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The Compatibility of Chest CT Scan with RT-PCR in Suspected COVID-19 Patients

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Abstract

BACKGROUND: Thoracic computed tomography (CT) scan plays a role in detecting and assessing the progression of COVID-19. It can evaluate the response to the therapy given. In diagnosis, the CT scan of the chest may complement the limitations of reverse transcription polymerase chain reaction (RT-PCR). Several recent studies have discussed the importance of CT scans in COVID-19 patients with false-negative RT-PCR results. The sensitivity of chest CT scan in the diagnosis of COVID-19 is reportedly around 98%.

AIM: This study aimed to determine the compatibility of CT scan of the thorax with RT-PCR in suspected COVID-19 patients.

MATERIALS AND METHODS: This research was conducted in the Radiology Department of the Wahidin Sudirohusodo Hospital Makassar from April to December 2020 with 350 patients. The method used was a 2 × 2 table diagnostic test.

RESULTS: The study included 188 male patients (53.7%) and 162 female patients (46.2%). The most common age group was 46–65 years (35.4%). The most common types of lesions were ground-glass opacity (163 cases), consolidation (128 cases), and fibrosis (124 cases), mostly found in the inferior lobe with a predominantly peripheral or subpleural distribution. The sensitivity of the CT scan to the PCR examination was 86%, and the specificity was 91%.

CONCLUSION: Thoracic CT scan was a good modality in establishing the diagnosis of COVID-19. CT scan of the chest with abnormalities could confirm the diagnosis in 88% of cases based on RT-PCR examination. It excluded the diagnosis in 91% based on the RT-PCR examination. The accuracy of the thoracic CT scan was 88% with RT-PCR as the reference value.

Introduction

On December 31, 2019, the World Health Organization (WHO) China Country Office reported a case of pneumonia of unknown etiology in Wuhan City, Hubei Province [1], [2]. On January 7, 2020, China identified the pneumonia of unknown etiology as a new type of coronavirus [3], [4].

Thoracic computed tomography (CT) scan plays a role in detecting and assessing the progression of COVID-19 and can evaluate the response to the therapy given. In diagnosis, the CT scan of the chest may complement the limitations of reverse transcription polymerase chain reaction (RT-PCR) [5]. Several recent studies have discussed the importance of CT scans in COVID-19 patients with false-negative RT-PCR results [6], [7], [8]. The SARS-CoV-2 genome has been found in biological samples using rRT-PCR technology. Despite being approved by the Centers for Disease Control and Prevention and the WHO as the gold standard test for the confirmation of COVID-19 and having a moderate sensitivity and high specificity, this approach has produced a significant number of false-negative results, which should be carefully considered. Pre-test (pre-analytical) errors and factors may have an impact on the results, such as the sampling method, sampling location, sampling time, sample size, sample transfer, and storage errors. Factors during the test (analytical) are also possible, such as nucleic acid extraction, cDNA synthesis, and PCR process. Finally, post-analytical errors, such as interpretation and analysis of the results and test report, can have an impact [9].

The reported sensitivity of chest CT scan in the diagnosis of COVID-19 is around 98%. It can show different features depending on the onset and severity of the disease [10]. Imaging in COVID-19 may show bilateral opacities, subsegmental consolidation, lobar or collapsed lung or nodules, or ground-glass appearance. In the early stages, multiple shadows of small plaques with clear interstitial changes are seen in the periphery of the lung and then progress to multiple ground-glass shadows and infiltrates in both lungs. In severe cases, pulmonary consolidation may be found, even rarely “white lung” and pleural effusion [11].

Based on the findings of the thoracic CT scan, groupings of COVID-19 diagnoses have been made from several previous studies. This prediction based on chest CT scan was valid even before the RT-PCR results were available [12].

