RSNA-STR-ACR Consensus Statement for COVID-19 CT Patterns: Interreader Agreement in 240 Consecutive Patients and Association With RT-PCR Status

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Purpose: The aim of this study was to study interreader agreement of the RSNA-STR-ACR (Radiological Society of North America/Society of Thoracic Radiology/American College of Radiology) consensus statement on reporting chest computed tomography (CT) findings related to COVID-19 on a sample of consecutive patients confirmed with reverse transcriptase–polymerase chain reaction (RT-PCR) for severe acute respiratory syndrome coronavirus 2.

Materials and Methods: This institutional review board–approved retrospective study included 240 cases with a mean age of 47.6 ± 15.9 years, ranging from 20 to 90 years, who had a chest CT and RT-PCR performed. Computed tomography images were independently analyzed by 2 thoracic radiologists to identify patterns defined by the RSNA-STR-ACR consensus statement, and concordance was determined with weighted κ tests. Also, CT findings and CT severity scores were tabulated and compared.

Results: Of the 240 cases, 118 had findings on CT. The most frequent on the RT-PCR–positive group were areas of ground-glass opacities (80.5%), crazy-paving pattern (32.2%), and rounded pseudonodular ground-glass opacities (22.9%). Regarding the CT patterns, the most frequent in the RT-PCR–positive group was typical in 75.9%, followed by negative in 17.1%. The interreader agreement was 0.90 (95% confidence interval, 0.80–0.96) in this group. The CT severity score had a mean difference of −0.07 (95% confidence interval, −0.48 to 0.34) among the readers, showing no significant differences regarding visual estimation.

Conclusions: The RSNA-STR-ACR consensus statement on reporting chest CT patterns for COVID-19 presents a high interreader agreement, with the typical pattern being more frequently associated with RT-PCR–positive examinations.

Key Words: COVID-19, CT, interreader agreement, reliability, SARS-CoV-2

(*J Comput Assist Tomogr* 2021;00: 00–00)

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Received for publication July 21, 2020; accepted October 22, 2020.
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The authors declare no conflict of interest.
Statement of data access and integrity: The authors declare that they had full access to all of the data in this study, and the authors take complete responsibility for the integrity of the data and the accuracy of the data analysis.
Authors' contributions: C.S., J.A., C.R., J.V., J.C.D., C.V., and M.B. contributed to the conception and design of the study, acquisition and interpretation of data, manuscript draft and critical revision, and the final approval of the version to be published, and they are accountable for all aspects of the work regarding accuracy or integrity. C.S. contributed to the statistical analysis of data.

DOI: 10.1097/RCT.0000000000001162

Since December 2019, the world has been subject to a new disease caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), pathogen to COVID-19.[1,2] This led the World Health Organization to declare a pandemic on March 11, 2020. To date (April 23, 2020), more than 9,180,000 cases have been confirmed.[3]

Several publications have described findings on CT, which are similar to organizing pneumonia and pose as characteristic of this entity.[4–9] Thoracic imaging societies have presented their position against performing computed tomography (CT) with screening purposes to identify cases of COVID-19,[10–12] given overlapping conditions that prevent these patterns from being pathognomonic.

Recently, the Radiological Society of North America (RSNA), the Society of Thoracic Radiology (STR), and the American College of Radiology (ACR) have presented a statement regarding reporting chest CT findings in this scenario.[13] This document serves as a guide for the radiologist to decide if a probability threshold for COVID-19 should be included (in the setting of a patient with clinical suspicion). It also allows to state differential diagnosis when the images show elements that require to consider other entities that may account for the findings. They propose 4 categories and a suggested standardized language: typical, indeterminate, atypical, or negative for pneumonia.

For this categorization to have widespread use, it is necessary to assess the agreement among different radiologists. Reproducibility is a must for the applicability of such structured language. It allows for later data mining if we consider that classification performed in various centers should be similar and reliable. Especially if multicenter studies are expected to occur, it is of the utmost importance to have high reliability on the interreader agreement.

