

Comparison of Different Slice Thicknesses on Chest Computed Tomography for Evaluation of COVID-19-Associated Pneumonia

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Abstract

OBJECTIVE: To compare the value of chest computed tomography at 1-mm and 5-mm slice thickness in terms of computed tomography severity score and computed tomography evaluation time in the diagnosis of COVID-19.

MATERIAL AND METHODS: Sixty-five patients were included in the study group who are reverse-transcription polymerase chain reaction-positive for COVID-19 and had chest computed tomography. The 1 mm and 5 mm reconstructed images were evaluated in 2 different sessions with 4-week intervals by 2 certificated general radiologists. The presence of COVID-19-related findings, COVID-19 final category, and evaluation time were recorded. Thin and thick slices were compared for these variables and inter-reader reliability calculated with the Statistical Package for the Social Sciences (SPSS) for Windows.

RESULTS: There was no significant difference between the COVID-19-related findings on thorax computed tomography between 1-mm and 5-mm slices except crazy paving appearance, microvascular enlargement, and septal thickening. The frequency of the final categories of computed tomography results was consistent between the thick and thin slices. The computed tomography assessment time was significantly lower in 5 mm slices. The inter-reader reproducibility analysis results demonstrated good and excellent reproducibility of measurements between readers for both slice thicknesses.

CONCLUSION: It was found that 5-mm reconstruction thickness of chest computed tomography can be employed for the initial detection of COVID-19-related findings and the final diagnostic category-related COVID-19 rather than 1-mm slices with a faster availability of results which can be beneficial on pandemic hospitals.

KEYWORDS: Chest CT, COVID-19, slice thickness

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INTRODUCTION

The rationale of the chest computed tomography (CT) usage on the coronavirus disease 2019 (COVID-19) pandemic has still been debated.¹⁻⁶ However, it has been used worldwide in different clinical scenarios such as confirming the diagnosis, predicting severity, or detecting complications of the disease, excluding other differentials. The radiology departments served the referred patients from pandemic clinics with variable chest CT protocols in different centers.⁷

On one hand, chest CT protocols have some adopted points that are agreed upon globally. One of them is using unenhanced chest CT protocols unless CT pulmonary angiography is required to identify pulmonary embolism.⁶ Another common point is to acquire the images during a single respiratory phase in order to reduce the radiation dose of the patient and exclude air trapping, which can be observed in expiratory phase images.⁸ In addition, the sharp kernel reconstruction technique is recommended.⁸

On the other hand, some marks remained unclear: one of which is the optimal slice thickness for image acquisition and evaluation.⁷ Although thin sections are known as ideal for determining pulmonary opacities, in some scanners, it prolongs the scan times and affects patients' radiation dose during image acquisition.⁷ In addition, not only reconstruction and transmission of thin slices to picture archiving and communication systems (PACS) but also evaluation of thin sections may take more time compared to thick slices.

The presented study aims to compare the thick (5 mm) and thin (1 mm) reconstructions on chest CT regarding the diagnosis of COVID-19, CT severity score, and CT evaluation time.

MATERIAL AND METHODS

Study Population and Design

The study was approved by Ethics committee of Sivas Cumhuriyet University (Approval No: 2020-06/30) and written informed consent was obtained routinely before chest CT examination. This study was designed as a retrospective,

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single-center observational study. There were 111 patients who had suggestive symptoms for COVID-19 disease at the time of hospital admission with a positive reverse-transcription polymerase chain reaction (RT-PCR) test from the nasopharyngeal swab and a chest CT imaging done between March 1, 2020, and June 1, 2020. Forty-six patients were excluded from further analyses because of severe motion artifacts or lack of specific slice thicknesses on PACS. The remaining 65 patients were included in the study group.

Chest Computed Tomography Image Acquisition

Chest CT imaging was acquired using one of 16-detector CT scanners (Alexion, Toshiba or Aquillion, Toshiba, Tokyo, Japan). Computed tomography images were obtained during a single inspiratory phase on supine position without contrast medium injection. Computed tomography scan parameters: Tube voltages 120 KVp with automatic tube current modulation, rotation time 0.5 second (Aquillion, Toshiba) -0.75 second (Alexion, Toshiba), pitch factor 0.938. The 1-mm and 5-mm thick images were reconstructed and stored in the PACS system.

