Description of the CT Chest Findings in COVID-19 Infection and Validation of CORADS Criteria in Establishing Diagnosis

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Abstract

Introduction: Coronavirus disease 2019 (COVID-19) first emerged in China and rapidly spread in the world causing a pandemic. The pandemic of COVID-19 has caused a major global crisis and continues to put tremendous stress on health-care systems worldwide. It is essential to detect the disease at an early stage to isolate infected persons from the healthy population and give them appropriate treatment. Because most patients infected with *COVID-19* had characteristic CT imaging patterns, radiologic examinations have become vital in early diagnosis of disease course. For standardization, Dutch Radiological Society developed CO-RADS criteria. **Aim:** to describe the spectrum CT findings in *COVID-19* and to validate CORADS system, using the RT-PCR for COVID 19 as gold standard. **Methods:** A group of 195 patients proved to have *COVID-19* infection (by positive RT-PCR) and underwent CT chest studies were recruited excluding patients who had negative RT-PCR test or whom CT chest exams were technically insufficient. CT images were reviewed for: presence of lesions, types of lesions, and distribution of lesions. The CORADS score were assigned for each case. Then the classification of the lesions and CORADS score were compared to the RT-PCR test results. **Results:** Lesions were present in 166 patients while 29 patients had normal CT chest. Median CO-RADS score was 5. Compared to PCR, CO-RADS sensitivity was 72.7%, with a false-negative rate of 27.3%. **Conclusion:** CORADS system is no so sensitive and we cannot depend on it alone to exclude the possibility of *COVID-19* infection.

Keywords: CT chest, *COVID-19* infection, CORADS.

Introduction:

A large outbreak of a novel coronavirus infection occurred in Wuhan, Hubei Province, China in December 2019. The 2019 novel corona virus (2019-nCoV) or the severe acute respiratory corona virus 2 (SARS-CoV-2) or the coronavirus disease (*COVID-19*) as it is named by the World Health Organization (WHO), rapidly spread from its origin to the rest of the world causing a pandemic **(1).**

The pandemic of COVID-19 has caused a major global crisis and continues to put tremendous stress on health-care systems and societies worldwide. Early diagnosis, quarantine, and supportive treatments are essential to cure patients **(2).**

Because most patients infected with COVID-19 had pneumonia and characteristic CT imaging patterns, radiologic examinations have become vital in early diagnosis and the assessment of disease course **(3)**.

Structured reporting systems simplify the interpretation and reporting of imaging examinations, serve as a framework for consistent generation of recommendations, and improve the quality of patient care. While cardiothoracic radiologists may be familiar with some of these terms, the present variability in lexicon may be confusing for other radiology sub-specialties and referring healthcare providers. To ensure coherent and consistent communication between the healthcare providers, development of a standardized reporting format and lexicon is essential **(4).**

The Dutch Radiological Society (NVvR) developed CO-RADS based on other efforts for standardization, such as Lung-RADS or BI-RADS. CO-RADS assess the suspicion for pulmonary involvement of *COVID-19* on a scale from 1 (very low) to 5 (very high). The system is meant to be used in patients presenting with moderate to severe symptoms of *COVID-19* **(5).**

Although CORADS system has meaningful diagnostic power in symptomatic patients, it has some limitations. CORADS sensitivity in asymptomatic patients is insufficient to justify its use as screening approach. Another main limitation is that most studies were conducted in the pandemic phase of *COVID-19* infection, in a time frame with low prevalence of other respiratory viral infections such as influenza that can induce similar radiological abnormalities **(6)**.

Aim of the work:

The aim of the work is to describe the spectrum CT findings in COVID-19 and to validate CORADS criteria as a mean of establishing the diagnosis of COVID-19, using the RT-PCR for COVID 19 as gold standard.

Patients and Methods:

Patients

Study design:

- Retrospective, diagnostic accuracy study.

Study population:

- The study population included 195 patients who underwent CT chest studies in Benha university hospital and national institute of chest diseases (NICD), during the period from February 2020 to August 2020.

Inclusion criteria:

- Patients with positive RT-PCR test (Gold standard).
- Patients who did CT chest examination during the 2nd to 14th day of the onset of the symptoms.

Exclusion Criteria:

The following groups of patients are excluded:

- Patients with negative RT-PCR test.

- Patients with no available RT-PCR test results.
- Patients whom CT chest exams were technically insufficient.

Methodology:

The study was conducted according to the guidelines of the ethics committee of Benha University and was approved by Benha University Institutional Review Board.