The following study analyzes interreader concordance, using images from patients with chest CT and real-time reverse transcriptase–polymerase chain reaction (RT-PCR) results (performed before the CT), using routine clinical settings. Measuring these elements is necessary for the extensive use of standardized reporting in the current COVID-19 pandemic.

MATERIALS AND METHODS

We performed a retrospective, single-center study of consecutive patients with clinical suspicion of COVID-19, who were studied with CT, during the period March 14 and April 4, 2020. We analyzed separately the CT by groups of SARS-CoV-2 confirmed and nondetected cases by real-time RT-PCR. The ethics and institutional review board committee of Facultad de Medicina Clinica Alemana-Universidad del Desarrollo approved this study, allowing a waiver for informed consent.

The date of initial symptoms and characteristics of these symptoms were extracted from the electronic medical record and registered in a standardized manner. Upper respiratory tract specimens were collected from all patients through a nasopharyngeal swab and subject to real-time RT-PCR for SARS-CoV-2 (Genesig Real-Time PCR Assay; Primerdesign Ltd).

CT Technique

All CT scans were acquired with the patient on supine position, without intravenous contrast injection, during end inspiration. The scanners were 1 of the following: Siemens Definition AS+ (Siemens Healthcare), GE Revolution HD (General Electric Healthcare), or Siemens Go Top (Siemens Healthcare).

Images were obtained with a standard dose protocol (120 kV tube voltage, tube current regulated by automatic dose modulation from 100–350 mA), from apex to lung bases, and reconstructed to 1.0 mm slice thickness and 1 mm increment. A sharp reconstruction kernel was used for lung parenchyma (B70f or HR68 for Siemens, and Lung HR for GE), as well as a standard mediastinal kernel (I30s or Br36 for Siemens, and Standard for GE), in a 512 × 512 matrix. Lung windows settings were −1500 HU width and −600 HU level, and mediastinal settings were 400 HU width and 40 HU level.

Image Interpretation

Cases were selected by a thoracic radiologist with 10 years of experience, who identified all patients who met the inclusion criteria of having a positive RT-PCR result or any lung parenchyma findings on original CT report. All CT images were interpreted independently by 2 thoracic radiologists with 14 and 10 years of experience, on Impax 6.5.2.657 (AGFA), who were unaware on clinical history or RT-PCR results. Answers were tabulated for interreader agreement assessment. On disagreement, for the analysis that followed, a third experienced thoracic radiologist with 22 years of experience gave a final decision.

All cases were evaluated for patterns defined as the RSNA-STR-ACR consensus statement recommends.[13] Briefly, a "typical appearance" would include peripheral, bilateral ground-glass opacities (GGOs), with or without intralobular lines ("crazy paving") or multifocal rounded GGO with or without "crazy paving" or findings suggestive of organizing pneumonia. The "indeterminate" category would require the absence of typical features and multifocal, diffuse, or unilateral nonrounded GGO. An "atypical" case will be if there is an absence of the previous features and presence of segmental consolidation, "tree-in-bud," cavitation, or interlobular septal thickening with pleural effusion. Finally, the "negative" category would require no CT features suggestive of pneumonia to be identified.

Also, characteristics such as distribution, density, presence of septal thickening, "crazy paving," pleural effusion, and lymphadenopathy were evaluated. Computed tomography severity score was calculated based on the involvement of 6 sectors dividing each lung into thirds, and classifying as none (0%), minimal (1%–25%), mild (26%–50%), moderate (51%–75%), or severe (76%–100%), assigning a score of 0, 1, 2, 3, or 4, respectively. The total severity score corresponds to the sum of the 6 zones, ranging from 0 to 24.