Image Analysis

The patients' chest CT images with different slice thicknesses (1 mm and 5 mm) were evaluated in 2 different sessions with 4-week intervals. In these sessions, all images were independently reviewed by 2 national board certificated general radiologists (N.C. and H.C. with 8 years of experience), blinded to the clinical data. All images were assessed on a PACS workstation (FONET, Ankara, Turkey).

Thorax CT images of subjects were evaluated in lung/soft tissue algorithm. The presence of typical and atypical signs of COVID-19 pneumonia such as ground-glass opacity, consolidation, crazy paving appearance, air cysts, microvascular enlargement, fibrotic changes, air bronchogram, bronchial distortion, centrilobular nodules, pleural thickening, pleural effusion, halo sign, and lymphadenopathy were recorded at each evaluation. For each assessment, a final category was defined as "typical appearance for viral pneumonia," "indeterminate appearance for viral pneumonia," "atypical appearance for viral pneumonia," and "negative for pneumonia." Computed tomography severity score was calculated for all patients in both sessions using a scoring system based on a lobar assessment of ground-glass opacity and consolidation.

MAIN POINTS

- Chest computed tomography has been exploited for diagnosis and extensity of lung disease, excluding other differentials in some COVID-19 cases; however, there has not been a consensus on neither indications nor imaging parameters for chest computed tomography yet.
- It was found that thick slices (5 mm) are valuable to detect the chest computed tomography findings that are encountered at COVID-19 like thin slices (1 mm).
- It was found that 5-mm reconstructed chest computed tomography could be utilized for the initial detection of COVID-19-related findings and the final diagnostic category-related COVID-19 rather than 1 mm slices with a faster availability of results which can be beneficial on pandemic hospitals.

Each lobe scored 0-5 points, depending on the percentage of the involved lobe: 0 (0%), 1 (1-5%), 2 (6-25%), 3 (26-50%), 4 (51-75%), or 5 (76-100%). The total score was between 0 and 25. Time was kept with a stopwatch during each evaluation.

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS) for Windows was used for statistical analysis (Version 23.0; IBM, Armonk, NY, USA). The data were assessed with Kolmogorov-Smirnov and Shapiro-Wilk tests in terms of normal distribution. The frequency of each COVID-19-related findings on CT was statistically compared between 1-mm and 5-mm CT using the Mc Nemar test. The Mc Nemar-Bowker test was used to compare the final category of CT results which had more than 2 categories. In addition, for the CT assessment time and CT score, the differences were statistically compared using the paired *t*-test and Wilcoxon signed-rank test between slice thicknesses. Inter-reader reliability was assessed by the inter-reader correlation coefficient for continuous variables (CT score and CT evaluation time) and Cohen's kappa for categorical variables (final CT category). The inter-correlation coefficient was defined as poor if it was <0.4, moderate if it was 0.40-0.59, good if it was 0.60-0.74, and excellent if it was ≥ 0.75 .⁹ Cohen's kappa was considered almost perfect if the coefficients were between 0.81 and 1.00, substantial if the values were between 0.61 and 0.80, moderate if between 0.41 and 0.60, fair if between 0.21 and 0.40, and slight if between 0 and 0.20.¹⁰ Values of $P < .05$ were considered statistically significant.

RESULTS

The frequency of COVID-19-related findings for both readers and the difference between the thick and thin slices are demonstrated in Table 1. There was no significant difference between the COVID-19-related findings on thorax CT between 1-mm and 5-mm slices except crazy paving appearance for the first reader. Microvascular enlargement and septal thickening were much more frequently detected on thin-section CT than on 5-mm CT, with a significant statistical difference on the second reader's evaluation.

The final category of diagnosis on CT assessments for readers is summarized in Table 2. The frequency of the final categories of CT results was consistent between the thick and thin slices for both readers significantly. There was a moderate correlation between readers for both 1-mm and 5-mm slice thicknesses (Kappa value 0.610 with a $P < .001$ and 0.640 with a $P < .001$, respectively). There was 1 patient who was classified as negative for pneumonia on the evaluation of the first reader's session in 5-mm slices, whereas it was categorized as typical for viral pneumonia in 1-mm slices (Figure 1). This patient is classified under the "indeterminate group" by the second reader. In addition, 3 patients were determined as "negative for pneumonia" in thick slices, one of which turned to be in the "atypical findings" group and 2 of which classified in "indeterminate group" in thin slices (Figures 2 and 3).

