CHEST

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

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Abstract

Background In the vast majority of the laboratory-confirmed coronavirus disease 2019 (COVID-19) patients, computed tomography (CT) examinations yield a typical pattern and the sensitivity of this modality has been reported to be 97% in a large-scale study. 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.

Purpose To compose a comprehensive lexicon for description of the imaging findings and propose a grading system and structured reporting format for CT findings in COVID-19.

Material and methods We updated our published systematic review on imaging findings in COVID-19 to include 37 published studies pertaining to diagnostic features of COVID-19 in chest CT. Using the reported imaging findings of 3647 patients, we summarized the typical chest CT findings, atypical features, and temporal changes of COVID-19 in chest CT. Subsequently, we extracted a list of descriptive terms and mapped it to the terminology that is commonly used in imaging literature.

Results We composed a comprehensive lexicon that can be used for documentation and reporting of typical and atypical CT imaging findings in COVID-19 patients. Using the same data, we propose a grading system with five COVID-RADS categories. Each COVID-RADS grade corresponds to a low, moderate, or high level of suspicion for pulmonary involvement of COVID-19.

Conclusion The proposed COVID-RADS and common lexicon would improve the communication of findings to other healthcare providers, thus facilitating the diagnosis and management of COVID-19 patients.

Key Points
- *Chest CT has high sensitivity in diagnosing the coronavirus disease 2019 (COVID-19).*
- *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.*
- *The proposed COVID-RADS and common lexicon would improve the communication of findings to other healthcare providers, thus facilitating the diagnosis and management of COVID-19 patients.*

Keywords Coronavirus · Tomography, X-ray computed · Pneumonia, viral · Diagnosis · Pandemics · COVID-19

Abbreviations

ACR	American College of Radiology
COVID-19	Coronavirus disease 2019
COVID-RADS	Coronavirus disease 2019 imaging reporting and data system
CT	Computed tomography
GGO	Ground glass opacity
RT-PCR	Reverse transcription polymerase chain reaction

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Table 1 Summary of common pattern and distribution of pulmonary involvement on initial computed tomography images of coronavirus disease 2019 (COVID-19) from 37 studies

CT finding*	Number of studies	Number of reported cases/total number of patients (%)
Bilateral involvement	16	756/938 (80%)
Peripheral distribution	16	467/624 (74.8%)
Posterior involvement	1	41/51 (80%)
Multilobar involvement	7	426/477 (89.3%)
Ground glass opacity	25	649/749 (86.6%)
Consolidation	14	133/403 (33%)
Vascular enlargement	3	229/382 (60%)

*Findings of Salehi et al [17] were updated with seven additional studies [5, 19, 22–26]

Introduction

Coronavirus disease 2019 (COVID-19) is the most recent global health emergency with more than 850,000 cases and 41,000 deaths reported in over 180 countries as of March 31, 2020 [1]. Early diagnosis of COVID-19 is crucial for patient isolation and prompt clinical interventions. Reverse transcription polymerase chain reaction (RT-PCR) is a highly specific test and the gold standard for the diagnosis of COVID-19. However, the variable sensitivity of RT-PCR and its lengthy turnaround time (24–48 h [2]) underscore the need for a complementary diagnostic approach [3–6]. Besides, multiple negative RT-PCR test results may be needed to rule out the disease in patients with a high clinical suspicion of COVID-19 [7].

Table 2 The proposed lexicon for description of chest CT imaging findings in coronavirus disease 2019 (COVID-19)

	Findings	Important definitions
Distribution pattern of lesion	Unilateral/bilateral Anterior/posterior Peripheral predominant/central predominant Focal/multifocal Round/linear/wedge-shaped/irregular opacity Right upper/right middle/right lower/left upper/left lower lobe One lobe/two lobes/three lobes/four lobes/five lobes involved	The outermost one-third of the lung field is considered peripheral and the rest is considered central Posterior/anterior is determined according to the mid-axillary line
Type of lesion	Pure GGO GGO with superimposed consolidation Reticulation Consolidation without GGO Predominant consolidation pattern Air bronchogram Crazy paving pattern White lung stage Melted sugar sign Parenchymal fibrotic bands Pleural effusion Cavity Pulmonary nodules Nodular pattern Lymphadenopathy Peribronchovascular distribution Bronchial wall thickening Halo sign Tree-in-bud pattern Bronchiectasis Airway secretions Interstitial emphysema Pulmonary fibrosis Pleural thickening Pneumothorax Pericardial effusion Vascular enlargement	Pure GGO: A hazy intensification in lung attenuation without obscuration of the underlying vessels GGO with consolidation: A central opacification with obscuring the underlying vessels surrounded by GGO Melted sugar sign: Gradual decrease in density of consolidation and turning into GGO Halo sign: Pulmonary nodule surrounded by GGO, representative of hemorrhage Tree-in-bud pattern: Multiple sites of centrilobular nodules along with branching linear opacities [29]

