



COMPARISON OF CT REPORTING SYSTEMS IN PATIENTS UNDERGOING THORAX COMPUTED TOMOGRAPHY FOR COVID-19 PNEUMONIA

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SUMMARY – We aimed to compare three commonly used computed tomography (CT) reporting systems for COVID-19, i.e., Radiological Society of North America (RSNA) Consensus, British Society of Thoracic Imaging (BSTI) Guideline, and Dutch Radiological Society Categorical CT Assessment Scheme: COVID-19 Reporting and Data System (CO-RADS). Three thousand thoracic CT scans taken consecutively because of COVID-19 suspicion, diagnosis or follow-up after admission to our hospital between March 2020 and May 2020 were studied. All CT examinations were assigned to the appropriate groups of the aforementioned CT reporting systems and these systems were compared with each other. Thorax CT imaging did not reveal any findings indicative of infection (RSNA: 40.7%, BSTI: nonapplicable, and CO-RADS: 40.1%) in the vast majority of polymerase chain reaction (PCR) (+) cases in all three reporting systems. The highest number of cases was included in the groups classified as typical/classic/CO-RADS 5 findings in all three reporting systems (RSNA: 213, BSTI: 212, and CO-RADS:101) in COVID-19 diagnosed cases with lung findings. There was no significant difference between PCR (+) and (-) cases with probable COVID-19 infection according to BSTI reporting system and CO-RADS 4 cases (30/23, $p=0.381$ and 22/19, $p=0.245$, respectively). In addition, typical thoracic CT findings were observed in RSNA: 70, BSTI: 71, CO-RADS: 71 individuals in all three classifications, but the PCR result was detected negative. When the three reporting systems were compared, we concluded that they did not show distinct advantage to each other and all three ensured that patients were properly classified with similar accuracy.

Keywords: *COVID-19; Computed tomography; Pneumonia; Thorax; Polymerase chain reaction*

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Introduction

As a global problem, the COVID-19 pandemic has become the primary problem in all countries of the world. In diagnosis, in addition to the polymerase chain reaction test (PCR), it is stated that it is very valuable to see typical diffuse ground-glass infiltrations on thoracic computed tomography (CT)¹. CT has become an examination with widespread clinical use in the pandemic process thanks to its rapid applicability and high diagnosis rate². Recognition of possible COVID-19 infections with CT enables early isolation of suspected cases and early initiation of treatment¹. Causes other than viral pathologies can also produce clinical findings similar to COVID-19 pneumonia, and CT examination is frequently used in differential diagnosis³. For the reasons explained above, the need to recognize the COVID-19 thorax imaging findings and to report the findings in a common language has come to the fore.

Since the beginning of the pandemic, various attempts have been made to standardize the reporting of thoracic CTs taken for this purpose, with a range of articles that have contributed to the whole world in which thorax findings of COVID-19 are analyzed. Among these initiatives, the most accepted and used ones are thoracic imaging in COVID-19 infection guide prepared by The British Society of Thoracic Imaging (BSTI)⁴, expert consensus statement on reporting chest CT findings related to COVID-19, published by Radiological Society of North America (RSNA)⁵, and COVID-19 Reporting and Data System (CORADS) published by the Dutch Radiological Society⁶. All of the aforementioned three reporting systems aim to develop and standardize a common language in the reporting of thorax CTs. Although any of these classifications can be preferred in clinical practice, there are limited studies in the literature comparing these three classifications with each other, and so far, there is only one study on this subject⁷.

In this study, we aimed to compare three CT reporting systems for COVID-19 commonly used all over the world and to determine which system was more successful in detecting PCR positivity.

By accepting PCR positivity as the gold standard, we aimed to determine which of the three commonly used CT reporting systems for COVID-19 has

strongest correlation to either PCR positivity or negativity. This will help determine the compatibility and consistency between the systems. If there is a difference, it will clarify which is the better choice.

Material and Methods

Ethical issues

After obtaining special permissions from the national and local authorities (Ministry of Health and Provincial Health Directorates) for this study, the Ethics Committee approval was granted with the application letter dated June 1, 2020 and protocol number 2020/295.