The CT assessment time was significantly lower in 5-mm slices for both readers ($P < .001$). The mean evaluation time for the first and second readers was 150 second (± 50.27) and 195

Table 1. Frequency of COVID-19-Related Findings on Computed Tomography for 2 Readers

Positive findings	First Reader		P	Second Reader		P#
	1 mm	5 mm		1 mm	5 mm	
	n (%)			n (%)		
Ground glass opacities	46	43	0.508	43	42	1.000
Consolidation	15	11	0.344	26	23	.250
Crazy paving appearance	15	7	0.039	10	8	.688
Air cysts	1	1	1.000	0	0	null
Microvascular enlargement	2	0	0.500	27	12	.000
Fibrotic changes	21	15	0.146	6	6	1.000
Air bronchogram	9	6	0.453	23	19	.289
Bronchial distortion	3	0	0.250	2	0	.500
Centrilobular nodules	0	0	null	1	1	1.000
Septal thickening	13	11	0.754	14	4	.002
Pleural thickening	3	1	0.500	4	3	1.000
Pleural effusion	2	1	1.000	1	1	1.000
Halo sign	2	1	1.000	4	1	.250
Lymphadenopathy	8	3	0.063	5	2	.250

#P value.

(±76.10), respectively, for 1 mm and 82 second (±29.89) and 120 second (±56.20) for 5 mm, respectively. A good correlation between readers was detected on evaluation times (ICC 0.676 for 1 mm and 0.658 for 5 mm, $P < .001$)

The mean CT score was 5.89 (±6.25) on thin slices which was higher than thick slices on the first reviewer’s evaluation (mean 5.34 ± 6.19, $P = .005$). However, there was no significant difference for the second reader on CT scoring (mean 1-mm CT score = 5.40 ± 6.04; 5-mm CT score 5.29 ± 6.06; $P = .327$). There was an excellent correlation between readers (ICC 0.963 for 1-mm and 0.982 for 5-mm, $P < .001$).

DISCUSSION

The RT-PCR laboratory test is accepted as the standard for confirming COVID-19; however, chest CT has been acting a complementary role as a diagnostic tool in the assessment of patients with COVID-19. Although chest CT has been utilized

for diagnosis, extensity of lung disease, excluding other differentials worldwide, there has not been a consensus on neither indications nor imaging parameters for chest CT yet. In most centers, non-contrast enhanced, respiratory phase images with sharp kernel reconstruction were acquired for evaluation; yet, it is not clear which slice thickness should be preferred.^{7,8} Thus, this study aimed to compare the value of 5-mm and 1-mm reconstruction thickness of chest CT among COVID-19 patients.

In the present study, it was found that thick slices are valuable to detect the chest CT findings that are encountered with pulmonary COVID-19 as like thin slices. The most common chest CT findings of COVID-19 are ground-glass opacities with bilateral, lower lobe, and posterior predilection (>70%).¹¹ Consolidation, septal thickening, crazy-paving pattern, air bronchogram, pleural thickening, halo sign, bronchiectasis, nodules are at intermediate incidence (10%-70%).¹¹ Pleural effusion and lymphadenopathy, central lesion

Table 2. Final Category of Diagnosis for 1-mm and 5-mm Slices for Both Readers

	Final Category	1 mm	5 mm	P
		n (%)		
Reader 1	Typical for viral pneumonia	39	36	.109
	Indeterminate appearance viral pneumonia	8	3	
	Atypical for viral pneumonia	3	7	
	Negative for pneumonia	15	19	
Reader 2	Typical for viral pneumonia	35	35	.368
	Indeterminate appearance viral pneumonia	8	7	
	Atypical for viral pneumonia	3	2	
	Negative for pneumonia	19	21	