Table 3 The proposed coronavirus disease 2019 (COVID-19) imaging reporting and data system (COVID-RADS)

CT findings	Description	COVID-RADS grade	Level of suspicion
Normal Chest CT		0	Low[a]
Atypical findings (Inconsistent with COVID-19)	- Pleural effusion - Cavity - Pulmonary nodule(s) - Nodular pattern - Lymphadenopathy - Peribronchovascular distribution - Halo sign - Tree-in-bud sign - Bronchiectasis - Airway secretions - Pulmonary emphysema - Pulmonary fibrosis - Isolated pleural thickening[b] - Pneumothorax - Pericardial effusion	1	Low
Fairly typical findings	- Single GGO (early) - Consolidation without GGO (late/complicated)[c] - Focal pleural thickening[d] - Vascular enlargement[e] - Air bronchogram - Bronchial wall thickening - White lung stage (late/complicated) - Parenchymal fibrotic bands (late/remission)	2A	Moderate
Combination of atypical findings with typical/fairly typical findings		2B	Moderate
Typical findings[f]	- Multifocal GGO - GGO with superimposed consolidation - Consolidation predominant pattern (late/complicated) - Linear opacities (late/complicated) - Crazy paving pattern (late/complicated) - Melted sugar sign (late/remission)	3	High

COVID-RADS, coronavirus disease imaging reporting and data system; *GGO*, ground glass opacity

[a] Although there is no imaging feature suggestive of COVID-19, it cannot exclude the disease

[b] Focal or diffused pleural thickening in the absence of GGO or consolidation

[c] This finding is not highly suggestive of the COVID-19. However, in advanced stages, it may be the only present finding

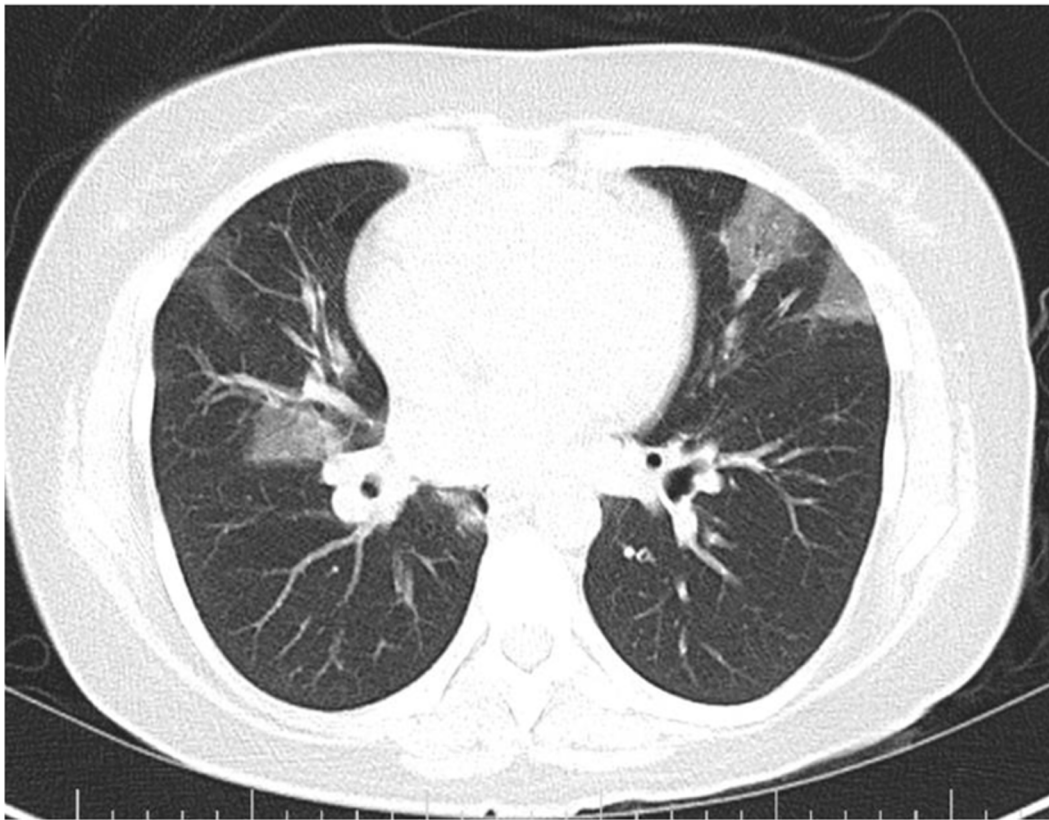[d] Thickening of the pleura associated with the adjacent GGO or consolidation