Statistical Analysis

Data were expressed as mean ± standard deviation or median and interquartile range for continuous variables and as frequencies (percentages) for categorical variables. Shapiro-Wilk test was used to check the assumption of normal distribution. Student *t* test or Mann-Whitney *U* test was used for continuous variables, when appropriate. Percentages were compared using either a χ^2 test or, in appropriate cases, Fisher exact test. Weighted Cohen κ was used to assess interobserver and intertechnique agreement. Landis and Koch values were used as the magnitude of agreement: <0 indicates no agreement, 0–0.20 as slight, 0.21–0.40 as fair, 0.41–0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1 as almost perfect agreement. Statistical analyses were performed using Stata 16.1 (StataCorp LLC, College Station, TX). Bland-Altman comparison of severity score results comparing radiologists was performed. *P* value less than 0.05 was considered statistically significant, and 95% confidence intervals (95% CIs) were calculated.

RESULTS

Demographic and Clinical Characteristics

During the period studied, 246 examinations were performed in 240 patients. Six patients had a follow-up CT for clinical deterioration; that second examination was excluded for further analysis. The mean age for the final sample was 47.5 ± 15.9 years, with a range from 19 to 90 years. One hundred fifty-one patients were female (62.9%), with a mean age of 45.3 years (95% CI, 42.7–54.4), and 89 were male with a mean age of 53.9 years (95% CI, 47.9–54.4), with a *P* value less than 0.01.

Eighty-seven CT examinations had a positive RT-PCR result (36.3%), and the remaining 153 CT cases performed had a negative RT-PCR result.

Symptoms

The period between initial symptoms and CT examination was between 0 and 3 days in 28.8% (69/240), 4 and 7 days in 32.1% (77/240), 8 and 14 days in 31.7% (76/240), and more than 14 days apart in 7.5% (18/240) of cases.

The median amount of symptomatic days before CT was 9.5 days (interquartile range, 14.8). A total of 33.6% (38/113) had less than 7 days from initial symptoms to CT.

Symptoms are presented in Table 1. Considering multiples symptoms spontaneously mentioned by patients on their first assessment, nonproductive cough was the most frequent symptom in 66.3% of the patients, fever in 50.8%, dyspnea on 48.8%, and odynophagia in 45%. There was a spontaneous mention for anosmia in only 3.8% of patients and ageusia in 1.3%.

CT Findings

The period between RT-PCR sampling and the CT examination was on the same day for 70.8% (170/240), between 1 and 3 days in 11.7% (28/240), 4 and 7 days in 10.8% (26/240), 8 and 10 days

TABLE 1. Frequency of Symptoms

Symptom	Number Times Mentioned	% Patients With Symptom (n = 240)
Nonproductive cough	159	66.3
Fever	122	50.8
Dyspnea	117	48.8
Sore throat	108	45.0
Myalgias	94	39.2
Headache	73	30.4
Nasal discharge	58	24.2
Chest pain	33	13.8
Diarrhea	29	12.1
Abdominal pain	12	5.0
Anosmia	9	3.8
Ageusia	3	1.3

in 3.8% (9/240), and more than 10 days apart in 2.9% (7/240) of cases (Figs. 1, 2).

The CT pattern most observed on the RT-PCR–positive group was typical in 75.9% (66/87), followed by negative in 17.1% (15/87), indeterminate in 3.5% (3/87), and atypical in 3.5% (3/87). On the RT-PCR–negative group, the CT patterns observed were 5.9% (9/153) typical, 8.5% (13/153) indeterminate, 5.9% (9/153) atypical, and 79.7% (122/153) negative. As presented in Table 2, the finding of a typical pattern is more associated with a positive RT-PCR test result, and either an indeterminate, atypical, or negative for pneumonia pattern, a negative RT-PCR test result was more probable (all *P*'s < 0.01). Among the 15 RT-PCR–positive cases with a "negative for pneumonia" pattern, 10 cases (66.7%) had less than 5 days of symptoms.

Among the most frequent findings on CT in the RT-PCR–positive group (Table 3), 70/87 (80.5%) had areas of GGO, 28/87 (32.2%) had a crazy-paving pattern, and 20/87 (22.9%) presented rounded pseudonodular GGO. On the RT-PCR–negative group, those that presented findings were consolidation in 68/153 (44.4%), peripheral GGO areas were identified in 30/153 (19.6%), and subpleural bands were identified in 26/153 (35%).