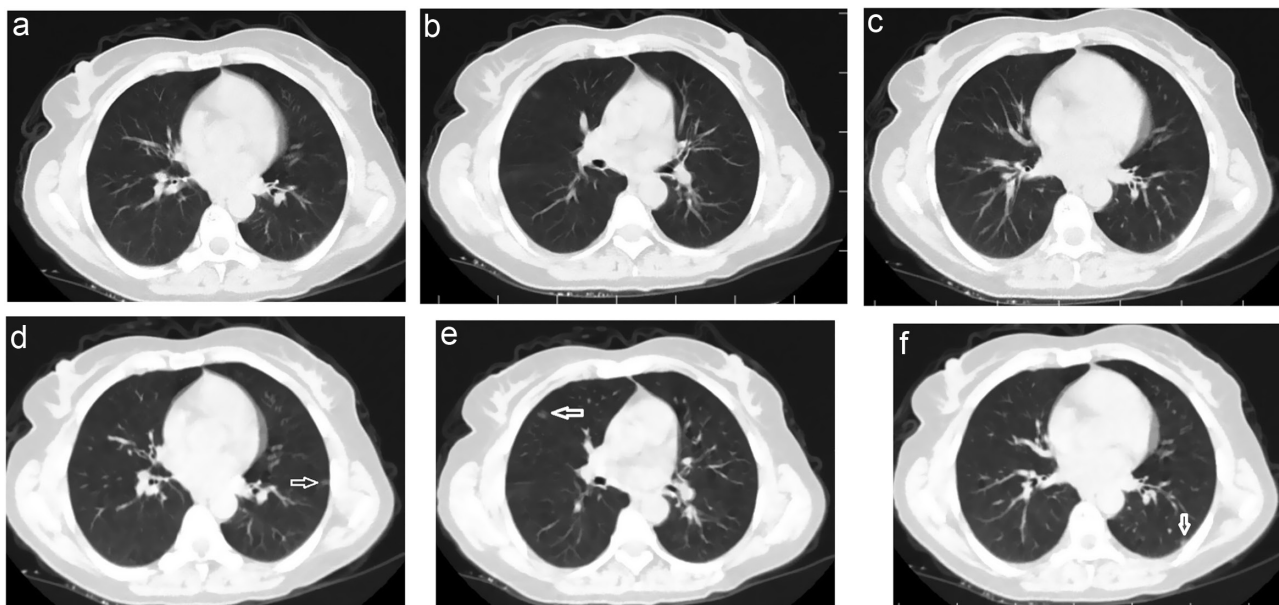


Figure 1. The figure a-c are chest CT with a slice thickness of 5-mm and the images were classified as negative for pneumonia. However, in the evaluation of the same patient’s images with 1-mm slice thickness (e-g), the subpleural tiny ground glass opacity nodules (arrows) were identified and the patient was categorized as typical for viral pneumonia.

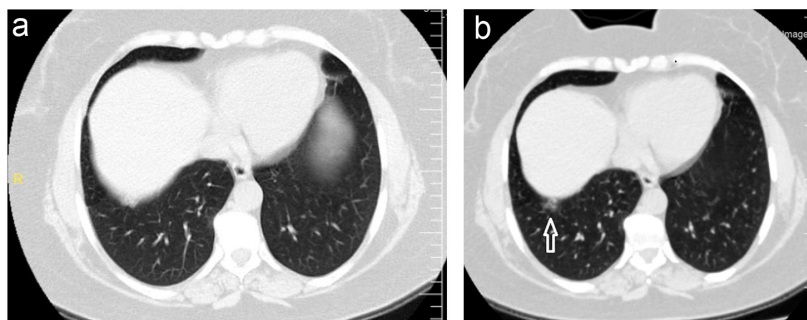


Figure 2. The figure (a) was 5-mm thick slice and was classified negative for pneumonia. Though, on 1-mm thin slice (b), the focal solitary ground glass opacity (arrow) was adjacent to the right diaphragm and the patient was categorized in the “atypical findings” group.