[e] Vascular enlargment refers to both luminal dilation and mural thickening of the pulmonary vessels [30]

[f] Bilateral and peripheral lung involvement generally indicate a high level of suspicion for COVID-19

Role of chest CT and its relationship with RT-PCR

Computed tomography (CT) imaging plays a key role in the diagnosis, management, and follow-up of COVID-19 patients. RT-PCR is the confirmatory test for the diagnosis of COVID-19 with high specificity. Numerous studies have endorsed the important role of CT in the management of these patients. However, several scientific societies have recommended against the routine use of CT for the screening of COVID-19 [8, 9]. Some countries have established the use of imaging as their frontline diagnostic test [2, 5, 7]. In the vast majority of the laboratory-confirmed patients, CT examinations yield a typical pattern and the sensitivity of this modality has been reported to be 97% in a study on 1014 patients [5]. The diagnostic value of this modality has been proven in clinically suspicious cases with inconclusive laboratory test results, as well as asymptomatic individuals with known exposure [3, 10]. In many healthcare settings, such as developing countries, CT imaging may be the only available diagnostic test due to a shortage of diagnostic laboratory kits, while validated COVID-19 laboratory test kits are limited in quantity even in industrialized nations [7, 11].

CT findings	Yes	No	Description	COVID-RADS grade	Level of suspicion
Normal Chest CT	✓	-		0	Low
Atypical findings (Inconsistent with COVID-19)	✓	-		1	Low
Fairly typical findings	✓	-		2A	Moderate
Combination of atypical findings with typical/ fairly typical findings	✓	-		2B	Moderate
Typical findings	✓		Multi-focal pure GGO	**3**	**High**

Fig. 1 An example report card for grading of the imaging based on the proposed classification. Corresponding COVID-RADS grade and the level of suspicion (COVID-RADS 3/high suspicion) for COVID-19 are underlined. GGO, ground glass opacity

Need for a uniform lexicon and standardized reporting scheme

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 [12–16]. Our systematic review of the CT manifestations of COVID-19 showed a substantial inconsistency in description of imaging findings across the growing number of published studies [17]. We encountered the common use of several ambiguous and non-specific terms, such as fibrous stripes (or striped fibrosis), fibrotic streaks, lung fiber cord focus, vacuolar sign, bronchus distortion, patchy shadows, hazy opacities, patchy opacities, airspace disease, and interstitial disease [17–21]. While cardiothoracic radiologists may be familiar with some of these terms, the

CT findings	Yes	No	Description	COVID-RADS grade	Level of suspicion
Normal Chest CT		✓	-	0	Low
Atypical findings (Inconsistent with COVID-19)	✓		Pleural effusion	1	Low
Fairly typical findings	✓		Air-bronchogram	2A	Moderate
Combination of atypical findings with typical/ fairly typical findings	✓			**2B**	**Moderate**
Typical findings	✓		GGO with superimposed consolidation	3	High

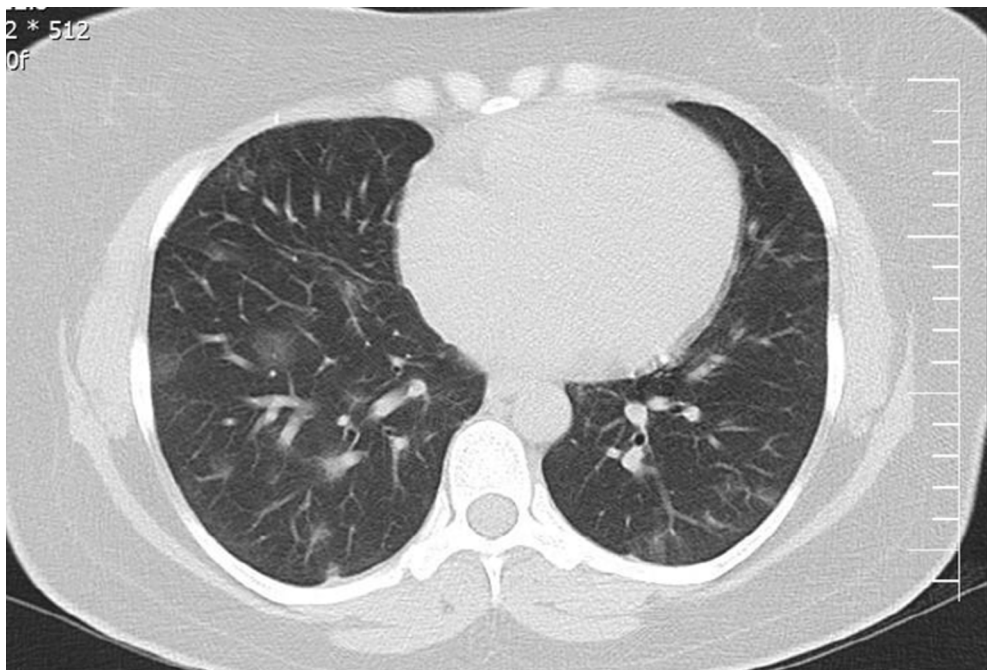**Fig. 2** An example report card for grading of the imaging based on the proposed classification. Corresponding COVID-RADS grade and the level of suspicion for COVID-19 are underlined (COVID-RADS 2B/ moderate suspicion). GGO, ground glass opacity