Patient selection

Three thousand consecutive thoracic CT scans from cases with any COVID-19 contact or symptom were included in the study. Symptoms ranged from fever, dry cough, joint pain or sore throat to higher severity such as shortness of breath, respiratory failure or multiple organ dysfunction syndrome. These were cases with a COVID-19 diagnosis⁸ or follow-up after admission to the Department of Radiology, University of Health Sciences, Gulhane Education and Research Hospital, Ankara, Turkey, between March 2020 and May 2020.

Only thoracic CT examinations performed on one scanner dedicated to COVID-19 patients in our hospital were included in the study. Extrathoracic CT examinations of COVID-19 patients on the dedicated scanner or thoracic CT examinations taken on a different CT scanner due to COVID-19 not considered in the preliminary diagnosis were excluded from the study. Age was not used as an exclusion criterion for this study.

Patient evaluation

In addition to the evaluation of CT imaging findings of the patients, epidemiological characteristics of the cases were included in the study by accessing electronic medical records. Simultaneously, results of the reverse transcriptase polymerase chain reaction (RT-PCR) performed for the diagnosis of suspected COVID-19 were recorded.

The radiologists that evaluated CT images did not know that the patients were positive for COVID-19 except for the 141 patients whose request was stated to be PCR positive and were therefore classified as CO-RADS 6. CT studies of 3000 patients were included in the scope of evaluation and statistical calculations were made by accepting the PCR test result as the gold standard for the diagnosis of COVID-19 infection. Those in whom PCR test was not performed or whose test results could not be obtained for any reason were excluded from statistical evaluation. Cases with positive initial PCR or cases that were positive on repeated PCR test were considered as being diagnosed with COVID-19.

CT imaging protocol

All CT examinations were obtained on a 64-row CT scanner (Aquillon 64, Toshiba, Japan) with specified parameters without using contrast agents. CT scans were obtained with the following parameters: 100-120 kV, 50-150 mAs, 2-3 mm slice thickness, 1-2 mm slice interval, 500 ms rotation time, holding breath, arms up, 300-400 mm FOV, covering the whole lung from apex to basal. The images obtained were sent to the hospital Picture Archiving and Communication System (PACS).

Evaluation of CT images

All CT examinations were evaluated together by 2 radiologists (U.B. with 20 years and H.M.S. with 3 years of experience). In case of disagreement between the evaluations, final decision was made with consensus of both radiologists. All CT examinations were assigned to the appropriate group according to three different CT reporting systems evaluated in our study based on CT findings.

As previously described in the literature, all CT studies were divided into four groups as typical appearance, indeterminate appearance, atypical appearance, and negative for pneumonia group according to the RSNA expert consensus statement classification system; four groups as classic, probable, indeterminate and non-COVID groups according to the BSTI classification system; six groups as CO-RADS 1, -2, -3, -4, -5 and -6 groups according to the CO-RADS classification system⁴⁻⁶ (summarized in Table 1).

After deciding which groups the CT studies belonged to, three different reporting systems were compared with each other.

Statistical analyses

Statistical analyses were performed by the IBM SPSS for Windows version 23.0. Numerical variables were summarized as median (minimum-maximum). Categorical variables were given as frequencies and percentages. Categorical variables were compared by Pearson χ^2 -test or Fisher exact test. The normality of continuous variables was evaluated by Kolmogorov-Smirnov test. Differences between the groups for continuous variables were determined by independent samples t-test or Mann-Whitney U test, as appropriate. A p value less than 0.05 was considered as statistically significant.

Results

Results of the RT-PCR test were obtained in 845 of 3000 patients included in the study. There were 489 male and 356 female patients, their mean age was 52.78 (range, 2-99 years). When demographic data were examined, the PCR test result showed similar result distribution by gender ($p=0.708$). Median age of those with positive and negative PCR test was 50.85 and 55.71, respectively, yielding a statistically significant difference ($p=0.001$) (Table 2).