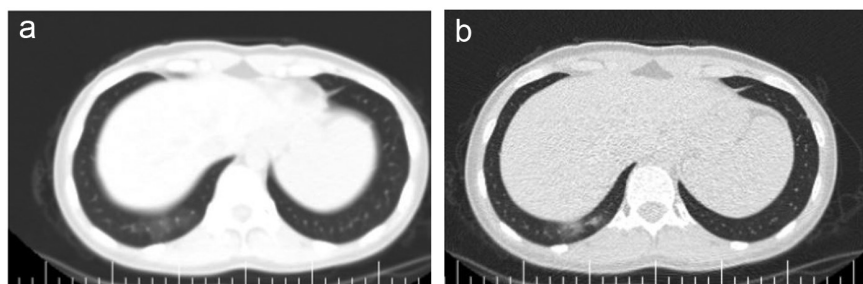


Figure 3. The figure (a) was 5-mm slice thickness and classified as negative for pneumonia; the ground glass opacity on the right lower lobe was assessed as artifact; however, the focal solitary ground glass opacity was more apparent on thin slice (b) and the patient was categorized in the “atypical findings” group.

distribution show low incidence (<10%).¹¹ In this research, both thick and thin slices are efficacious in detecting most of these findings correlatively. The 3 findings in which thin slices were found to be more effective to confirm were crazy paving appearance, microvascular enlargement, and septal thickening which may be a disadvantage for thick slices.

We revealed that 5-mm chest CT can be as effective as 1-mm slices on determining patients’ chest CT categorization related to COVID-19. Besides, another pro of thick slices is faster

availability of the decision-related COVID-19 from chest CT rather than thin slices. Although routine usage of chest CT on the diagnosis of asymptomatic patients or patients with mild symptoms is not recommended,¹² the high false-negative rate of RT-PCR and challenges on accession to the RT-PCR in some centers promote the expanding usage of chest CT for diagnosis of COVID-19.⁷ Four categories (typical appearance, indeterminate appearance, atypical appearance, and negative for pneumonia) are suggested for COVID-19 reporting to reduce uncertainty among radiologists and to advance

communication with clinicians.^{13,14} This classification was used to categorize patients in the current study as this is also the routine approach in our hospital. In some centers, this categorization is used to isolate patients rapidly before RT-PCR results and begin treatment regimen immediately. Provided thick slices are utilized initially for diagnosis instead of thin slices, the rapid and accurate results can be achieved as in thin slices.

Although thick slices are found to be statistically adequate for the evaluation of COVID-19 diagnostic categories in this study, there are some false-negative patients. This study suggests the initial usage of 5-mm chest CT for diagnostic classification instead of 1 mm; however, we reckon that would be reasonable to further evaluate the thin slices after a negative result for pneumonia on 5 mm slices to avoid false-negative results.

In some studies, it is indicated that chest CT scoring systems could be used as a prognostic tool for patients' outcomes with demonstrating the severity of lung involvement.^{15,16} We used a lobar-based CT scoring system. Even if there was an excellent correlation between readers, the thin section assessment is found to be significantly different from the thick section on the first reader's evaluation. However, it is beyond the scope of this study to find which one is more correlative to clinical severity.

Our study has some limitations. Firstly, it was not investigated whether there was a difference in existing artifacts between different slice thicknesses which may affect the evaluation of findings properly. There is 1 study¹⁷ that suggested that thicker slices may reduce the artifacts. Secondly, in our paper, the images are acquired in a thin format and then converted into thicker slices by post-processing methods. So future studies may target the efficiency of slices that are acquired directly thick, which may also have a valuable role in reducing the patients' dose and CT acquisition time. Thirdly, the effect of different post-processing methods that can improve the image quality and enhance the detection of findings was not focused on in this paper. One example of this is minimum intensity projection (MinIP) projections.¹⁸ Finally, the retrospective design of this study made the evaluation times differ from the real scenarios. In a real scenario, it may help to investigate the time from beginning to CT acquisition to creating the final radiological report.

CONCLUSION

It was found that 5-mm reconstructed chest CT can be utilized for initial detection of COVID-19-related findings, the final diagnostic category instead of 1-mm slices. It offers a faster availability of results which can be beneficial for pandemic hospitals with the burden of patients. Future studies are needed on different CT protocols to shorten the patient dose and evaluation time with an increment on diagnostic accuracy.

Ethics Committee Approval: This study was approved by Ethics committee of Sivas Cumhuriyet University (Approval No: 2020-06/30).

Informed Consent: Written informed consent was obtained from the patients routinely before chest CT examination.

Peer-review: Externally peer-reviewed.

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