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. It will also be vital for the ongoing clinical research, as well as an efficient organization of imaging data input for infectious disease registries.

COVID-19 lexicon and imaging reporting and data system

We updated our published systematic review of chest CT manifestations of COVID-19, which was performed using

a search of PubMed, Embase, Google Scholar, and the WHO database of COVID-19 literature on February 19, 2020, and included 30 studies [17]. For the purpose of the current proposal, seven studies that were published after our initial search were added, and a total of 37 studies pertaining to diagnostic features of COVID-19 in chest CT were included [5, 17, 19, 22–26]. Using the reported imaging findings of 3647 patients, we summarized the typical chest CT findings, atypical features, and temporal changes of COVID-19 in chest CT. A summary of the most common chest CT findings is reported in Table 1. Subsequently, we extracted a list of descriptive terms and mapped it to the terminology that is commonly used in imaging literature, including Fleischner Society's
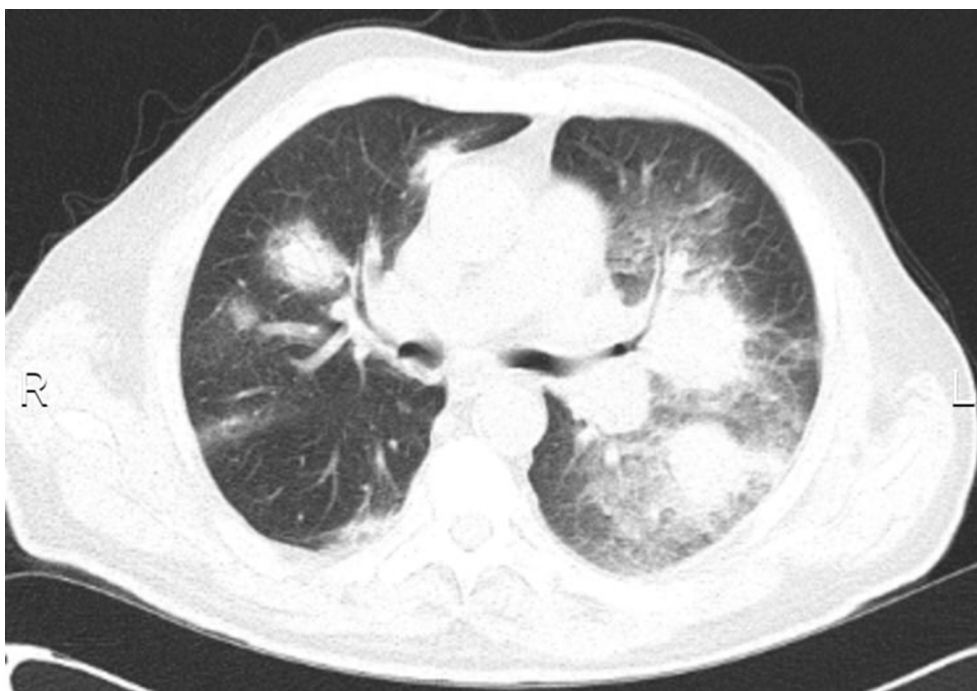
CT findings	Yes	No	Description	COVID-RADS grade	Level of suspicion
Normal Chest CT		✓	-	0	Low
Atypical findings (Inconsistent with COVID-19)		✓	-	1	Low
Fairly typical findings		✓	-	2A	Moderate
Combination of atypical findings with typical/ fairly typical findings		✓	-	2B	Moderate
Typical findings	✓		Multi-focal pure GGO	_3_	**High**

Fig. 3 An example report card for grading of the imaging based on the proposed classification. Corresponding COVID-RADS grade and the level of suspicion for COVID-19 are underlined (COVID-RADS 3/high suspicion). GGO, ground glass opacity