When all three reporting systems and CT findings in our study were evaluated together, in the vast majority of PCR (+) cases, thorax CT imaging did not reveal any finding indicative of infection (RSNA: 40.7%, BSTI: nonapplicable, and CO-RADS: 40.1%). The rate of BSTI classification could not be included due to the lack of an additional category within it, in which there was no finding indicating infection (Table 3).

In the cases with diagnosed COVID-19 infection and detected lung CT findings, the highest number of the cases was included in the groups classified as typical/classic/CO-RADS 5 findings in all three reporting systems (RSNA: 213, BSTI: 212, and CO-RADS: 101) (Table 3).

There was no significant difference between PCR (+) and (-) cases with probable COVID-19 infection

Table 1. Groups according to three reporting systems and their definitions

Reporting system		
Radiological Society of North America (RSNA) Consensus	Typical	<ul style="list-style-type: none"> Peripheral, bilateral, ground-glass opacities with or without consolidation or visible intralobular lines ('crazy-paving') Multifocal ground-glass opacities of rounded morphology with or without consolidation or visible intralobular lines ('crazy-paving') Reverse halo sign or other findings of organizing pneumonia (seen later in the disease)
	Indeterminate	Absence of typical features AND presence of: <ul style="list-style-type: none"> Multifocal, diffuse, perihilar, or unilateral ground-glass opacities with or without consolidation lacking a specific distribution and are nonrounded or nonperipheral Few very small ground-glass opacities with a nonrounded and nonperipheral distribution
	Atypical	Absence of typical or indeterminate features AND presence of: <ul style="list-style-type: none"> Isolated lobar or segmental consolidation without ground-glass opacities Discrete small nodules (centrilobular, 'tree-in-bud') Lung cavitation Smooth interlobular septal thickening with pleural effusion
	Negative	<ul style="list-style-type: none"> No CT features to suggest pneumonia
British Society of Thoracic Imaging (BSTI) Guideline	Classic	Lower lobe predominant, peripheral predominant, multiple, bilateral* foci of ground-glass opacities ± <ul style="list-style-type: none"> Crazy-paving Peripheral consolidation** Air bronchograms Reverse halo/perilobular pattern** * >1 lesion, but could still be unilateral; usually but not universally bilateral ** i.e. organizing pneumonia patterns
	Probable COVID-19	<ul style="list-style-type: none"> Lower lobe predominant mix of bronchocentric and peripheral consolidation Reverse halo/perilobular pattern** Ground-glass opacities scarce
	Indeterminate	<ul style="list-style-type: none"> Does not fit into definite, probable or non-COVID Manifests above patterns but the clinical context is wrong, or suggests an alternative diagnosis (e.g., an interstitial lung disease in a connective tissue disease setting)
	Non-COVID-19	<ul style="list-style-type: none"> Lobar pneumonia Cavitating infections Tree-in bud/centrilobular nodularity Lymphadenopathy, effusions Established pulmonary fibrosis
Dutch Radiological Society Categorical CT Assessment Scheme: COVID-19 Reporting and Data System (CO-RADS)	CO-RADS 1	No CT features to suggest pneumonia
	CO-RADS 2	<ul style="list-style-type: none"> Bronchitis, infectious bronchiolitis, bronchopneumonia, lobar pneumonia, and pulmonary abscess Tree-in-bud sign, a centrilobular nodular pattern, lobar or segmental consolidation, and lung cavitation
	CO-RADS 3	<ul style="list-style-type: none"> Perihilar ground-glass opacity, homogeneous extensive ground-glass opacity with or without sparing of some secondary pulmonary lobules, or ground-glass opacity together with smooth interlobular septal thickening with or without pleural effusion in the absence of other typical CT findings Small ground-glass opacities that are not centrilobular or not located close to the visceral pleura Patterns of consolidation compatible with organizing pneumonia without other typical findings of COVID-19
	CO-RADS 4	<ul style="list-style-type: none"> Findings are similar to CO-RADS 5 but are not located in contact with the visceral pleura or are located strictly unilaterally, are in a predominant peribronchovascular distribution, or are superimposed on severe diffuse pre-existing pulmonary abnormalities
	CO-RADS 5	<ul style="list-style-type: none"> Ground-glass opacities with or without consolidations in lung regions close to visceral pleural surfaces, including the fissures, and a multifocal bilateral distribution
	CO-RADS 6	<ul style="list-style-type: none"> Indicate proven COVID-19, as signified by positive RT-PCR test results for virus-specific nucleic acid

