Radiology

ORIGINAL RESEARCH • THORACIC IMAGING

Chest CT Features of COVID-19 in Rome, Italy

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Conflicts of interest are listed at the end of this article.

Radiology 2020; 296:E79–E85 • https://doi.org/10.1148/radiol.2020201237 • Content codes: CH CT

Background: The standard for diagnosis of severe acute respiratory syndrome coronavirus 2 is a reverse transcription polymerase chain reaction (RT-PCR) test, but chest CT may play a complimentary role in the early detection of Coronavirus Disease 2019 (COVID-19) pneumonia.

Purpose: To investigate CT features of patients with COVID-19 in Rome, Italy, and to compare the accuracy of CT with that of RT-PCR.

Materials and Methods: In this prospective study from March 4, 2020, until March 19, 2020, consecutive patients suspected of having COVID-19 infection and respiratory symptoms were enrolled. Exclusion criteria were contrast material–enhanced chest CT performed for vascular indications, patients who refused chest CT or hospitalization, and severe CT motion artifact. All patients underwent RT-PCR and chest CT. Diagnostic performance of CT was calculated using RT-PCR as the reference standard. Chest CT features were calculated in a subgroup of patients with positive RT-PCR and CT findings. CT features of hospitalized patients and patients in home isolation were compared using the Pearson χ^2 test.

Results: The study population included 158 consecutive participants (83 male, 75 female; mean age, 57 years ± 17 [standard deviation]). Of the 158 participants, fever was observed in 97 (61%), cough was observed in 88 (56%), dyspnea was observed in 52 (33%), lymphocytopenia was observed in 95 (60%), increased C-reactive protein level was observed in 139 (88%), and elevated lactate dehydrogenase level was observed in 128 (81%). Sensitivity, specificity, and accuracy of CT were 97% (95% confidence interval [CI]: 88%, 99%) (60 of 62), 56% (95% CI: 45%, 66%) (54 of 96), and 72% (95% CI: 64%, 78%) (114 of 158), respectively. In the subgroup of 58 participants with positive RT-PCR and CT findings, ground-glass opacities were present in all 58 (100%), both multilobe and posterior involvement were present in 54 (93%), bilateral pneumonia was present in 53 (91%), and subsegmental vessel enlargement (>3 mm) was present in 52 (89%).

Conclusion: The typical pattern of COVID-19 pneumonia in Rome, Italy, was peripheral ground-glass opacities with multilobe and posterior involvement, bilateral distribution, and subsegmental vessel enlargement (>3 mm). Chest CT had high sensitivity (97%) but lower specificity (56%).

A novel coronavirus, named severe acute respiratory syndrome coronavirus 2, was identified related to the new emerging viral pneumonia consequently named Coronavirus Disease 2019 (COVID-19) (1,2). In accordance with the guidelines (3), the reference standard for the diagnosis of severe acute respiratory syndrome coronavirus 2 infection is next-generation sequencing or real-time reverse transcription polymerase chain reaction (RT-PCR) methods applied to respiratory tract specimens. However, because of intrinsic limitations (ie, collection and transportation of samples and diagnostic kit performance), sensitivity of RT-PCR at initial presentation ranges from 60% to 71% (4–7).

As reported by Ai et al (5), in a cohort of 1014 patients in Wuhan, China, the sensitivity, specificity, and accuracy of chest CT in the detection of COVID-19 pneumonia were 97%, 25%, and 68%, respectively, using RT-PCR results as the reference standard. Similar results were found in other studies, suggesting that CT imaging may be helpful in early detection of interstitial pneumonia in patients with a high degree of suspicion for COVID-19 pneumonia (6,8).

Typical chest CT patterns of COVID-19 viral pneumonia include multifocal bilateral peripheral ground-glass areas associated with subsegmental patchy consolidations, mostly subpleural, and predominantly involving lower lung lobes and posterior segments (8–14).

The aim of this study was to investigate chest CT features of patients with COVID-19 in Rome, Italy, and to compare the diagnostic performance of chest CT with that of RT-PCR.

Materials and Methods

Patient Population and Study Design

This prospective study was approved by our local institutional review board, and written informed consent was obtained from all study participants. In case of inability of the patients to provide informed consent, it was received from the relatives or the admitting physicians who requested CT examination.