As presented in Table 3, those findings that reached differences statistically were the presence of rounded pseudonodular GGO, crazy paving, and peripheral GGO (*P* < 0.01), favoring the RT-PCR–positive group. These CT findings were associated with a risk ratio (RR) for a positive RT-PCR result of 35.1 (95% CI, 4.8–157.5) for rounded pseudonodular GGO, of 12.3 (95% CI, 4.5–33.9) for crazy paving, and of 4.1 (95% CI, 2.9–5.7) for peripheral GGO (all *P*'s < 0.01).

There were no cases of lymphadenopathy or pleural effusion.

Intertechnique and Interreader Agreement

The weighted κ value obtained for the group was 0.90 (95% CI, 0.80–0.96). When analyzed by RT-PCR status, we see that the κ value obtained for interreader agreement on the RT-PCR–positive group was 0.92 (95% CI, 0.89–0.93) and for the RT-PCR–negative group was 0.84 (95% CI, 0.68–0.90).

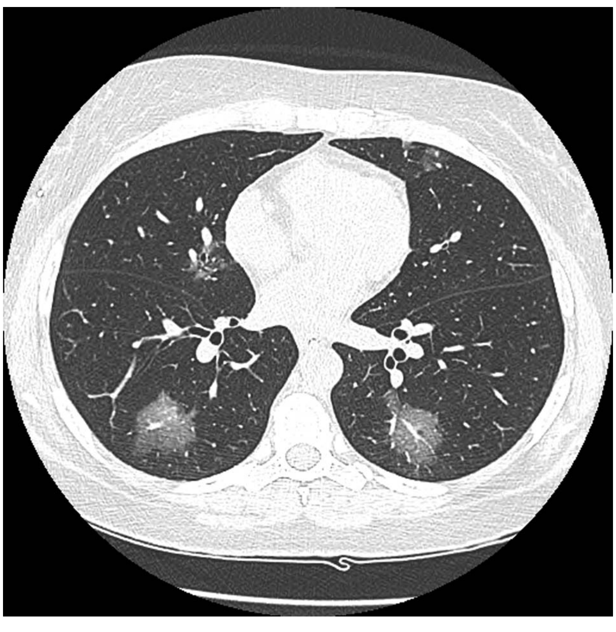

FIGURE 1. Axial (A) and coronal (B) image of a typical CT appearance for COVID-19, both readers agreed.

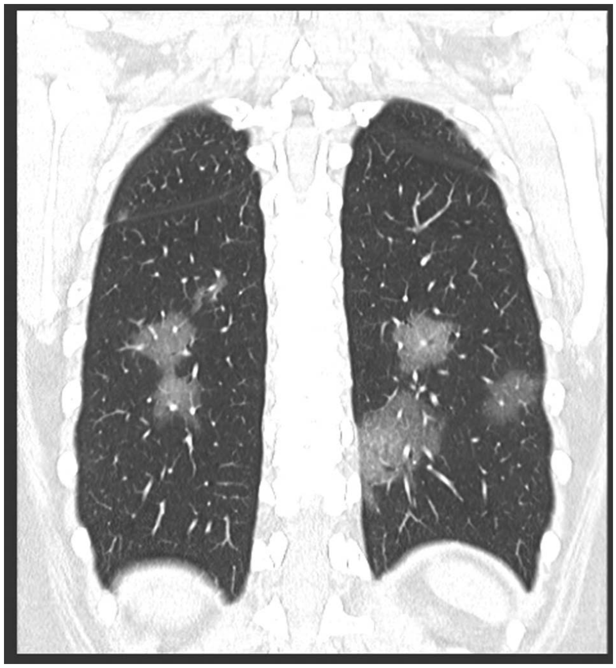

FIGURE 2. Axial (A) and coronal (B) image of a typical CT appearance for COVID-19, both readers agreed.

A total of 60.9% (14/23) of the cases of disagreement between radiologists were RT-PCR–negative cases. Eleven of those 23 cases occurred when classifying between indeterminate and atypical categories, and 8 cases were between typical and indeterminate (Fig. 3).