In various previous studies, the samples used were patients with suspected COVID-19 without excluding other comorbid conditions. The authors have not found a study in Indonesia, especially in South Sulawesi, on the suitability of chest CT scan imaging with RT-PCR results to diagnose COVID-19. Although the definitive diagnosis of COVID-19 is through RT-PCR examination, in Indonesia, not all provinces have adequate RT-PCR facilities. Specimens must be sent to a suitable laboratory, which takes a long time. This study aimed to determine the compatibility of thoracic CT scan with RT-PCR to diagnose suspected COVID-19 patients.

Materials and Methods

This was a cross-sectional study of 350 patients suspected of having COVID-19. It was conducted in the Radiology Department, Dr. Wahidin Sudirohusodo Hospital Makassar, from April 2020 to December 2020. The study was approved by the Health Research Ethics Committee of Hasanuddin University (No. 41/ UN4.6.4.5.31/PP36/2021).

The population of this study was patients sent to the radiology section of RSUP Dr. Wahidin Sudirohusodo Hospital to undergo a chest CT scan and RT-PCR nasopharyngeal swab. They were selected by consecutive sampling. The inclusion criteria were all patients suspected by a clinician of having COVID-19 who underwent a chest CT scan and RT-PCR nasopharyngeal swab. All patients whose thoracic CT scan images had many artifacts, and all referred patients who underwent a thoracic CT scan and were PCR-positive for COVID-19 at a hospital other than Wahidin Sudirohusodo Hospital, were excluded from the study.

CT scan imaging

The chest CT scans were radiological images taken from suspected COVID-19 patients. They were performed for the 1st time, close to the RT-PCR examination at Dr. Wahidin Sudirohusodo Hospital. The following imaging characteristics were recorded: Consolidation, ground-glass opacity (GGO), crazy paving, halo sign, air bronchogram sign (ABS), lung nodules, lymphadenopathy, fibrosis line, and pleural effusion [12]. The location of the lesion is based on the anatomy of the five lobes of the right and left lungs: Right lobe (right upper lobe, right middle lobe, and right lower lobe [RLL]) and left lobe (left upper lobe and left lower lobe [LLL]) [13].

Polymerase chain reaction

The RT-PCR in this study was a biomolecular examination with samples taken from a 1st-time nasopharyngeal swab of a patient suspected of COVID-19 at the time closest to the first thoracic CT scan. The results were grouped into positive and negative.

Data collection

The identity of patients who met the inclusion criteria in the thoracic CT scan examination was recorded. The patient’s position was lying supine quietly on the examination table. The thoracic scan was performed during deep inspiration. The scan used a 1.25-mm scan slice, axial slice, and coronal and sagittal reformat. The researchers recorded the results of the RT-PCR examination based on the results from the clinical pathology laboratory, then recorded the patient’s primary and secondary diagnoses based on the decision of the clinician. The researchers analyzed the characteristics of the CT scan of the thorax and recorded the results. They then analyzed the compatibility between the CT scan and the results of the RT-PCR examination.

Statistical analysis

Statistical analysis in this study used Statistical Package for the Social Sciences software version 19.0 (Armonk, NY, USA: IBM Corp.). Statistical analysis used a 2 × 2 table diagnostic test. The data analysis methods used were univariate and bivariate analysis. Univariate analysis described with numbers and percentages each group of GGO variables, lesion location, consolidation, crazy paving, halo sign, lung nodules, tree-in-bud, ABS, lymphadenopathy, fibrosis lines, and pleural effusion with RT-PCR results. Bivariate analysis aimed using the Chi-square test to analyze whether a significant relationship existed between the RT-PCR results and the descriptions of each group from the GGO variables, lesion location, consolidation, crazy paving, halo sign, lung nodules, tree-in-bud, ABS, lymphadenopathy, fibrosis lines, and pleural effusion.

Results

Table 1 shows the demographics of the research sample based on age group and sex.

Table 1: Distribution based on age and gender

Category	n	%
Sex		
Male	188	53.7
Female	162	46.2
Age (years)		
≤11	21	6
12–25	38	10.8
26–45	113	32.2
45–65	124	35.4
>65	54	15.4

Most participants were male (188; 53.7%), with a minority female (162; 46.2%). Most were in the age range of 46–65 years (35.4%), with the fewest in the range of ≤11 years (6%).