Consecutive patients admitted at the emergency department of Sant'Andrea Hospital were enrolled from March

Abbreviations

CI = confidence interval, COVID-19 = Coronavirus Disease 2019, GGO = ground-glass opacities, RT-PCR = reverse transcription polymerase chain reaction

Summary

In Rome, Italy, Coronavirus Disease 2019 pneumonia is characterized by the constant presence of peripheral ground-glass opacities that are associated with multilobe and posterior involvement, bilateral distribution, and subsegmental vessel enlargement.

Key Results

- In this prospective study of patients in Rome, Italy, the sensitivity, specificity, and accuracy of CT for Coronavirus Disease 2019 (COVID-19) were 97%, 56%, and 72%, respectively, using reverse transcription polymerase chain reaction (RT-PCR) as the standard of reference.
- On chest CT, ground-glass opacities were present in 100% of patients with RT-PCR–confirmed COVID-19; 93% of patients had multilobe and posterior lung involvement, and 91% of patients had bilateral pneumonia.
- On CT, subsegmental vascular enlargement (more than 3-mm diameter) in areas of lung opacity was observed in 89% of patients with confirmed COVID-19 pneumonia, with unclear origin.

4, 2020, until March 19, 2020. Inclusion criteria were *(a)* fever and respiratory symptoms, such as cough, and dyspnea; *(b)* mild respiratory symptoms and close contact with a person with confirmed COVID-19; and *(c)* a previously positive test result.

Exclusion criteria were *(a)* contrast material–enhanced chest CT performed for a vascular indication (ie, pulmonary embolism, aortic dissection, coronary syndrome), *(b)* refusal to undergo chest CT or hospitalization, and *(c)* severe motion artifact on chest CT.

Clinical Data

All patients completed a prescreening questionnaire about COVID-19 symptoms in one of the six dedicated tents for people with COVID-19 located outside the emergency department to collect specific clinical information pertaining to fever, cough, and dyspnea. Fever was defined as a temperature greater than 37.5°C. Thereafter, specific blood tests (COVID-19 panel, internal disposition) and naso- and oropharyngeal swabs were obtained for each patient. To confirm a positive severe acute respiratory syndrome coronavirus 2 finding, RT-PCR (Charitè, Berlin, Germany) was used (15). Two nasopharyngeal and oropharyngeal swabs were performed in all patients at an interval of 24 hours. Patients were considered to not have COVID-19 after two consecutive negative RT-PCR results.

Patient characteristics, clinical signs and symptoms, and laboratory results were collected. Symptomatic patients (those with fever >37.5°C, cough, and dyspnea) with positive RT-PCR and CT findings were hospitalized, whereas patients with positive RT-PCR findings but negative CT findings (discussed later), mild symptoms (fever ≤37.5°C, no dyspnea), or both were discharged for home isolation, per our hospital guidelines. Data about hospitalization or home isolation were also collected.

CT Acquisition Technique

As part of our hospital COVID-19 guidelines, after the RT-PCR swabs, all patients underwent chest CT to determine the presence or absence of viral pneumonia. All chest CT examinations were performed with patients in the supine position during end-inspiration without contrast medium injection. Chest CT was performed on a 128-slice CT scanner (GE Revolution EVO 64 Slice CT Scanner; GE Medical Systems, Milwaukee, Wis) dedicated only to patients with COVID-19. The following technical parameters were used: tube voltage, 120 kV; tube current modulation, 100–250 mAs; spiral pitch factor, 0.98; and collimation width, 0.625. Reconstructions were made with the convolution kernel BONEPLUS (GE Medical Systems) at a slice thickness of 1.25 mm. Decontamination of the room consisted of surface disinfection with 62%–71% ethanol or 0.1% sodium hypochlorite. After each chest CT examination, passive air exchange was performed for 40–60 minutes.

CT Image Analysis

Digital Imaging and Communications in Medicine data were transferred onto a picture archiving and communication workstation (Centricity Universal Viewer, version 6.0; GE Medical Systems). Two radiologists in consensus with 15 and 25 years of thoracic imaging experience (D.C., A.L.) evaluated the images using a clinically available dedicated application (Thoracic VCAR, version 13.1; GE Medical Systems), defining patients as having positive CT findings when a diagnosis of viral pneumonia was reported.