In 2 of the 9 RT-PCR–negative cases with atypical CT pattern, a causative agent was identified (*Mycoplasma pneumoniae* and *Legionella* sp).

Total Severity Score

Reader 1 calculated a mean (SD) severity score of 6.8 (6.4), and reader 2 gave a mean (SD) score of 6.9 (6.1). The Bland-Altman analysis showed a mean difference of −0.07 (95% CI, −0.48 to 0.34) with limits of agreement of −4.47 to 4.33, showing no significant difference between the radiologists' estimation for severity score (Fig. 4).

DISCUSSION

The CT findings of COVID-19 have been described since the first reports in China,[14–19] and given its rapid expansion throughout the world, descriptions of the same CT findings repeat elsewhere. Given the importance of providing, a standardized approach to the reporting of COVID-19 cases, RSNA assembled an expert

TABLE 2. RSNA-STR-ACR CT Patterns Compared With PCR Results

Pattern	Positive PCR (n = 87)	Negative PCR (n = 153)	Total	*P*
Typical	66 (75.9%)	9 (5.9%)	75	<0.01
Indeterminate	3 (3.5%)	13 (8.5%)	16	<0.01
Atypical	3 (3.5%)	9 (5.9%)	12	<0.01
Negative for pneumonia	15 (17.1%)	122 (79.7%)	137	<0.01

TABLE 3. CT Findings Compared With PCR Results

Finding	Positive PCR (n = 87)	Negative PCR (n = 153)	*P*
GGOs	70	30	<0.01
Crazy paving	28	4	<0.01
Subpleural parallel bands	22	26	NS
Rounded pseudonodular GGO	20	1	<0.01
Consolidation	19	28	NS
Atoll sign	4	0	NS

NS, nonsignificant.

panel to address this issue and provide guidance to radiologists on how to report their CT findings coherently, with contributions from STR and ACR. For this approach to be widespread, it requires to be reproducible and reliable, therefore, with a high interreader agreement. This element is critical because it means that every radiologist who abides by the patterns described in this document will be reporting systematically and coherently, and providing the same result as the next one who reads it. This study provides evidence of the confidence level a referring physician may get when a specific pattern is included in their CT reports.

Our study shows a high interreader agreement for the detection of findings and description of patterns, as mentioned by the RSNA-STR-ACR consensus document. A κ value of 0.90 (95% CI, 0.80–0.96) for the sample falls in the range of almost perfect agreement, which is even stronger when considering the "typical appearance" and "negative for pneumonia" categories, both having a clinically actionable result. Most of the disagreements were present in the RT-PCR–negative group, with 82.6% (19/23) of those between adjacent patterns (indeterminate-atypical, for instance).

Among the specific signs for COVID-19 cases, those that posed a significant difference favoring SARS-CoV-2 infection with an RR for a positive RT-PCR result were rounded pseudonodular GGO (RR, 35.1; 95% CI, 4.8–157.5), crazy paving (RR, 12.3; 95% CI, 4.5–33.9), and peripheral GGO (RR, 4.1; 95% CI, 2.9–5.7). This stresses the importance of including these parameters in the "typical appearance" category and emphasizes the relevance to identify and report these elements.

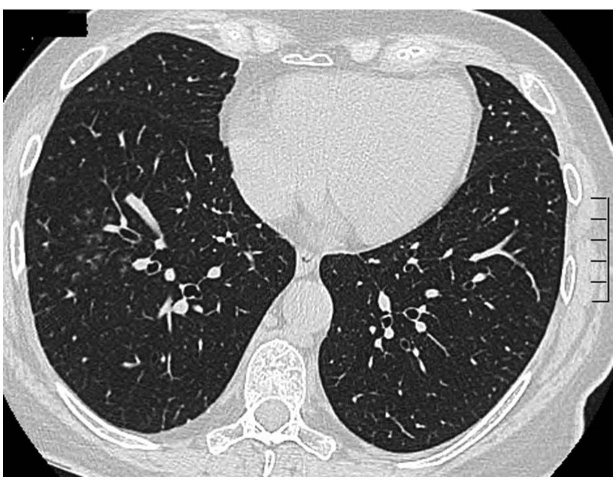

FIGURE 3. Axial image of a discordant case. Reader 1 classified as indeterminate, and reader 2 as atypical. Reader 3 classified it as atypical.