Glossary of Terms for Thoracic Imaging [27]. Using this approach, we composed a comprehensive lexicon that includes the most pertinent terms and can be used for documentation and reporting of typical and atypical imaging findings in COVID-19 patients (Table 2). Using the same data, we propose the COVID-19 imaging reporting and data system (COVID-RADS), which is a grading system for CT findings with five categories (Table 3). Each COVID-RADS grade corresponds to a low, moderate, or high level of suspicion for pulmonary COVID-19 involvement. The levels of suspicion that we proposed here are based on the similarity between the findings of a given imaging exam and the typical CT manifestations of COVID-19 that are reported in the available literature. In other words, the proposed levels of suspicion are not based on the empirical data and the "true" suspicion levels are based on the clinical context and the level of pretest probability. The diagnosis should be made based on the whole clinical picture and confirmed based on the RT-PCR test results. Representative CT images along with corresponding COVID-RADS report cards are presented in Figs. 1, 2, 3, 4, 5, 6, 7, 8, and 9. Normal chest CT
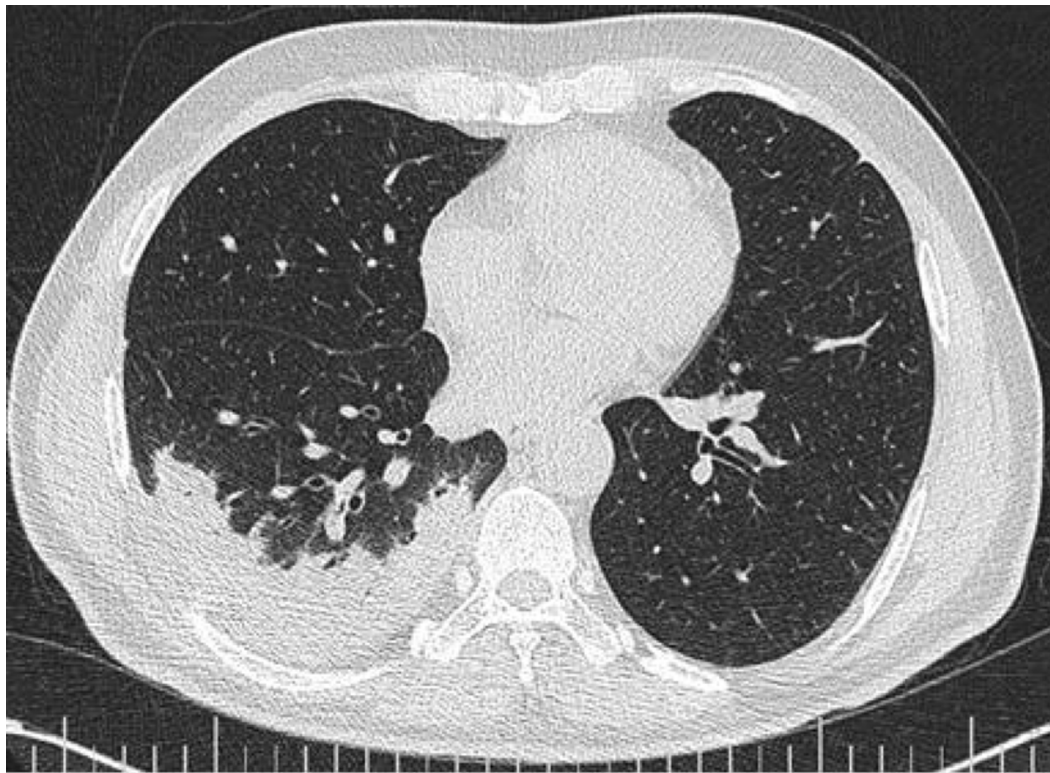
CT findings	Yes	No	Description	COVID-RADS grade	Level of suspicion
Normal Chest CT	✓	-		0	Low
Atypical findings (Inconsistent with COVID-19)	✓	-		1	Low
Fairly typical findings	✓	-		2A	Moderate
Combination of atypical findings with typical/ fairly typical findings	✓	-		2B	Moderate
Typical findings	✓		**GGO with superimposed consolidation**	<u>_</u>	<u>**High**</u>