The following CT features were also recorded (16): *(a)* ground-glass opacities (GGOs), *(b)* GGO pattern, *(c)* GGO location, *(d)* consolidation, *(e)* multilobe involvement, *(f)* bilateral distribution, *(g)* location of consolidation or GGO, *(h)* pulmonary nodules surrounded by GGO, *(i)* interlobular septal thickening, *(j)* air bronchogram, *(k)* halo sign, *(l)* presence of cavitation, *(m)* bronchial wall thickening, *(n)* bronchiectasis, *(o)* perilesional vessel diameter, *(p)* lymphadenopathy (defined as a lymph node with a short axis >10 mm), *(q)* pleural pericardial effusion, and *(r)* pericardial effusion.

Statistical Analysis

Statistical analysis was performed using SPSS, version 21.0 (SPSS, Chicago, Ill). All continuous variables were expressed as medians and ranges, and categorical variables were expressed as counts and percentages. The diagnostic performance of CT was evaluated with sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy considering RT-PCR as the reference standard. CT findings for patients who required hospitalization versus those who were able to isolate at home were compared using the Pearson χ^2 test. $P < .05$ indicated a significant difference. A 95% confidence interval (CI) was obtained with the Wilson score method.

Results

Patient Population and Clinical Data

The study population included 158 consecutive study participants (83 male, 75 female; mean age, 57 years ± 17;

age range, 18–89 years). Of the 158 participants, fever was observed in 97 (61%) and cough and dyspnea were present in 88 (56%) and 52 (33%), respectively.

Laboratory blood test results at admission showed lymphocytopenia (lymphocyte count $<1.1 \times 10^9$/L), with a mean lymphocyte count of $(1.08 \pm 0.47) \times 10^9$/L in 95 of 158 cases (60%), increased (>0.50 mg/dL) C-reactive protein levels (mean, 13.64 mg/dL ± 38.68) in 139 of 158 (88%) participants, and increased (>220 U/L) lactate dehydrogenase levels (mean, 339.50 U/L ± 124.15) in 128 of 158 (81%) patients. Full results are reported in Table 1.

Table 1: Clinical Data

Characteristic	Finding (*n* = 158)
Patient demographics	
Mean age (y)	57 ± 17
Age range (y)	18–89
Total no. of patients	158 (100)
Male	83 (52)
Female	75 (47)
Result of RT-PCR assay	
Positive	62 (39)
Negative	96 (61)
Signs	
Fever (>37.5°C)	97 (61)
Cough	88 (56)
Dyspnea	52 (33)
Laboratory test	
C-reactive protein level (mg/L)	
Increased	139 (88)
Normal	19 (12)
Lactic acid dehydrogenase level (U/L)	
Increased	128 (81)
Normal	30 (19)
Lymphocytes ($\times 10^9$/L)	
Increased	13 (8)
Decreased	95 (60)
Normal	50 (32)

Note.—Unless otherwise indicated, data are numbers of patients, and data in parentheses are percentages. Normal range of C-reactive protein level is 0.00–0.50 mg/L. Normal range of lactic acid dehydrogenase level is 125–220 U/L. Normal range of lymphocytes is 1.5–3.0 $\times 10^9$/L. RT-PCR = reverse- transcription polymerase chain reaction.

CT Diagnostic Performance

Of the 158 patients, 62 (39%) had positive RT-PCR results and 102 (64%) had positive CT findings. Detailed results are reported in Table 2. With RT-PCR serving as the reference standard, sensitivity, specificity, and accuracy of CT for COVID-19 pneumonia were 97% (95% CI: 88%, 99%) (60 of 62 participants), 56% (95% CI: 45%, 66%) (54 of 96 participants), and 72% (95% CI: 64%, 78%) (114 of 158 participants), respectively.

CT Image Analysis

To understand the CT features of patients with COVID-19 pneumonia, a subanalysis was performed considering only study participants with positive RT-PCR test results and chest CT findings. Of 158 study participants, 62 had positive RT-PCR results, and among these, 60 had positive CT findings. In consideration of the exclusion of two study participants because of the presence of severe chest CT motion artifact, 58 study participants were evaluated in this subanalysis (Fig 1).

GGOs were present in 58 of 58 patients (100%), both multilobe involvement (two or more lobes) and posterior involvement were present in 54 of 58 (93%) participants, 53 of 58 (91%) participants had bilateral pneumonia distribution, and peripheral GGO location was observed in 52 of 58 (89%) participants.