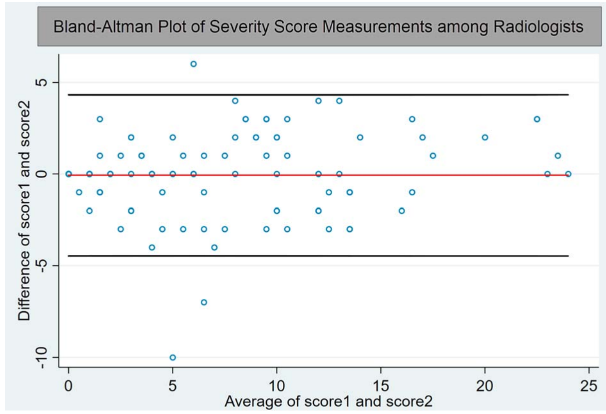

FIGURE 4. Bland-Altman plot for severity score measurements among radiologists.

Although it is tempting to calculate classical diagnostic test performance such as sensitivity and specificity, this is not methodologically accurate in this setting. We studied all patients with suspicion of COVID-19 and who had an RT-PCR performed before the examination; therefore, something on the clinical condition of the patient compelled the need to perform imaging (not all positive RT-PCR results will have a CT performed). Therefore, there are very few cases of mild symptoms and positive RT-PCR result (only 2 asymptomatic), posing a selection bias for the calculation of performance parameters to be used for screening purposes. This study was not aimed to analyze all patients studied with RT-PCR (reference standard) with a CT (test being studied). This has been performed in some studies,[14,20,21] in the setting of highly selected cases (therefore biased to a more diseased proportion of the sample), which could be misinterpreted as CT being able to replace RT-PCR. Most studies can accurately provide information on concordance among both techniques, such as we presented. We stand with the position of thoracic radiology professional societies such as the STR,[22] European Society of Radiology/European Society of Thoracic Imaging,[11] British Society of Thoracic Imaging,[23] Fleischner Society,[12] and RSNA,[10,13] among others, stating that CT should not be performed as a screening test on patients with mild or no symptoms and only be reserved to patients who present with dyspnea and desaturation, high severity according to clinical assessment, or suspicion of complications.

A negative for pneumonia pattern could be seen in a subset of RT-PCR–positive cases, and this is could be expected because, as presented in other series,[14,21,24] the absence of CT findings does not rule out a SARS-CoV-2 infection. In our study, 60.8% of patients had a period of fewer than 7 days from symptoms to CT, and among those who had a positive RT-PCR result, 17.1% had a "negative for pneumonia" pattern. The RSNA-STR-ACR consensus statement stresses this consideration as to include in the suggested report of a negative for pneumonia classification "Note: CT may be negative in the early stages of COVID-19."[13] Our results support this consideration.

Among the limitations to identify is that this a single institution study, where all studies were reanalyzed by thoracic radiologists with more than 10 years' experience, which may not be the standard for all centers imaging COVID-19 patients.

This COVID-19 condition will be with us for an extended period, and we will need to adapt to a new way of living, primarily until an effective vaccine is available. It is essential to convey to our referring physicians an accurate and reproducible standardized reporting system. Also, the need of agreement is necessary for an adequate incorporation of standardized reporting terminology. This allows the radiologists from different centers to speak in the same terms and communicate the same relevant findings. The RSNA-STR-ACR consensus reporting statement contributes to this, achieving a high interreader agreement in our study. This scheme can allow data mining among different institutions, taking into consideration the categories already defined, and using big data analysis, bring new light into the understanding of this new entity. Hopefully, this will provide prognostic imaging parameters to assist our referring physicians and patients better.

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