Fig. 4 An example report card for grading of the imaging based on the proposed classification. Corresponding COVID-RADS grade and the level of suspicion for COVID-19 are underlined (COVID-RADS 3/high suspicion). GGO, ground glass opacity

findings (COVID-RADS 0) or atypical features (COVID-RADS 1) are generally inconsistent with pulmonary manifestation of COVID-19. However, these features have been reported in a number of laboratory-confirmed symptomatic patients, hence indicating a low level of suspicion in our proposed grading system. Based on the current literature, the vast majority of the patients present with typical chest CT findings (COVID-RADS 3), which are commonly described as a peripheral, multifocal ground glass pattern. Typical findings are associated with the temporal stage of the disease but occasionally indicate the presence of complications. For instance, single ground glass opacity (GGO) is a fairly typical finding that may be present at the very early stages of the disease, while multifocal GGO, GGO with superimposed consolidation, and consolidation predominant pattern may be seen at progression/complicated stage. Linear opacities, crazy paving pattern, and white lung can be observed later in the course of progression/complicated stage. Imaging signs of remission, which may appear after the second week of the disease, include the melted sugar sign and parenchymal fibrotic bands [17, 18, 21, 28]. Some of the typical findings may be observed across different stages of the disease and interval changes in imaging

CT findings	Yes	No	Description	COVID-RADS grade	Level of suspicion
Normal Chest CT		✓	-	0	Low
Atypical findings (Inconsistent with COVID-19)		✓	-	1	Low
Fairly typical findings	✓		**Consolidation without GGO**	**2A**	**Moderate**
Combination of atypical findings with typical/ fairly typical findings		✓	-	2B	Moderate
Typical findings		✓	-	3	High

Fig. 5 An example report card for grading of the imaging based on the proposed classification. Corresponding COVID-RADS grade and the level of suspicion (COVID-RADS 2A/moderate suspicion) for COVID-19 are underlined. GGO, ground glass opacity

studies should be taken into consideration for proper staging. Regardless, the typical findings denote a high level of suspicion for pulmonary involvement in COVID-19.

Implications of COVID-RADS and lexicon

The COVID-19 outbreak is an illustrative case that emphasizes the importance of structured reporting in a scenario that requires large numbers of patients to be screened, diagnosed, and treated according to their CT imaging findings. Owing to the important burgeoning role of CT in the evaluation of COVID-19 patients, a comprehensive knowledge of imaging manifestations is crucial, and a uniform reporting format is needed to ensure effective communication between the healthcare providers.

During the current global state of emergency, some healthcare facilities around the world are experiencing
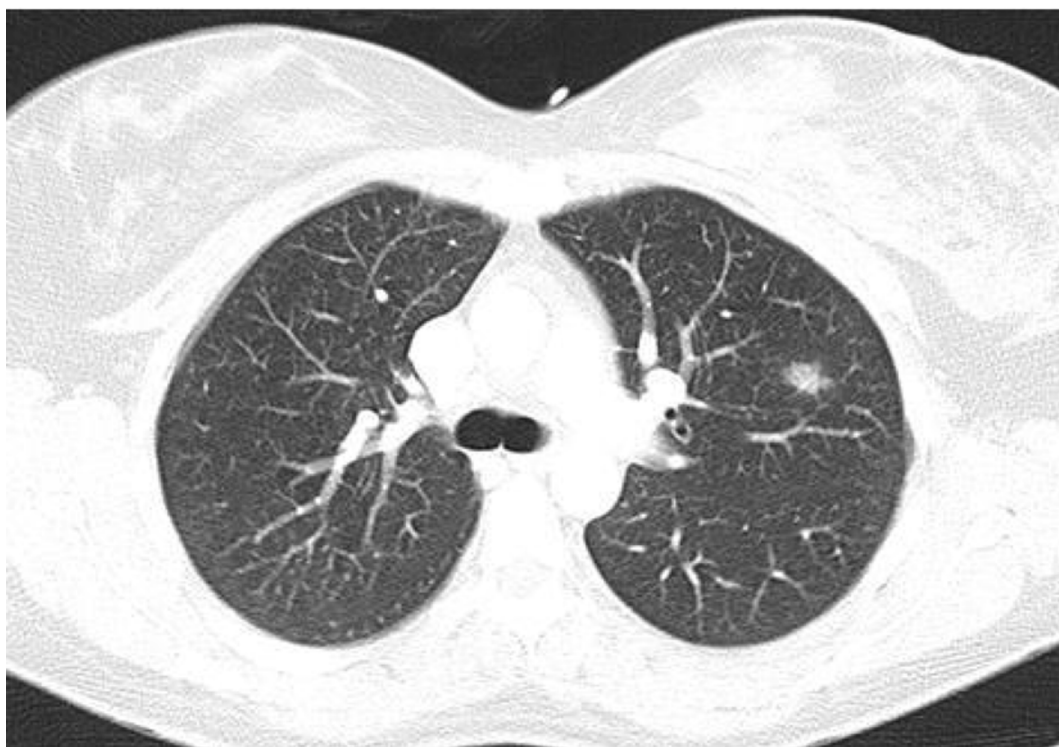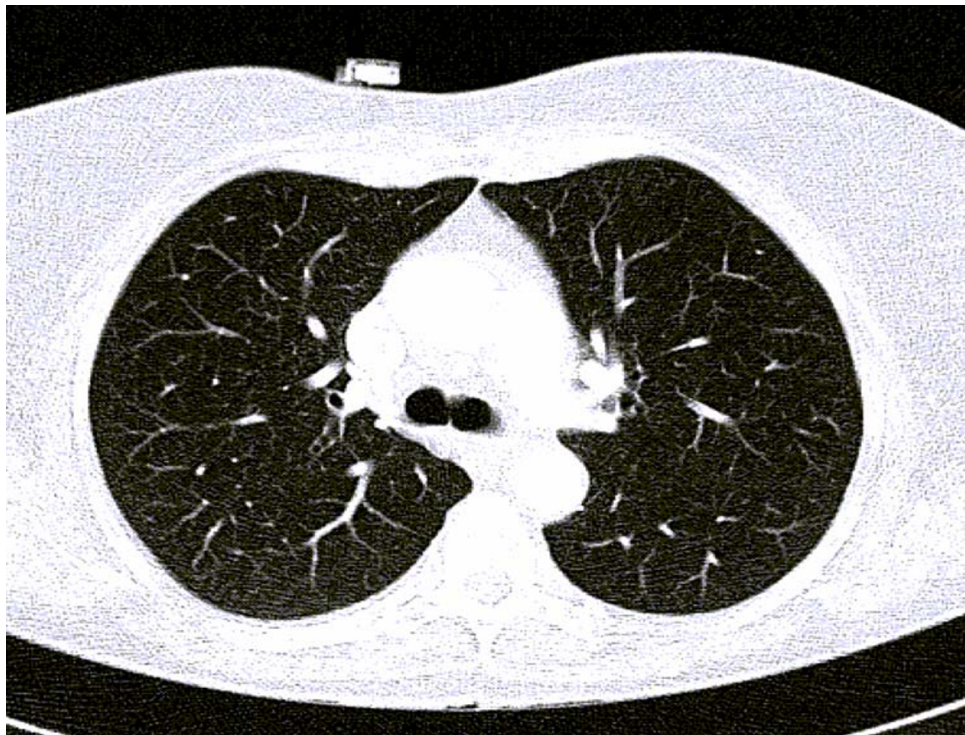
CT findings	Yes	No	Description	COVID-RADS grade	Level of suspicion
Normal Chest CT		✓	-	0	Low
Atypical findings (Inconsistent with COVID-19)		✓	-	1	Low
Fairly typical findings	✓		**Single GGO**	**2A**	**Moderate**
Combination of atypical findings with typical/ fairly typical findings		✓	-	2B	Moderate
Typical findings		✓	-	3	High