A simultaneous involvement of all five lobes was observed in 43 of 58 participants (74%). The right lower lobe was the most affected in 53 of 58 participants (93%), followed by involvement of the left lower lobe and right upper lobe in 51 of 58 participants (both 91%). In regard to GGO, three patterns were observed in order of frequency: crazy paving in 23 of 58 participants (39%), rounded morphology in 19 of 58 participants (32%), and linear opacities in 16 of 58 participants (27%).

An enlarged subsegmental vessel, defined as a vessel diameter greater than 3 mm, was observed in 52 of 58 participants (89%), with mean vessel diameter of 3.9 mm ± 0.6. Consolidation was observed in 42 of 58 participants (72%), including 32 of 58 (55%) with subsegmental involvement. Presence of lymphadenopathy was reported in 34 of 58 participants (59%). Less frequent findings are shown in Tables 3 and 4. Examples of chest CT findings are shown in Figures 2 and 3.

Chest CT features were compared between participants who required hospitalization (inpatients, 49 participants) and those who were referred for home isolation (outpatients, nine participants). There were no significant differences in chest CT findings between these groups (Table 5, $P > .06$ for all findings).

Table 2: Diagnostic Performance of Chest CT for COVID-19 Infection with RT-PCR as the Reference Standard

Statistic	TP	TN	FP	FN	Sensitivity	Specificity	PPV	NPV	Accuracy
No. of findings	60	54	42	2	60/62 (97)	54/96 (56)	60/102 (59)	54/56 (96)	114/158 (72)
95% CI (%)	…	…	…	…	88, 99	45, 66	53, 64	87, 99	64, 78

Note.—Data in parentheses are percentages. CI = confidence interval, COVID-19 = Coronavirus Disease 2019, FN = false-negative, FP = false-positive, NPV = negative predictive value, PPV = positive predictive value, RT-PCR = reverse transcription polymerase chain reaction, TN = true-negative, TP = true-positive.

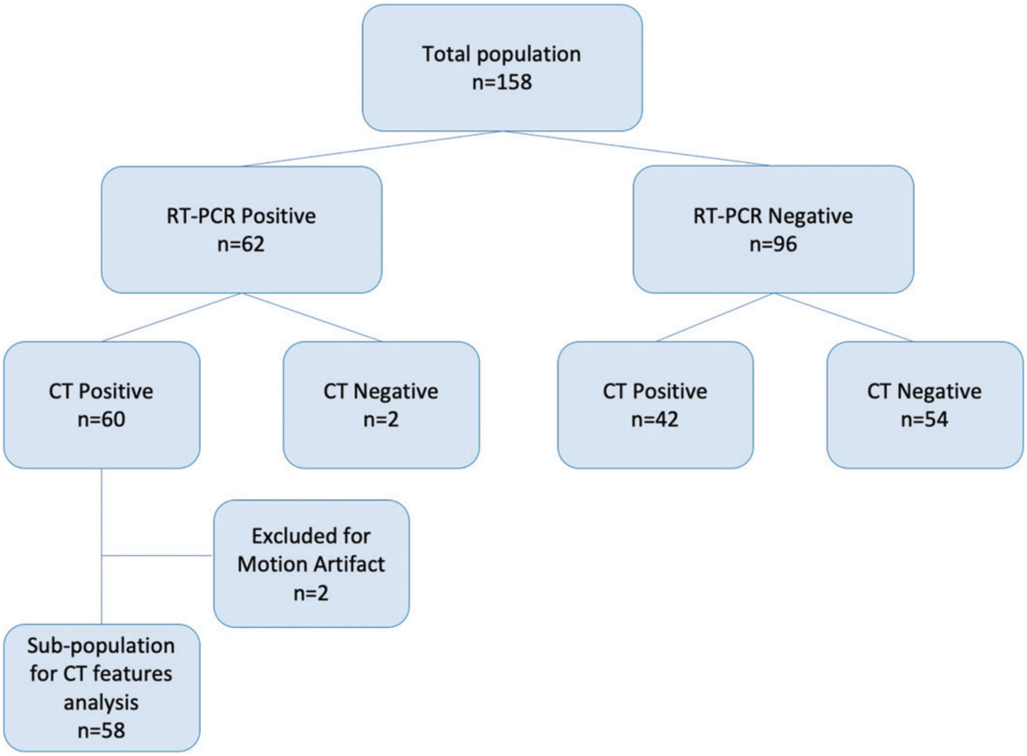

Figure 1: Flowchart of the study. RT-PCR = reverse transcription polymerase chain reaction.