Distribution of lesion types

Table 2 shows that the most common type of lesion was GGO, appearing in 163 cases, followed by consolidation in 128 cases and fibrosis in 124 cases.

Table 2: Lesion distribution

Lesion type	n	PCR (+)	PCR (-)
GGO	163	158	5
Consolidation	128	88	40
Crazy paving	94	91	3
Halo sign	11	11	0
Nodule	5	1	4
Tree-in-bud	19	4	15
ABS	23	5	17
Lymphadenopathy	10	2	8
Fibrosis	124	78	46
Pleural effusion	20	4	16

Distribution of lesion location

The distribution of the lesion locations in the lung parenchyma is presented in Table 3.

Table 3 shows that GGO lesions were more common in RT-PCR-positive patients with LLL (10) in 110 cases, followed by RLL (10) in 103 cases. Consolidated lesions were more common in RT-PCR-positive patients with RLL locations (10), with 94 cases, followed by LLL locations (10) in 86 cases. Fibrosis lesions were more common in RT-PCR-positive patients with RLL location (10), with 72 cases, followed by LLL location (10) in 68 cases. Crazy paving lesions were more common in RT-PCR-positive patients with LLL location (10), with 74 cases, followed by RLL location (10) in 87 cases. Nodular lesions were more common in RT-PCR-negative patients, with four cases. Tree-in-bud lesions were more common in RT-PCR-negative patients, with 15 cases. Halo sign lesions were more common in RT-PCR-positive patients, with 11 cases. ABS lesions mostly occurred in RT-PCR-negative patients, with 17 cases.

Distribution of pleural effusion location

Table 4 shows that the most common location of lesions was unilateral in RT-PCR negative patients, and lymphadenopathic lesions occurred in RT-PCR-negative patients in 10 cases.

Data analysis

The data obtained in the study were analyzed by epidemiological analysis. The distribution of CT and PCR examinations is presented in Table 5.

Sensitivity and specificity

The calculation of the sensitivity and specificity tests obtained the results as shown in Table 6.

Table 6 shows that the sensitivity of the CT scan to the PCR examination was 86%. This means that the positive CT scan findings could confirm 86% of COVID-19 patients according to the PCR examination. The specificity was 91%, meaning that the CT scan could exclude COVID-19 in 91% of patients based on the PCR examination.

The results of the positive predictive value (PPV) and negative predictive value (NPV) tests obtained the results as shown in Table 7.

Table 3: Lesion location distribution

Location	CT Imaging and PCR															
	GGO		Consolidation		Crazy paving		Halo sign		Lung nodules		Tree-in-bud		ABS		Fibrosis line	
	PCR		PCR		PCR		PCR		PCR		PCR		PCR		PCR	
	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-
RUL (1)	60	1	34	23	16	0	0	0	0	0	0	12	0	0	26	16
RUL (2)	59	0	46	40	12	0	0	0	0	0	2	8	3	8	31	20
RUL (3)	40	0	37	24	23	0	0	0	0	0	0	0	0	0	28	15
RML (4)	48	0	26	21	18	2	0	0	0	0	0	0	0	0	18	12
RML (5)	44	0	33	24	23	0	0	0	0	0	0	0	1	3	14	8
RLL (6)	81	1	56	17	45	3	0	0	0	0	0	0	0	0	18	12
RLL (7)	76	0	63	17	52	2	0	0	0	0	0	0	0	0	42	15
RLL (8)	72	0	76	15	71	0	0	0	0	0	2	5	0	0	54	23
RLL (9)	98	0	78	14	74	0	1	0	0	3	0	0	0	0	43	35
RLL (10)	103	0	84	16	87	2	4	0	0	0	0	0	0	0	72	14
LUL (1)	55	1	52	11	16	0	0	0	1	2	0	8	0	6	18	20
LUL (2)	63	2	67	18	13	0	0	0	0	0	0	4	0	5	14	12
LUL (3)	46	2	28	11	16	0	0	0	0	0	0	5	0	8	18	10
LUL (4)	62	0	36	15	14	0	0	0	0	0	0	0	0	0	15	8
LUL (5)	56	0	63	12	12	0	0	0	0	0	0	0	0	2	12	10
LLL (6)	76	1	34	8	42	0	0	0	0	0	0	0	0	6	42	14
LLL (7)	83	0	39	7	56	0	1	0	0	2	0	0	0	3	53	21
LLL (8)	94	0	42	10	61	2	1	0	0	2	0	0	1	4	67	26
LLL (9)	97	0	52	13	68	0	1	0	0	0	0	0	1	1	54	22
LLL (10)	110	0	86	12	74	0	3	0	0	0	0	0	1	5	68	11