according to BSTI reporting system and CO-RADS 4 cases (30/23 p=0.381, 22/19 p=0.245, respectively) (Table 3). Since there is no specific category for possible COVID-19 findings in the RSNA classification, comparison could not be made.

When the cases that were classified as unclear whether COVID-19 was present (RSNA indeterminate, BSTI indeterminate and possible COVID-19, CO-RADS 3 and 4), we found that the number of patients with negative PCR results was higher than the number of patients with positive results (96/83, 97/84 and 99/60, respectively) (Table 3).

In addition, typical thoracic CT findings in all three classifications were observed in RSNA: 70, BSTI: 71 and CO-RADS: 71 patients, but we found that the PCR result was negative (Table 3).

Discussion

The highest distribution in PCR (+) cases evaluated in our study was in the category without thoracic CT findings indicating pneumonia in the RSNA and CO-RADS classification system (40.7% and 40.1%,

Table 2. Demographic findings of the study

		PCR test (-)	PCR test (+)	Total	p value
		Median (min-max) or n (%)	Median (min-max) or n (%)	Median (min-max) or n (%)	
Gender	Female	137 (42.95)	219 (41.6)	356 (42.1)	0.708
	Male	182 (57.1)	307 (58.4)	489 (57.9)	
Age		55.71 (10-95)	50.85 (2-95)	52.78 (2-99)	0.001

PCR = polymerase chain reaction

Table 3. Correlation of PCR test results with different CT reporting systems

Reporting system		PCR test		Total	p value
		Negative	Positive		
Radiological Society of North America (RSNA) Consensus	Typical	70 (21.9%)	213 (40.5%)	283 (33.5%)	<0.001
	Indeterminate	96 (30.1%)	83 (15.8%)	179 (21.2%)	<0.001
	Atypical	65 (20.4%)	16 (3.0%)	81 (9.6%)	<0.001
	Negative	88 (27.6%)	214 (40.7%)	302 (35.7%)	<0.001
British Society of Thoracic Imaging (BSTI) Guideline	Classic	71 (22.3%)	212 (40.3%)	283 (33.5%)	<0.001
	Probable	23 (7.2%)	30 (5.7%)	53 (6.3%)	0.381
	Indeterminate	74 (23.2%)	54 (10.3%)	128 (15.1%)	<0.001
	Non-COVID-19	151 (47.3%)	230 (43.7%)	381 (45.1%)	0.301
Dutch Radiological Society Categorical CT Assessment Scheme: COVID-19 Reporting and Data System (CO-RADS)	CO-RADS 1	88 (27.9%)	211 (40.1%)	299 (35.5%)	<0.001
	CO-RADS 2	61 (19.1%)	13 (2.5%)	74 (8.8%)	<0.001
	CO-RADS 3	80 (25.1%)	38 (7.2%)	118 (14.0%)	<0.001
	CO-RADS 4	19 (6.0%)	22 (4.2%)	41 (4.9%)	0.245
	CO-RADS 5	71 (21.9%)	101 (19.2%)	172 (20.2%)	0.336
	CO-RADS 6	0 (0%)	141 (26.8%)	141 (16.7%)	<0.001

CT = computed tomography; PCR = polymerase chain reaction

respectively). It was evaluated that COVID-19 infection predominantly progressed without causing lung findings on CT (Table 3). When two meta-analyses are reviewed in the available literature, it is observed that the rate of no finding on CT in PCR positive cases varies between 2% and 91%^{2,9}. Although the rate we found in our study was within this range, differences in rates can be related to the number of patients in the studies, one or more examinations performed in patients, patient inclusion criteria (symptomatic or asymptomatic), using PCR positive and/or clinical positivity as the gold standard, time differences between the onset of symptoms and timing of CT, etc. The fact that in our study, PCR positive cases were found in the category where no positive CT imaging finding was detected supports consideration that CT should not be used as an exclusion criterion for COVID-19 infection⁷.