Ct images were extracted from the picture archiving and communicating system (PACS), and imported onto a secure browser-based viewing system for CT scans. The software displayed cross-sectional CT images with soft tissue and lung windows and allowed for dynamic scrolling, window width-widow level adjustment, panning, and zoom.

CT chest examinations done were assessed separately by three radiologists, each with more than 5 years' experience in chest CT interpretation. Their results were compared and tabulated.

CT images were reviewed for: presence of lesions, types of lesions, and distribution of lesions. The lesion type and distribution were classified into: typical, atypical, and very atypical according to the CORADS criteria. *(Table 1)*.

The CORADS score were assigned for each case *(Table 2)*. Then the classification of the

lesions and CORADS score were compared to the RT-PCR test results.

Statistical analysis:

Data management and statistical analysis were done using SPSS vs.25. (IBM, Armonk, New York, United States).

Numerical data were summarized as means and standard deviations or medians and ranges. Categorical data were summarized as numbers and percentages.

Sensitivity and false-negative rates of CO-RADS in diagnosing COVID were calculated compared to PCR results. The patients with false positive CO-RADS results could not be calculated as no patients with negative RT-PCR results for COVID 19 were involved in our study. The patients with false positive CO-RADS results are not considered of high clinical importance or represent danger on the community health, so, they were excluded from the scope of our study.

CO-RADS score was compared between both genders and according to different outcomes using the Mann Whitney U test.

Correlation analysis was done between CO-RADS and age using Spearman's correlation. "r" is the correlation coefficient. It ranges from -1 to +1. -1 indicates a strong negative correlation. +1 indicates a strong positive correlation, while 0 indicates no correlation.

All P values were two-sided. P values less than 0.05 were considered significant.

Results:

Out of the 195 patients proved to have COVID-*19* infection (by positive RT-PCR) included in this study, there was 105 males (54 %) and 90 females (46 %).

CT findings in whole the study population

Lesions were present in 166 patients (85.3%) while 29 patients (14.7 %) had normal CT chest. As regard the type of lesions, 150 patients (90.3%) were typical and 16 patients (9.6%) were atypical. As regard lesions distribution, 140 patients (84.3%) were typical while 26 patients (15.6%) were atypical. The Median CO-RADS score was 5, (ranged from 1 to 5 in all patients). Those with CO-RADS $\leq$ 3 represented 27.2% (53 patients), and those >3 represented 72.8% (142 patients) *(Table 3)*

CO-RADS sensitivity and false-negative rate compared to the gold standard "PCR"

Compared to the gold standard PCR, CO-RADS sensitivity was 72.8%, with a false-negative rate of 27.2%.

Table (1): Typical Features for Pulmonary Involvement of COVID-19 (3)

Typical features
- Multi-focal ground glass opacities.
- Peripheral and basal distribution.
- Unsharp demarcation.
- Vascular thickening.
- Rounded.
- Crazy paving.
- Ground glass and consolidation.
- Reversed halo.
- Spider web.

Atypical features
- Central or peribronchovascular.
- More apical distribution.
- Lymphadenopathy.
- Pleural effusion.

Very atypical features
- Cavitation.
- Calcifications.
- Tree in bud.
- Bronchiolitis.
- Nodular pattern.
- Mass.
- Pleural thickening.

Table (2): Overview of CO-RADS categories and the corresponding level of suspicion for pulmonary involvement in COVID-19 infection. (16)

CO-RADS category	Level of suspicion for pulmonary involvement of COVID-19 infection	Summary
0	not interpretable	Scan technically insufficient for assigning a score
1	Very low	Normal or noninfectious
2	Low	Typical for other infection but not COVID-19
3	Equivocal /unsure	Features compatible for COVID-19 but also other diseases
4	High	Suspicious for COVID-19
5	Very high	Typical for COVID-19
6	Proven	RT-PCR positive for SARS-Co V-2

Table (3) CT findings in the whole study population

CT findings		
Presence of lesions	n (%)	166 (85.3)
Type of lesion	Typical n (%)	150 (90.3)
	Atypical n (%)	16 (9.6)
Distribution of lesions	Typical n (%)	140 (84.3)
	Atypical n (%)	26 (15.6)
CO-RADS score	Median (range)	5 (1 - 5)
CO-RADS classification	≤3 n (%)	53 (27.2)
	> 3 n (%)	142 (72.8)

Discussion:

Coronavirus disease 2019 (COVID-19) first emerged in China and rapidly spread in the world causing a pandemic. Chest computed tomography (CT) continues to play an important role in the diagnosis and follow-up of the disease due to shortcomings of the real-time reverse transcription-polymerase chain reaction (RT-PCR) test, which is the gold standard in the diagnosis of this disease **(8)**.

