorded. The effective dose values (mSv) of chest CT scan examinations were calculated by multiplying dose-length product (DLP) with conversion coefficients. To calculate the cancer risk, mean effective dose values obtained from standard-dose and low-dose CT scan examinations were multiplied by the risk coefficient (0.041 Sv^{-1}).

Statistical analyses

Statistical software (SPSS 18 for Windows, IBM Co, Chicago, Il, USA) was used for statistical analyses. Kolmogorov Smirnov test was applied to the study variables for normality analysis. Variables that fit into normal distribution were conducted with independent samples t test and expressed as means and standard deviations. Other variables that not fit into normal distribution were expressed as median (min-max) and compared with Mann-Whitney U test. Categorical variables were compared between study groups with chi-square test and given as numbers and percentages. It is considered as significant when the p value was lower than 5%.

To assess the inter-reader agreement between low-dose and standard-dose, kappa (κ) test was utilized, and intraclass coefficient correlation (ICC) was used to compare the agreement between the two radiologists. A κ value lower than 0.20 indicated poor agreement; 0.21–0.40, fair agreement; 0.41–0.60, moderate agreement; 0.61–0.80, good agreement; and 0.81–1.00, excellent agreement. An ICC below 0.50 indicated poor agreement, between 0.50 and 0.75 moderate, between 0.75 and 0.90 good, and above 0.90 excellent.

Results

The study population consisted of 149 cases, 76 of whom underwent Low Dose CT (LDCT)

Table 1. Lung involvement rates in low-dose and standard-dose CT according to the RSNA classification

RSNA		LDCT (n, %)	SDCT (n %)	Total (n, %)	*p*
	Typical appearance	58 (76,3)	63 (86,3)	121 (81.2)	=0,269
	Indeterminate appearance	14 (18.4)	7 (9.6)	21 (14.1)	
	Atypic appearance	4 (5.3)	3 (4.1)	7 (4.7)	
TOTAL		76	73	149	

Table 2. Comparative evaluation of PCR results in low-dose and standard-dose CT scans.

		LDCT (n, %)	SDCT (n, %)	Total (n, %)	*p*
RT-PCR	Positive	59 (77,6)	58 (79.5)	117 (78.5)	=0. 787
	Negative	17 (22.4)	15 (20.5)	32 (21.5)	
TOTAL		76	73	149	

Table 3. Radiologists' scoring scale for LDCT and SDCT.

	Low Dose CT (n=76)				Standard Dose CT (n=73)				t	*p*
	Mean	Std	Min	Max	Mean	Std	Min	Max		
Radiologist 1	3.67	0.473	3	4	4.79	0.407	4	5	-15,564	<0.001
Radiologist 2	3.71	0.457	3	4	4.71	0.456	4	5	-13,401	<0.001

and 73 underwent Standard Dose CT (SDCT) imaging. The mean age in the LDCT and SDCT groups was 39.75 ± 10.1 and 50.58 ± 12.8, respectively. There were 33 females and 43 males in the LDCT group, and 31 females and 42 males in the SDCT group. No significant difference was observed between the groups in terms of gender distribution (*p*=0.9).

There was no significant difference between the groups in terms of mortality rate (*p*=0.14), positivity of CT findings (*p*=0.32), RT-PCR positivity (*p*=0.78), and lung involvement rates (*p*=0.269), as summarized in tables 1 and 2.

However, significant differences were observed between the two groups in terms of type of medical care (inpatient and outpatient) (*p*=0.004) and accompanying comorbidities (*p*<0.001).

Both radiologists gave significantly lower scores to low-dose CTs compared to high-dose CTs, but they rated the low-dose CTs as sufficient-good in terms of image quality. The interclass correlation among radiologists was calculated as 0.945, and Cohen's Kappa value was found to be 0.837, indicating a high degree of agreement among radiologists. The LDCT and SDCT scoring scale of the radiologists is summarized in Table 3.

There was no significant difference between the groups in terms of lung SNR (*p*=0.554), lung CNR (*p*=0.551), and vertebral CNR (*p*=0.06). However, significant differences were found between the groups in terms of pectoral SNR (*p*=0.005), pectoral CNR (*p*<0.001), axillary SNR (*p*<0.001), axillary CNR (*p*<0.001), and vertebral SNR values.

There was a significant difference between the groups in terms of tube current-time product (*p*<0.001), CTDI (*p*<0.001), DLP (*p*<0.001), effective dose (*p*<0.001), and cancer risk (*p*<0.001). The LDCT and SDCT findings are summarized in Table 4.

Table 4. LDCT and SDCT findings.