When the non-COVID-19 finding category in the BSTI classification was examined, it was seen that 43.7% of the PCR (+) cases and 47.3% of the PCR (-) cases were in this group, and there was no statistically significant difference between these two patient groups ($p=0.301$). In the study by Inui *et al.*, the PCR (+) rate of cases in the group of non-COVID findings in the BSTI classification is reported as 8.7%, and the rate of

PCR (-) cases as 44.7%; however, no data on statistical comparison are available⁷. The reason for not finding any statistical difference between the two groups in our study could be the fact that the non-COVID-19 finding category may have included both findings without pulmonary involvement and findings suggesting non-COVID-19 infection (Fig. 1).

Another major finding in our study was that, if COVID-19 infection caused findings in CT, thorax CT findings fitting the group classified as typical findings in all three reporting systems were most common (Table 3). When the literature is reviewed, we see that the most common findings in most cases diagnosed with COVID-19 infection are typical CT findings^{5,7,10}. In this respect, our study is similar to the results of the studies in the literature.

In our study, when we compared the cases evaluated in the group of probable COVID-19 infection according to the BSTI classification and cases in the category CO-RADS 4, there was no statistically significant difference between PCR (+) and PCR (-) in these groups ($p=0.381$ and $p=0.245$, respectively) (Figs. 2 and 3). This situation was thought to occur because of the fact that COVID-like thorax CT findings could also be seen in viral pneumonias other than COVID-19^{3,10}. When the