Fig. 6 An example report card for grading of the imaging based on the proposed classification. Corresponding COVID-RADS grade and the level of suspicion (COVID-RADS 2A/moderate suspicion) for COVID-19 are underlined. GGO, ground glass opacity

historic high patient workflows. The implementation of COVID-RADS grading and lexicon would establish a structured reporting format that enables a consistent, rapid, and efficient communication between the diagnosticians and clinicians. The use of COVID-RADS will render exam reports brief yet concise and informative and in part enhance the quality of patient management and

decrease the rate of missed diagnosis. The proposed structured reporting would facilitate the decision-making process, leading to timely patient isolation and prompt initiation of treatments.

Our proposed system is primarily applicable to the epidemic areas affected by the current pandemic, as well as the individuals with a high clinical suspicion
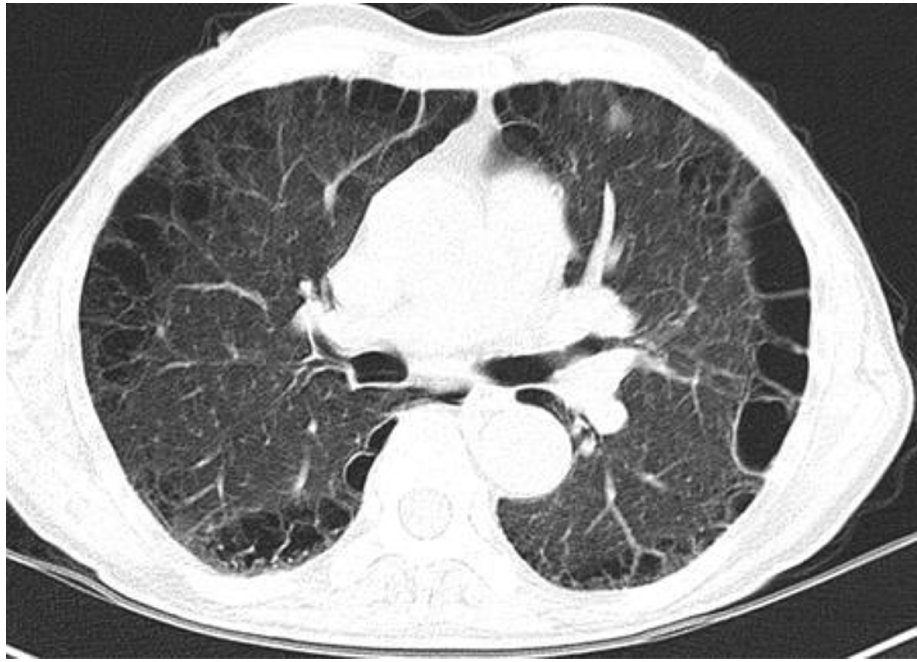
CT findings	Yes	No	Description	COVID-RADS grade	Level of suspicion
Normal Chest CT	✓	-		<u>**0**</u>	<u>**Low**</u>
Atypical findings (Inconsistent with COVID-19)	✓	-		1	Low
Fairly typical findings	✓	-		2A	Moderate
Combination of atypical findings with typical/ fairly typical findings	✓	-		2B	Moderate
Typical findings	✓	-		3	High