Table 3: CT Features in Participants with COVID-19 Infection Confirmed with RT-PCR

CT Feature	No. of Participants (*n* = 58)	Percentage
GGO	58	100
Multilobe involvement (≥2 lobes)	54	93 (86, 99)
Bilateral distribution	53	91 (83, 98)
Posterior involvement	54	93 (86, 99)
GGO location (peripheral)	52	89 (81, 97)
Subsegmental vessel enlargement (>3 mm)	52*	89 (81, 97)
Consolidation	42	72 (60, 83)
Subsegmental	32	55 (42, 67)
Segmental	10	17 (7, 26)
Lymphadenopathy	34	58 (45, 70)
Bronchiectasis	24	41 (28, 53)
Air bronchogram	21	36 (26, 45)
Pulmonary nodules surrounded by GGO	10	17 (7, 26)
Interlobular septal thickening	8	13 (4, 21)
Halo sign	7	12 (3, 20)
Pericardial effusion	3	5 (0, 10)
Pleural effusion	2	3 (0, 7)
Bronchial wall thickening	1	1 (0, 3)
Cavitation	0	0

Note.—Data in parentheses are 95% confidence intervals. COVID-19 = Coronavirus Disease 2019, GGO = ground-glass opacity, RT-PCR = reverse transcription polymerase chain reaction.
* Mean ± standard deviation is 3.9 mm ± 0.6.

Discussion

To date, the majority of results evaluating the use of chest CT for Coronavirus Disease 2019 (COVID-19) pneumonia were in patient populations in China. We conducted a prospective study at our institution in Rome, Italy, in which we compared chest CT with reverse transcription polymerase chain reaction (RT-PCR) for COVID-19 infection. Two RT-PCR tests within 24 hours were used to confirm the presence or absence of COVID-19 infection. In 158 study participants, the sensitivity and specificity of chest CT were 97% (95% confidence

Table 4: CT Feature in Participants with RT-PCR–confirmed COVID-19 Infection

CT Features Subanalysis	No. of Patients (n = 58)	Percentage
No. of lobes involved		
0	0	0
1	4	6 (0, 12)
2	2	3 (0, 7)
3	3	5 (0, 10)
4	6	10 (2, 17)
5	43	74 (62, 85)
Frequency of lobe involvement		
Right upper lobe	53	91 (83, 98)
Right middle lobe	48	82 (72, 91)
Right lower lobe	54	93 (86, 99)
Left upper lobe	49	84 (74, 93)
Left lower lobe	53	91 (83, 98)
GGO pattern		
Crazy paving	23	39 (26, 51)
Rounded morphology	19	32 (19, 44)
Linear opacities	16	27 (15, 38)

Note.—Data in parentheses are 95% confidence intervals. COVID-19 = Coronavirus Disease 2019, GGO = ground-glass opacity, RT-PCR = reverse transcription polymerase chain reaction.