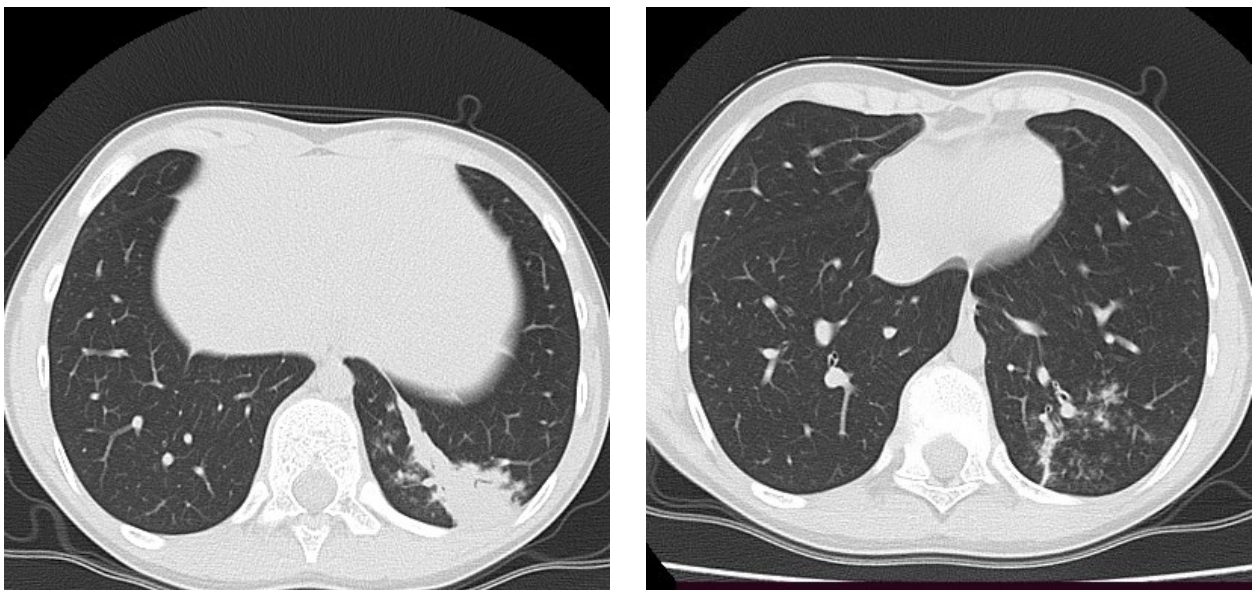


Fig. 1. Two axial images of the same patient show a tree-in-bud pattern and segmental consolidation in the left lower lobe. CT study was categorized as atypical appearance in RSNA consensus, non-COVID-19 in BTSI Guideline, and CO-RADS 2 in CO-RADS system. PCR test result of the patient was negative.

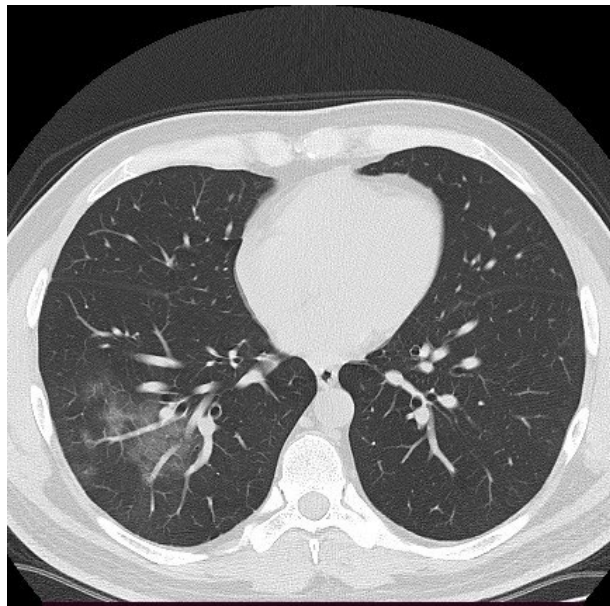


Fig. 2. Axial CT image shows peribronchovascular, ground-glass opacity in the right lower lobe. CT study was categorized as indeterminate appearance in RSNA consensus, probable COVID-19 in BSTI Guideline, and CO-RADS 4 in CO-RADS system. PCR test result of the patient was negative.

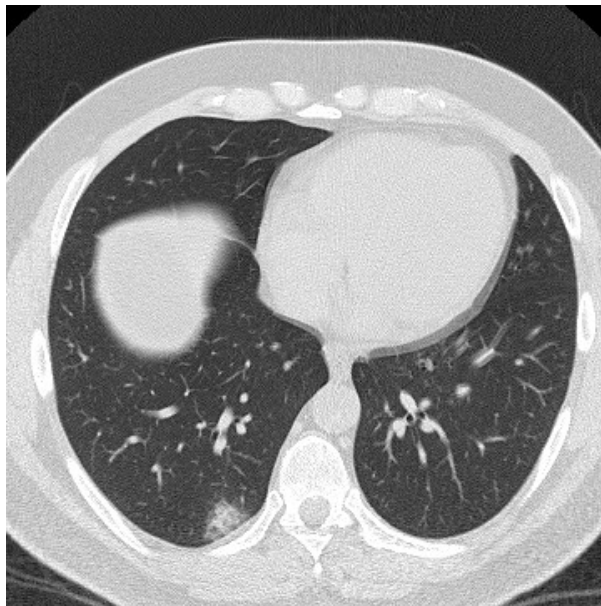


Fig. 3. Axial CT image shows peripheral, ground-glass opacity in the right lower lobe (there were no ground-glass opacities seen in other lobes). CT study was categorized as indeterminate appearance in RSNA consensus, probable COVID-19 in BSTI Guideline, and CO-RADS 4. PCR test result of the patient was positive.

literature is reviewed for probable COVID-19 (according to BSTI category) and CO-RADS 4 cases, it is observed that there is no significant difference between RT-PCR (+) and RT-PCR (-), supporting this idea (BSTI: 6.7%-6.7% and CO-RADS: 21%-20.7%, respectively)⁷. In our study, we found the following rates: BSTI: 5.7%-7.2%, and CO-RADS: 4.2%-6%.