Fig. 7 An example report card for grading of the imaging based on the proposed classification. Corresponding COVID-RADS grade and the level of suspicion (COVID-RADS 0/low suspicion) for COVID-19 are underlined

for COVID-19 (high pretest probability). Our proposed lexicon is a concise list of terms required for description of chest CT findings in COVID-19, while routine CT examinations may require a more exhaustive lexicon with additional terms. Our proposed format is informed by an evidence-based systematic review of the available literature on COVID-19 and should be validated by empirical data.

It has to be emphasized that this is the first proposal for a RADS-system for COVID-19. The system is based on "interpretation" of numerous publications, but not on a very detailed statistical analysis of a huge database of COVID-19 cases. It may guide radiologists for now, but is not yet a validated system (as with other RADS). Clinicians should interpret COVID-RADS as just one part of the diagnostic puzzle and take into account the whole

CT findings	Yes	No	Description	COVID-RADS grade	Level of suspicion
Normal Chest CT		✓	-	0	Low
Atypical findings (Inconsistent with COVID-19)	✓		**Pulmonary emphysema**	**1**	**Low**
Fairly typical findings		✓	-	2A	Moderate
Combination of atypical findings with typical/ fairly typical findings		✓	-	2B	Moderate
Typical findings		✓	-	3	High

Fig. 8 An example report card for grading of the imaging based on the proposed classification. Corresponding COVID-RADS grade and the level of suspicion (COVID-RADS 1/low suspicion) for COVID-19 are underlined

clinical picture. Furthermore, our understanding of the chest imaging features of COVID-19 is rapidly expanding and the current proposal is bound to the level of evidence of the studies that it is derived from, majority of which are case reports and small case series. While standardized reporting systems are intended to promote consistency, radiologists may need to adapt our proposed system based on their local or institutional policies and future guidelines. The Reporting and Data Systems (RADS) framework was developed by the American College of Radiology (ACR), aiming to standardize the radiology reports. Hence, validation and further modification of the proposed COVID-RADS grading system require the support of professional societies.

CT findings	Yes	No	Description	COVID-RADS grade	Level of suspicion
Normal Chest CT		✓	-	0	Low
Atypical findings (Inconsistent with COVID-19)	✓		**Pulmonary nodule**	<u>**1**</u>	<u>**Low**</u>
Fairly typical findings		✓	-	2A	Moderate
Combination of atypical findings with typical/ fairly typical findings		✓	-	2B	Moderate
Typical findings		✓	-	3	High

Fig. 9 An example report card for grading of the imaging based on the proposed classification. Corresponding COVID-RADS grade and the level of suspicion (COVID-RADS 1/low suspicion) for COVID-19 are underlined

Conclusion

By introducing a standardized approach to reporting, the proposed COVID-RADS and common lexicon may improve the communication of findings to other healthcare providers, thus facilitating the diagnosis and management of COVID-19 patients.

Compliance with ethical standards

Guarantor The scientific guarantor of this publication is Ali Gholamrezanezhad, MD.

Conflict of interest The authors of this manuscript declare no relationships with any companies whose products or services may be related to the subject matter of the article.

Statistics and biometry No complex statistical methods were necessary for this paper.

Informed consent Not applicable.
This work is a proposal based on previous studies.

Ethical approval Not applicable.
This work is a proposal based on previous studies.

Study subjects or cohorts overlap Not applicable.

Methodology
• Evidence-based report
• Performed at one institution

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