+: Positive. -: Negative, RUL: Right upper lobe, RML: Right middle lobe, RLL: Right lower lobe, LUL: Left upper lobe, LLL: Left lower lobe.

Table 4: Distribution of pleural effusion location and lymphadenopathy lesion

Characteristic	PCR	
	Positive	Negative
Pleural effusion location		
Unilateral	3	10
Bilateral	1	6
Lymphadenopathy lesion	2	8

Table 7 shows that the PPV from the CT scans was 94%, which means that the CT scan could produce a 94% of probability of confirming COVID-19. The CT scan showed an NPV of 80.4%, which means that it had an 80.4% probability of excluding COVID-19.

Table 5: Distribution of CT and PCR examination

CT and PCR cross-tabulation		
Count	PCR	
	Positive	Negative
CT		
Positive	186	11
Negative	30	123

Discussion

This test of the suitability of thoracic CT scan with RT-PCR to diagnose COVID-19 showed that the sensitivity of the CT scan was 86%. Other studies reported 98% [10] and 89% [14]. With results above 80% in accordance with other studies, the sensitivity of CT scans in diagnosing COVID-19 is proven to be good. If we look at the 91% of specificity of the CT scan examination in this study, then the CT scan is appropriate to rule out the diagnosis of COVID-19. This result is in line with another study by Dangis *et al*. in Belgium, which obtained a specificity result of 93.6% [15]. A study by Xiong in China obtained a PPV value of 96.2% [16], not much different from this study, where the PPV value was 94.4%. These results show that CT scan examination can be used in the diagnosis of COVID-19.

Several types of lesions were most commonly found on chest CT scans in this study. GGO appeared in 163 cases, with 158 cases of confirmed PCR (+) and five cases of PCR (-). Consolidation appeared in 128 cases, with 88 cases of PCR (+) and 40 cases of PCR (-). Fibrosis appeared in 124 cases, with 78 cases of PCR (+) and 46 cases of PCR (-). Crazy paving appeared in 91 cases of confirmed PCR (+). These results are in accordance with the research of Kassem and Masallat [5], which showed several chest CT images in 53 cases of progressive confirmed PCR (+) COVID-19: GGO (20 cases), GGO and peribronchovascular consolidation (10 cases), GGO and crazy paving (eight cases), bilateral diffuse GGO (10 cases), and GGO and mediastinal lymphadenopathy (five cases). Another study by Zhou *et al*. [17] showed that CT scans of the thorax in COVID-19 pneumonia had several characteristics: GGO (64.7%); GGO with consolidation (32.4%); rounded opacities (29.4%), which may involve the peripheral lung area (35%); and crazy paving (23%).