Parameters	Low Dose CT (n=76)			Standard Dose CT (n=73)			*p*
	Median	Min	Max	Median	Min	Max	
Tube current (mA)	90	10	90	285	77	402	**<0.001**
CTDI	0.90	0.90	0.98	8.78	2.56	15.54	**<0.001**
DLP	33.35	28.63	41.02	307.65	97.85	478.56	**<0.001**
Effective Dose	0.42	0.32	0.69	4.00	1.03	8.85	**<0.001**
Cancer risk	0.02	0.01	0.03	0.16	0.04	0.36	**<0.001**
Lung SNR	10.06	4.95	20.88	9.66	3.65	23.44	=0.554
Lung CNR	0.16	0.40	0.72	0.15	0.20	0.88	=0.551
Pectoral CNR	0.14	0.02	0.52	0.24	0.03	0.89	**<0.001**
Axillary CNR	0.31	0.07	1.16	0.56	0.11	1.63	**<0.001**
Vertebral SNR	6.65	2.63	14.16	4.76	2.02	9.14	**<0.001**
Vertebral CNR	0.18	0.03	0.71	0.17	0.06	0.42	=0.06
	Mean		Std	Mean		Std	
Pectoral SNR	2.66		1.04	3.22		1.33	**=0.005**
Axillary SNR	6.24		1.64	8.03		2.11	**<0.001**

Discussion

The most important result of our study is that in low-dose CT scans, the tube current radiation time, CTDI, DLP, effective dose, and cancer risk were significantly lower compared to standard dose CT scans. Due to the predominance of ground-glass opacities in COVID pneumonia, the percentage of lung involvement can predict the course of the disease, and the presence of false negative PCR test results and the inadequacy of PAAG in determining parenchymal involvement, CT has become one of the main radiological methods for diagnosing and guiding treatment for COVID pneumonia. The widespread use of CT for diagnosis has led to concerns about the potential carcinogenic effects of high doses of radiation. Therefore, at the recommendation of the Ministry of Health, low-dose protocol CT scans have been performed in patients under the age of 50, significantly reducing effective dose and cancer risk. When the images were evaluated retrospectively by two radiologists, the image quality of low-dose CT scans was statistically significantly lower than that of high-dose CT scans, but the low-dose CT scans were evaluated as sufficient-good in terms of inter-radiologist agreement on image quality. In addition, in our study, CNR and SNR ratios were evaluated, and no significant difference was found between the CNR and SNR ratios measured from the lung parenchyma. High CNR and SNR ratios have a positive effect on image quality, while low ratios have a negative effect. The lack of difference in CNR and SNR ratios between low-dose and standard dose CT images in our study indicates that parenchymal findings can be adequately evaluated [13].

Our results demonstrate that low-dose CT examination significantly reduces cancer risk and allows for optimal evaluation of COVID-19 pulmonary findings, which is consistent with the literature [14,15]. Pathologies such as pulmonary nodules that require monitoring even before COVID-19 due to the high radiation and associated cancer risk in CT examinations have revealed the need for low-dose CT [16]. Several previous studies have suggested that it is possible to obtain a reliable and sensitive low-dose chest CT scan by utilizing reduced tube current, which can effectively detect intrathoracic pathologies like lung masses, pulmonary nodules, and parenchymal abnormalities [17,18]. For instance, Zhu and colleagues reported that a low-dose helical chest CT protocol, utilizing 40 or 25 mAs, produced diagnostic-quality images while minimizing patients' exposure to radiation [19]. According to a study by Kubo et al., utilizing a tube current of 50 mAs for routine chest CT scans yields diagnostic results comparable to those obtained with the standard dose of 150 mAs [20]. A recent publication by Tofighi and colleagues discusses the use of low-dose CT in diagnosing COVID-19 pneumonia. Their findings suggest that low-dose and ultralow-dose CT protocols have similar efficacy in detecting ground glass and consolidative opacities. The authors recommend that the use of low-dose and conventional protocols be compared in the early stages of the disease, as low-dose CT provides sufficient image quality and diagnostic accuracy in the intermediate and advanced stages of the disease [12]. Looking at the literature on low dose CT, it indicates that dose reduction techniques do not negatively affect parenchymal image quality or make evaluation more difficult, and these findings are consistent with our study.

Our study's main limitation is the small sample size. The data obtained can be correlated with larger studies. However, inadequate inspiration during imaging is also an important factor that affects image quality in addition to dose reduction techniques. Therefore, non-diagnostic images due to respiratory artifacts should be excluded from the study. Another limitation is the presence of atypical parenchymal findings in addition to typical COVID-19 pneumonia, making it difficult to achieve agreement among readers.