Our study was a retrospective study, reviewed the CT chest studies done in Benha University Hospital and National Institute of Diseases of the Chest (NIDC) for patients proven to be positive for COVID 19 infection by RT-PCR, during the time from February 2020 to August 2020. We calculated the CORADS score sensitivity against the RT-PCR findings.

Our study sample did not include patients with negative RT PCR results for COVID 19 infection (confirmed twice as negative), so, we were not able to calculate the specificity and predictive values for the CORADS scoring system. This limitation in the study design related to deficient data of the clinical outcome for the patients with negative RT-PCR results (as they were not followed by the health authorities). Considering RT-PCR as the gold standard test in the diagnosis of COVID 19 infection **(8)** and considering shortage of its availability in some areas where CT is available and used as screening to exclude COVID infection (using CORADS system), so, we postulated in our study that calculating the CORADS system sensitivity is of crucial clinical importance compared to

the calculation of the specificity and predictive values. Also, the patients with false positive CT findings are considered non-infective and thus of low importance on the community health.

In this study, lung parenchymal abnormalities were observed in 166 (85.3 %) cases whereas 29 (14.7 %) RT-PCR positive cases had a normal chest CT. This is of relative comparable percentage to the study done by researchers who found CT chest abnormalities in 97.2 % and 95 % of cases respectively. (**9 & 10**)

This is in contrast to what was found that 65.3 % of RT-PCR positive cases had normal CT chest, whereas only 34.7 % of cases had lung parenchymal abnormalities (**11**). Mild symptoms and early acquisition of the CT chest in the disease course may explain this disagreement.

In this study typical CT chest findings are found in 90.3 % of patients having lesions and 9.6 % were atypical. This is in agreement with others, where typical CT findings were found in 100 % and 94 % of patients. (**11 &** 10)

As regard distribution of lesions, in our study, typical distribution was found in 84.3 % of patients. This is of relative

comparable percentage to the studies done by ***before*** where it found typical distribution of CT chest abnormalities in 76.5 % , 71 % and 93 % of cases respectively. *(**11, 12 & 10**)* Compared to the gold stander RT-PCR, CORADS sensitivity in this study was 72.8 %. This is the same as others **(13) .**

This percentage is lower than the studies done by many studies **(14, 15 & 16)**) in which the CORADS sensitivity was 97 %, 89.4 % and 87.8 respectively. **(14)*, and* (15)** included in their studies only patients with severe acute respiratory syndrome corona virus 2 infection and **(16)** excluded any asymptomatic patient. This may explain this dissimilarity. **(14) (15) (16)**

CORADS sensitivity significantly increased when excluding asymptomatic/mild patients and considering only moderate and severe/critically ill patients.

Conclusions:

Our study concluded that CORADS system is no so sensitive (its sensitivity is 72.7%) and we cannot depend on it alone to exclude the possibility of COVID-19 infection, however, its sensitivity increases in critically ill patients.

References:

1. **Abdel-Tawab, M., Basha, M.A.A., Mohamed, I.A., Ibrahim, H.M., Zaitoun, M.M., Elsayed, S.B., et al, 2021.** Comparison of the CO-RADS and the RSNA chest CT classification system concerning sensitivity and reliability for the diagnosis of COVID-19 pneumonia. *Insights into Imaging*, *12*(1), pp.1-11.

2. **Ai, T., Yang, Z., Hou, H., Zhan, C., Chen, C., Lv, W., et al, 2020**. Correlation of chest CT and RT-PCR testing for coronavirus disease 2019 (COVID-19) in China: a report of 1014 cases. *Radiology*, *296*(2), pp.E32-E40.

3. **Bai, H.X., Hsieh, B., Xiong, Z., Halsey, K., Choi, J.W., Tran, T.M.L., et al, 2020.** Performance of radiologists in differentiating COVID-19 from non-COVID-19 viral pneumonia at chest CT. *Radiology*, *296*(2), pp.E46-E54.

4. **Ceylan, N., Çinkooğlu, A., Bayraktaroğlu, S. and Savaş, R., 2021.** Atypical chest CT findings of COVID-19 pneumonia: a pictorial review. *Diagnostic and Interventional Radiology*, *27*(3), p.344.