Table 6: Sensitivity and specificity tests

CT-PCR cross-tabulation	PCR	
	Positive	Negative
CT		
Positive		
Count	186	11
% within PCR	86%	9%
Negative		
Count	30	123
% within PCR	13%	91%

Table 7: Positive predictive value and negative predictive value tests

CT-PCR cross-tabulation	PCR	
	Positive	Negative
CT		
Positive		
Count	186	11
% within CT	94.4%	5.6%
Negative		
Count	30	123
% within CT	19.6%	80.4%

This study also found some chest CT images that are rare in COVID-19 patients. These were pleural effusion in 20 cases, with four confirmed cases of PCR (+) and 16 cases of PCR (-); nodules in five cases, with one case of PCR (+) and four cases of PCR (-); tree-in-bud in 19 cases, with four cases of PCR (+) and 15 cases of PCR (-); ABS in 23 cases, with five cases of PCR (+) and 17 cases of PCR (-); lymphadenopathy in 10 cases, with two cases of PCR (+) and eight cases of PCR (-); and a halo sign in 11 cases of confirmed PCR (+). These results are in accordance with alternative (non-COVID-19) CT images according to the British Society of Thoracic Imaging (BSTI), namely, isolated lobar or segmental consolidation, absent GGO, discrete nodules, centrilobular, tree-in-bud, cavities, thickened septa, lymphadenopathy, and pleura effusions [18], [19]. The same results were shown by Zhou *et al*. [17], where chest CT features such as pleural effusion (2.9%), enlarged lymph nodes (0%), and cavity (0%) were rarely found or even ruled out the possibility of COVID-19. According to Shi *et al*. [20], chest CT images such as pleural effusion, small nodules, tree-in-bud lesions, and enlarged lymph nodes are strongly associated with bacterial superinfection or even exclude the possibility of COVID-19 pneumonia. Based on the results of this study, the location of GGO lesions, fibrosis, consolidation, and crazy paving in PCR-positive confirmed patients was the inferior lobe, with a dominant distribution in the periphery or subpleural. The results of this study are in accordance with the classic chest CT image according to the BSTI, which shows lesions in the inferior lobe, peripheral distribution, and multiple and bilateral foci of GGO possibly accompanied by crazy paving and peripheral consolidation [18].

GGO on chest CT images represents increased lung opacity, as opposed to increased homogeneity of lung consolidation. The radiographic results of patients with SARS-CoV-2 vary, such as pulmonary consolidation, subsegmental pulmonary vasodilation, and interlobular septal thickening, with or without an air bronchogram, but GGO is the most common CT finding [21].

Cells infected with SARS-CoV-2 express many interferons and cytokines, including IL-1, IL-6, IL-7, IL-8, IL-9, IL-10, IL-12, granulocyte-macrophage colony-stimulating factor (GMCSF), interferon-γ, monocyte chemoattractant protein-1, and TNF-α. This abundance of cytokines is called a cytokine storm and it stimulates many leukocytes to attack virus-infected alveolar cells. Therefore, the infected alveolar cells are destroyed, causing an inflammatory process around the damaged cells, resulting in interstitial edema, collapse of the alveoli, and exudate, causing a GGO image on a thoracic CT scan [21], [22].

COVID-19 has four stages on chest CT: the early stage (0–5 days after the onset of symptoms), which is characterized by normal findings or mainly GGO; the progressive stage (5–8 days after symptom onset), characterized by increased GGO and a crazy paving appearance; the peak stage (9–13 days after symptom onset), which is characterized by progressive consolidation; and the advanced stage (≥14 days after symptom onset), which is characterized by a gradual decrease in consolidation and GGO, while signs of fibrosis (including parenchymal and traction bronchiectasis) manifest [6]. The limitations of this study were not looking attention to symptoms and severity of the disease, laboratory parameters, comorbidities, and comparison of patients with a history of COVID-19 vaccination and without a vaccine.

Conclusion

The most common lesions found on chest CT scans of patients with positive RT-PCR for COVID-19 were GGO, consolidation, and fibrosis, with a predilection for the inferior lobe of the posterobasal segment of the lung bilaterally and a predominantly peripheral or subpleural distribution. Thoracic CT scan showed a sensitivity of 86%, making it a good modality for establishing the diagnosis of COVID-19. It showed a specificity of 91% and can be used to exclude the diagnosis of COVID-19. CT scan of the chest with abnormalities can confirm as many as 88% of cases and exclude 91% based on RT-PCR examination. The accuracy of the CT scan was 88% with the reference value of RT-PCR.

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