In our study, patients that fell into the unclassifiable group of COVID-19 (RSNA indeterminate, BSTI indeterminate, and CO-RADS 3) were outnumbered by patients who came in negative with PCR results (Table 3), suggesting a trend towards PCR (-) in categories that were described as uncertain. A study conducted by Inui *et al.* similarly shows that cases with a negative PCR result are more numerous⁷.

In our study, according to the CO-RADS classification, the number of CO-RADS 5 subjects was close to the number of PCR (+) and (-) in the category. We think that this situation occurs because patients with typical COVID-19 findings not defined in any classification other than the CO-RADS classification

and with known PCR (+) are classified as CO-RADS 6 in the CO-RADS classification. When the literature is reviewed, since the CO-RADS 6 cases were not included in the classification, the positive rates of CO-RADS 5 cases were numerically higher than the negative ones, which is different from our study^{6,7}.

When all three classifications in our study were reviewed: RSNA: 70 (21.9%), BSTI: 71 (22.3%) and CO-RADS: 71 (21.9%), the reason that we detected thorax CT findings suggesting typical COVID-19 appearance but no positivity detected on PCR examination (Fig. 4) was thought to be related to false negativity of the PCR test, as suggested in the meta-analysis by Waller *et al.*⁹. In the study by Inui *et al.*, the following rates were recorded: RSNA: 69 (17.2%), BSTI: 24 (6%) and CO-RADS: 44 (11%)⁷.

Our study had some limitations. We could not count patients who had thorax CT scan but could not reach PCR results in electronic records from statistical evaluation, CTs were not evaluated in terms of COVID-RADS classification, our study was a

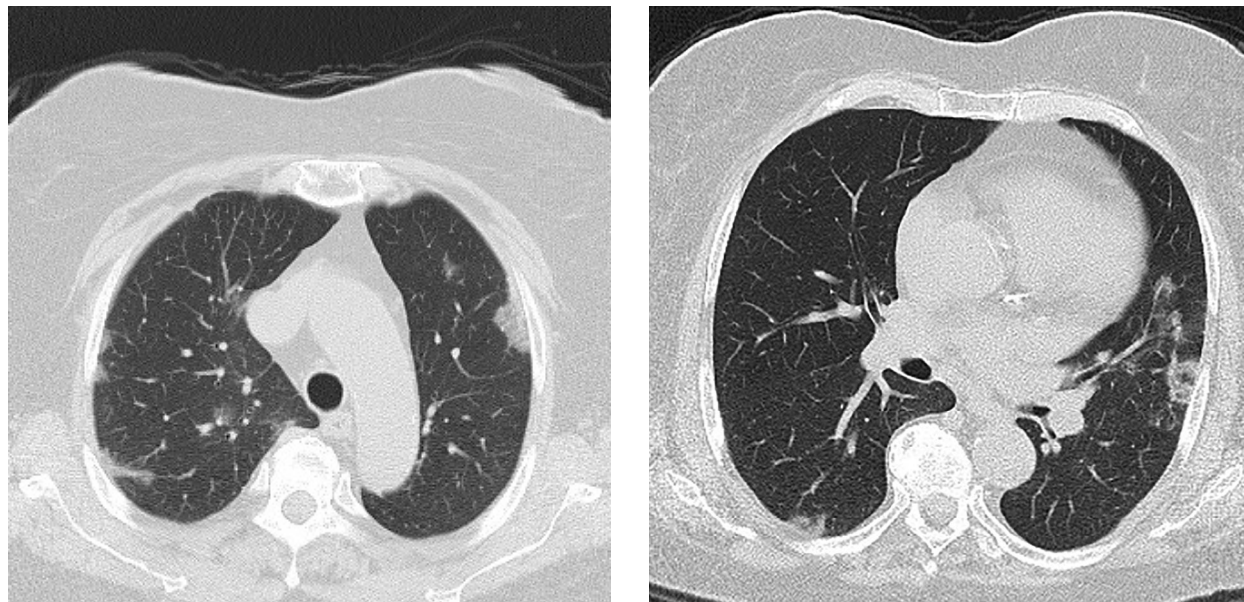


Fig. 4. Two axial images (a, b) of the same patient show peripheral, multilobar, ground-glass opacities. CT study was categorized as typical appearance in RSNA consensus, classic appearance in BSTI Guideline, and CO-RADS 5 in CO-RADS system. PCR test result of the patient was negative.

retrospective study, and no interobserver comparison was made.