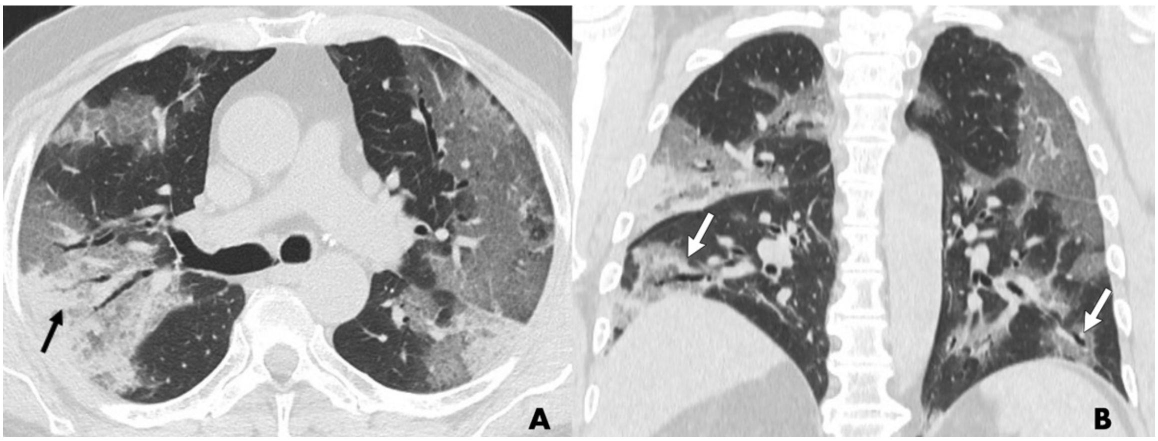

Figure 2: Axial and coronal thin-section unenhanced CT scan in a 65-year-old man with unknown exposure history who presented with fever and cough. *A*, Chest CT shows diffuse bilateral confluent and predominantly linear ground-glass opacities with a pronounced peripheral distribution and consolidation with an air bronchogram (arrow). *B*, Coronal thin-section unenhanced CT scan shows diffuse bronchiectasis of both lower lobes (arrows).

interval [CI]: 88%, 99%) (60 of 62 participants) and 56% (95% CI: 45%, 66%) (54 of 96 participants), respectively. Typical CT features of COVID-19 were GGO (58 of 58 [100%]), multilobe (more than two lobes) and posterior involvement (both 54 of 58 [93%]), and bilateral pneumonia distribution (53 of 58 [91%]). At CT, subsegmental vascular enlargement (>3-mm diameter) in areas of lung opacity was observed in 89% of participants with confirmed COVID-19 pneumonia. There were no significant differences in chest CT features for individuals with severe disease who were hospitalized versus those with mild disease who were referred for isolation, although the study size was small for this comparison (49 vs nine participants, respectively).

Our results are in accordance with the systematic review performed by Salehi et al (17) of 919 patients, despite some interesting differences: the population in our study showed a higher prevalence of pulmonary consolidations (72% vs 31%), GGO peripheral distribution (89% vs 76%), and GGO (100% vs 88%), respectively. Our population differs from the population in the Zhu et al study of 32 patients, where GGOs were found in only 47% of patients with COVID-19 (18). Recently, Chung et al analyzed a small population of 21 patients and found a very low frequency of crazy paving pattern compared with our results (19% vs 39%, respectively) (10). Mediastinal adenopathy was also much more frequent in our study (58%). In general, the participants in our study were somewhat older (mean age, 57 years), with more men (52%) described in prior reports.

An interesting chest CT feature was the presence of enlarged subsegmental pulmonary vessels in 89% of study participants.

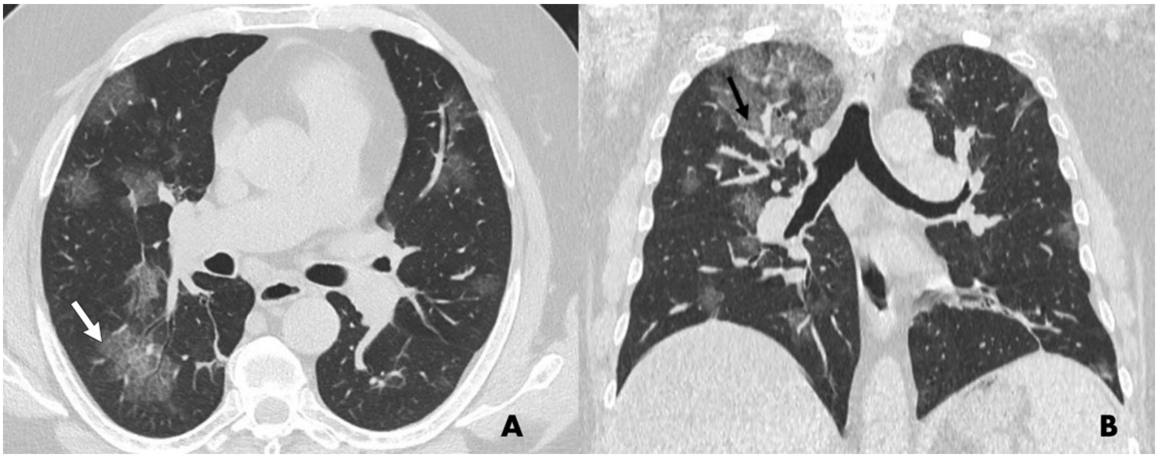

Figure 3: Axial and coronal thin-section unenhanced CT scans in a 55-year-old man with a history of recent travel to Milan, Italy, who presented with fever and dyspnea. *A*, Scan shows bilateral ground-glass opacities with rounded morphology (arrow) in both upper and lower lobes, as well as inter- and intralobular septal thickening (crazy paving pattern). *B*, Scan shows predominantly apical ground-glass opacities with tubular size increase of segmental and subsegmental vessels (arrow).