In conclusion, our study demonstrates that low-dose CT is a reliable and practical method for detecting COVID-19 pneumonia while significantly reducing radiation dose and estimated cancer risk. Therefore, low-dose CT imaging may be preferred for evaluating parenchymal involvement and disease progression in COVID-19 patients.

Funding: *The author(s) received no financial support for the research, authorship, and/or publication of this article.*
Conflict of Interest: *The authors declare that they have no conflict of interest.*
Ethical statement: *Ethics committee approval was received for this study from the ethics committee of Abant Izzet Baysal University (Approval No: 2023/20).*

References

[1]World Health Organization. Novel Coronavirus (COVID-19) situation.Available via https://who.sprinklr.com Accessed 28 april 2023).

[2]Huang P, Liu T, Huang L, et al. Use of chest CT in combination with negative RT-PCR assay for the 2019 novel coronavirus but high clinical suspicion. Radiology 2020;295(1):22-23.

[3]Rubin GD, Ryerson CJ, Haramati LB et al. The Role of Chest Imaging in Patient Management During the COVID-19 Pandemic: A Multinational Consensus Statement From the Fleischner Society. Chest. 2020;158(1):106-116.

[4]Fang Y, Zhang H, Xie J, et al. Sensitivity of Chest CT for COVID-19: Comparison to RT-PCR. Radiology. 2020;296(2):E115-E117

[5]Lee C. Managing Radiation Dose from Chest CT in Patients with COVID-19. Radiology. 2021;298(3):E158-E159.

[6]Akl EA, Blažić I, Yaacoub S, et al. Use of Chest Imaging in the Diagnosis and Management of COVID-19: A WHO Rapid Advice Guide. Radiology. 2021;298(2):E63-E69.

[7]Kang Z, Li X, Zhou S. Recommendation of low-dose CT in the detection and management of COVID-2019. Eur Radiol. 2020;30(8):4356-4357.

[8]Power SP, Moloney F, Twomey M, et al. Computed tomography and patient risk: Facts, perceptions and uncertainties. World J Radiol. 2016;8(12):902-915.

[9]Zheng C, Wang H, Liu Q, et al. Application effect of low-dose spiral CT on pulmonary nodules and its diagnostic value for benign and malignant nodules. Am J Transl Res. 2023;15(1):256-263.

[10]Dangis A, Gieraerts C, De Bruecker Y, et al. Accuracy and Reproducibility of Low-Dose Submillisievert Chest CT for the Diagnosis of COVID-19. Radiol Cardiothorac Imaging. 2020;2(2):e200196.

[11]Tabatabaei SMH, Talari H, Gholamrezanezhad A, et al. A low-dose chest CT protocol for the diagnosis of COVID-19 pneumonia: a prospective study. Emerg Radiol. 2020;27(6):607-615.

[12]Tofighi S, Najafi S, Johnston SK, et al. Low-dose CT in COVID-19 outbreak: radiation safety, image wisely, and image gently pledge. Emerg Radiol. 2020;27(6):601-605.

[13]Garg M, Karami V, Moazen J, et al. Radiation Exposure and Lifetime Attributable Risk of Cancer Incidence and Mortality from Low- and Standard-Dose CT Chest: Implications for COVID-19 Pneumonia Subjects. Diagnostics (Basel). 2022;12(12):3043.

[14]Atlı E, Uyanık SA, Öğüşlü U, et al. The Feasibility of Low-dose Chest CT Acquisition Protocol for the Imaging of COVID-19 Pneumonia. Curr Med Imaging. 2022;18(1):38-44.

[15]Tugwell-Allsup J, Owen BW, England A. Low-dose chest CT and the impact on nodule visibility. Radiography (Lond). 2021;27(1):24-30.

[16]Feghali JA, Russo RA, Mamou A, et al. Image quality assessment in low-dose COVID-19 chest CT examinations. Acta Radiol. 2023 Feb 6:2841851231153797.

[17]Macri F, Greffier J, Pereira F, et al. Value of ultra-low-dose chest CT with iterative reconstruction for selected emergency room patients with acute dyspnea. Eur J Radiol. 2016 ;85(9):1637-44.

[18]Blokhin I, Gombolevskiy V, Chernina V, et al. Inter-Observer Agreement between Low-Dose and Standard-Dose CT with Soft and

Sharp Convolution Kernels in COVID-19 Pneumonia. J Clin Med. 2022;11(3):669.

[19] Zhu X, Yu J, Huang Z. Low-dose chest CT: optimizing radiation protection for patients. AJR Am J oentgenol. 2004;183(3):809–816.

[20] Kubo T, Ohno Y, Nishino M, et al. iLEAD study group. Low dose chest CT protocol (50 mAs) as a routine protocol for comprehensive assessment of intrathoracic abnormality. Eur J Radiol Open. 2016;3:86-94.