In conclusion, when the three reporting systems are compared with each other, they do not show distinct advantage to each other in the classification of CT findings in terms of COVID-19 but ensure that patients are properly classified with similar accuracy.

Main points

- The highest distribution of PCR (+) cases evaluated in our study was in the category without thoracic CT findings indicating pneumonia.
- The fact that PCR positive cases were found in the category where no finding was detected on CT in our study supports the view that CT should not be used as an exclusion criterion.
- If COVID-19 infection causes findings in CT, thorax CT findings that fit the group classified as typical findings in all three reporting systems are most common.
- When we look at the cases evaluated in the group of probable COVID-19 infection according to

the BSTI classification and cases in the category CO-RADS 4, there is no statistically significant difference between PCR (+) and PCR (-) in these groups.

- Patients that fell into the unclassifiable group of COVID-19 (RSNA indeterminate, BSTI indeterminate, CO-RADS 3) were outnumbered by patients who came in negative with PCR results.

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Sažetak

USPOREDBA CT IZVJEŠĆA U BOLESNIKA PODVRGnutIH KOMPJUTORIZIRANOJ TOMOGRAFIJI PRSNOGA KOŠA ZBOG UPALE PLUĆA UZROKOVANE VIRUSOM COVID-19

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Cilj je bio usporediti tri najčešća načina izvješćivanja o nalazu kompjutorizirane tomografije (CT) za COVID-19, tj. *Radiological Society of North America (RSNA) Consensus*, *British Society of Thoracic Imaging (BSTI) Guideline* i *Dutch Radiological Society (DRS) Categorical CT Assessment Scheme: COVID-19 Reporting and Data System (CO-RADS)*. Ispitane su tri tisuće uzastopno uzetih CT prikaza prsnoga koša zbog sumnje, dijagnoze ili praćenja COVID-19 nakon prijma u našu bolnicu između ožujka 2020. i svibnja 2020. godine. Svi CT prikazi dodijeljeni su u odgovarajuće skupine gore spomenutih CT sustava izvješćivanja te su ovi sustavi međusobno uspoređeni. CT prikazi prsnoga koša nisu otkrili nikakve nalaze koji bi ukazivali na infekciju (RSNA: 40,7%, BSTI: nije primjenjivo i CO-RADS: 40,1%) u velikoj većini slučajeva pozitivnih na PCR (+) u sva tri sustava izvješćivanja. Kod slučajeva COVID-19 dijagnosticiranih pomoću plućnih nalaza najveći broj slučajeva bio je uključen u skupine klasificirane kao tipični/klasični/ CO-RADS 5 nalazi u sva tri sustava izvješćivanja. Nije bilo značajne razlike između nalaza PCR (+) i PCR (-) s mogućom infekcijom COVID-19 prema sustavu BSTI i CO-RADS 4 slučajevima (30/23, $p=0,381$ odnosno 22/19, $p=0,245$). Usto, tipični CT nalazi prsnoga koša zabilježeni su u svim trima klasifikacijama: RSNA: 70, BSTI: 71, CO-RADS: 71 osoba, ali je kod njih rezultat PCR bio negativan. Kad su uspoređena tri načina izvješćivanja došli smo do zaključka kako nijedan nema očitih prednosti u odnosu na druga dva, a sva tri podjednako točno osiguravaju ispravnu klasifikaciju bolesnika.

Ključne riječi: COVID-19; Kompjutorizirana tomografija; Upala pluća; Prsni koš; Lančana reakcija polimerazom