Table 5: Comparison of Chest CT Features in Participants Hospitalized for COVID-19 Pneumonia versus Those with Mild Disease Referred Home for Isolation

	Inpatients		Outpatients		
CT Feature	No. of Participants (n = 49)	Percentage	No. of Participants (n = 9)	Percentage	P Value
GGO	49	100	9	100	…
Multilobe involvement (≥2 lobes)	46	93 (85, 100)	8	88 (66, 100)	.58
Bilateral distribution	46	93 (85, 100)	7	77 (49, 100)	.11
Posterior involvement	46	93 (85, 100)	8	88 (66, 100)	.58
GGO location (peripheral)	45	91 (82, 99)	7	77 (49, 100)	.20
Subsegmental vessel enlargement (>3 mm)	43	87 (77, 96)	9	100	.66
Consolidation	37	75 (62, 87)	5	55 (22, 87)	.21
Lymphadenopathy	22	44 (30, 57)	1	11 (0, 31)	.06

Note.—Data in parentheses are confidence intervals. COVID-19 = Coronavirus Disease 2019, GGO = ground-glass opacity.

This finding was described by Albarello et al in two patients in Italy (19). Bai et al described subsegmental vascular enlargement in 59% of the patients with COVID-19 pneumonia versus 22% of those with nonviral pneumonia (14). Ye et al suggested vascular enlargement may be due to proinflammatory factors (16). Subsegmental vascular enlargement could reflect the hyperemia induced by severe acute respiratory syndrome coronavirus 2 infection versus viral pulmonary infections, such as severe acute respiratory syndrome coronavirus and Middle East respiratory syndrome coronavirus (20–22).

The diagnostic performance of chest CT in this study was in accordance with recently published data. We used RT-PCR as the reference standard and report a high sensitivity of 97%, a moderate specificity of 56%, and an accuracy of 72%. These results are similar to those of Ai et al who reported a sensitivity of 97%, a specificity of 25%, and an accuracy of 68% in patients from Wuhan, China (5).

Several limitations should be addressed. In our setting, clinical and laboratory data were limited because of the urgency of the situation. Patient outcomes were not available at the time of this communication. The size of this patient study was limited.

In conclusion, the typical pattern of Coronavirus Disease 2019 pneumonia on chest CT in Rome, Italy, was characterized by the consistent presence of peripheral ground-glass opacities associated with multilobe and posterior involvement, bilateral distribution, and subsegmental vessel enlargement (>3 mm).

Acknowledgements: The authors thank Paolo Anibaldi, MD, Giuseppe Argento, MD, Daniela Sergi, MD, and Antonio Cremona, MD, for clinical and CT data collection, and Mariarita Tarallo, MD, PhD, for manuscript editing. We also acknowledge the entire radiological medical and technical staff of the Radiology Unit of Sant'Andrea Academic Hospital in Rome.

Author contributions: Guarantors of integrity of entire study, all authors; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; approval of final version of submitted manuscript, all authors; agrees to ensure any questions related to the work are appropriately resolved, all authors; literature research, D.C., M.Z., M.P., F.P., T.P., C.R., G.G., B.B., C.D.D.; clinical studies, D.C., M.Z., M.P., F.P., T.P., C.R., G.G., B.B., C.D.D.; statistical analysis, D.C., M.Z.; and manuscript editing, D.C., M.Z., M.P., F.P., T.P., C.R., G.G., B.B., A.L.

Disclosures of Conflicts of Interest: **D.C.** disclosed no relevant relationships. **M.Z.** disclosed no relevant relationships. **M.P.** disclosed no relevant relationships. **F.P.** disclosed no relevant relationships. **T.P.** disclosed no relevant relationships. **C.R.** disclosed no relevant relationships. **G.G.** disclosed no relevant relationships. **B.B.** disclosed no relevant relationships. **C.D.D.** disclosed no relevant relationships. **A.L.** Activities related to the present article: disclosed no relevant relationships. Activities not related to the present article: gave lectures for Bracco, Bayer, GE Healthcare, Guerbet, and Merck Sharp & Dohme. Other relationships: disclosed no relevant relationships.

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