5. **Chang, D., Lin, M., Wei, L., Xie, L., Zhu, G., Cruz, C.S.D, et al, 2020.** Epidemiologic and clinical characteristics of novel coronavirus infections involving 13 patients outside Wuhan, China. *Jama*, *323*(11), pp.1092-1093.

6. **Chen, D., Jiang, X., Hong, Y., Wen, Z., Wei, S., Peng, G., et al, 2021.** Can chest CT features distinguish patients with negative from those with positive initial RT-PCR results for coronavirus disease (COVID-19)?. *American Journal of Roentgenology*, *216*(1), pp.66-70.

7. **De Smet, K., De Smet, D., Demedts, I., Bouckaert, B., Ryckaert, T., Laridon, E., et al, 2020.** Diagnostic power of chest CT for COVID-19: to screen or not to screen. *Available at SSRN 3605168*.

8. **Fujioka, T., Takahashi, M., Mori, M., Tsuchiya, J., Yamaga, E., Horii, T., et al, 2020.** Evaluation of the usefulness of CO-RADS for chest CT in patients suspected of having COVID-19. *Diagnostics*, *10*(9), p.608.

9. **Immovilli, P., Morelli, N., Antonucci, E., Radaelli, G., Barbera, M. and Guidetti, D., 2020.** COVID-19 mortality and ICU admission: the Italian experience. *Critical Care*, *24*, p.1.

10. **Li, Y. and Xia, L., 2020.** Coronavirus disease 2019 (COVID-19): role of chest CT in diagnosis and management. *American Journal of Roentgenology, 214(6), pp.1280-1286.*

11. **Lieveld, A.W., Azijli, K., Teunissen, B.P., van Haaften, R.M., Kootte, R.S., van den Berk, I.A., et al, 2021.** Chest CT in COVID-19 at the ED: validation of the COVID-19 reporting and data system (CO-RADS) and CT severity score: a prospective, multicenter, observational study. *Chest*, *159*(3), pp.1126-1135.

12. **Long, C., Xu, H., Shen, Q., Zhang, X., Fan, B., Wang, C., et al, 2020.** Diagnosis of the Coronavirus disease (COVID-19): rRT-PCR or CT?. *European journal of radiology*, *126*, p.108961.

13. **Miller, T.E., Garcia Beltran, W.F., Bard, A.Z., Gogakos, T., Anahtar, M.N., Astudillo, M.G., et al, 2020.** Clinical sensitivity and interpretation of PCR and

serological COVID-19 diagnostics for patients presenting to the hospital. *The FASEB Journal*, *34*(10), pp.13877-13884.

14. **Moon, S.S., Lee, K., Park, J., Yun, S., Lee, Y.S. and Lee, D.S., 2020.** Clinical characteristics and mortality predictors of COVID-19 patients hospitalized at nationally-designated treatment hospitals. *Journal of Korean medical science*, *35*(36).

15. **Parry, A.H., Wani, A.H., Yaseen, M., Dar, K.A., Choh, N.A., Khan, N.A., et al, 2020.** Spectrum of chest computed tomographic (CT) findings in coronavirus disease-19 (COVID-19) patients in India. *European Journal of Radiology*, *129*, p.109147.

16. **Prokop, M., Van Everdingen, W., van Rees Vellinga, T., Quarles van Ufford, H., Stöger, L., Beenen, L., et al, 2020.** CO-RADS: a categorical CT assessment scheme for patients suspected of having COVID-19—definition and evaluation. *Radiology*, *296*(2), pp.E97-E104.

17. **Salehi, S., Abedi, A., Balakrishnan, S. and Gholamrezanezhad, A., 2020.** Coronavirus disease 2019 (COVID-19) imaging reporting and data system (COVID-RADS) and common lexicon: a proposal based on the imaging data of 37 studies. *European radiology*, *30*(9), pp.4930-4942.

18. **Tabatabaei, S.M.H., Talari, H., Moghaddas, F. and Rajebi, H., 2020.** CT features and short-term prognosis of COVID-19 pneumonia: a single-center study from Kashan, Iran. *Radiology: Cardiothoracic Imaging*, *2*(2), p.e200130.

19. **Zhai, P., Ding, Y., Wu, X., Long, J., Zhong, Y. and Li, Y., 2020.** The epidemiology, diagnosis and treatment of COVID-19. *International journal of antimicrobial agents*, *55*(5), p.105955