ORIGINAL ARTICLE Chest Imaging

CT in patients with COVID-19: Imaging patterns, disease extent and evolution; our experience in a Greek reference University Hospital

Nikolaos-Achilleas Arkoudis, Athanasios Tsochatzis, Stylianos Argentos, Christina Kontopoulou, Maria Mademli, Stavros Spiliopoulos, Nikolaos Oikonomopoulos
2nd Department of Radiology, General University Hospital "Attikon", Greece

SUBMISSION: 15/6/2020 - ACCEPTANCE: 9/9/2020

ABSTRACT

Purpose: To present our experience from a large Greek reference University Hospital regarding the imaging patterns, severity and evolution of disease, in patients hospitalised with laboratory-confirmed COVID-19 infection.

Material and Methods: 79 consecutive reverse transcription polymerase chain reaction (RT-PCR) confirmed COVID-19 infected patients undergoing chest CT at our hospital between 03/03/2020 and 10/05/2020 were included in the study. All initial scans were evaluated for the presence of various imaging findings and their distribution, as well as for disease extent/severity using the Covid Visual Assessment Scale. Follow-up CTs acquired in 14 of these patients were also examined in order to estimate disease evolution.

Results: The most typical imaging findings were bilateral (86%), multilobar (92.4%) ground glass opacities (GGOs) ± consolidations (89.9%), GGOs with concomitant intralobular or interlobular thickening (crazy paving pattern) (53.1%) and subpleural line(s)/band(s) (55.7%), most often distributed peripherally (77.2%), posteriorly (55.7%) and in the lower zones (49.4%). Common findings

CORRESPONDING AUTHOR, GUARANTOR

Corresponding author: Nikolaos-Achilleas Arkoudis, 2nd Department of Radiology, General University Hospital “Attikon”, Medical School, National and Kapodistrian University of Athens, 1 Rimini Str., Chaidari 12462, Athens, Greece, E-mail: nick.arkoudis@gmail.com

Guarantor: Nikolaos Oikonomopoulos, 2nd Department of Radiology, General University Hospital “Attikon”, Medical School, National and Kapodistrian University of Athens, 1 Rimini Str., Chaidari 12462, Athens, Greece, E-mail: noikonom1959@gmail.com

included bronchial wall thickening (39.2%), bronchial dilatation (40.5%), vascular enlargement (46.8%), pleural thickening (32.9%) and air bronchogram(s) (29.1%). Less common findings were lymphadenopathy (25.3%), pleural effusion(s) (19%) and nodule(s) (20.2%). Most patients suffered from a mild (<25%) to moderate (<50%) imaging extent of disease. Increase in extent of disease was seen in 10/14 (71.4%) patients, with increase of both consolidations and GGOs seen in 8/10 (80%) of these patients.

Conclusions: Our findings further confirm formerly published radiological patterns of COVID-19 pneumonia and raise awareness regarding the prevalence of subtler findings such as the frequently occurring subpleural line(s)/band(s) more often noted in this study than previously described. Further research is necessary in order to detect a possible connection between certain imaging findings, clinical status, disease severity and outcome.

KEY WORDS | COVID-19; Chest; CT; Thorax; Radiology; Imaging

Introduction

Coronavirus disease 2019 (COVID-19) is the infectious disease caused by the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which has swiftly spread since the end of 2019 leading the World Health Organisation (WHO) to declare its outbreak as a pandemic in March 2020 [1, 2]. Spreading of the disease is thought to occur mainly through close contact, via respiratory droplets and by touching contaminated surfaces [2-4]. The commonest symptoms of COVID-19 include fever, dry cough, shortness of breath and fatigue [1, 2]. Most cases exhibit mild symptoms but serious illness can also be developed, mainly in patients with underlying comorbidities [2]. Final COVID-19 diagnosis mandates a positive reverse transcription polymerase chain reaction (RT-PCR) test. However, factors such as sampling handling and timing, specimen source and quality of detection kits can affect the RT-PCR test results [5, 6], a realisation which highlights the need for supplementary tools in clinical practice. Chest CT can demonstrate characteristic findings in patients with COVID-19 and has been reported to have high sensitivity for diagnosis [6]. This has made it valuable in recognising and characterising the disease as well as in the follow-up of affected patients. Imaging findings on CT can range from typical to atypical and vary according to the course of the disease at the time of imaging, with the most characteristic findings including bilateral multilobar ground glass opacities (GGOs), distributed mainly peripherally, posteriorly and in the lower lobes [7, 8]. The purpose of this study is to present our experience from a large Greek reference University Hospital regarding the imaging patterns, severity and evolution of disease, in patients hospitalised with laboratory-confirmed COVID-19 infection.

Material and Methods

The institutional review board of our hospital (UGHA) waived the requirement to obtain written informed consent for this retrospective study. The electronic database of the Department of Radiology was meticulously searched for all patients with confirmed COVID-19 infection who underwent chest CT at our hospital between 03/03/2020 and 10/05/2020. A total of 79 consecutive RT-PCR confirmed COVID-19 infected patients (50 men; 29 women, mean age of 65.2 ± 17 years, range 18-95 years) were included in the study. In our institution the RT-PCR test was obtained with a nasopharyngeal swab test. No exclusion criteria were applied. All CT examinations performed were of acceptable quality for evaluation, hence none were excluded. Patients undergoing chest CT imaging in our department were mainly those demonstrating signs and symptoms of respiratory distress (dyspnoea, desaturation) that were already RT-PCR positive for COVID-19 or those who were suspected to be RT-PCR positive for COVID-19 but their clinical condition mandated urgent imaging and could not afford the delay from the anticipation of RT-PCR test results. In the latter scenario, patients were handled as COVID-19 positive until their results were avail-

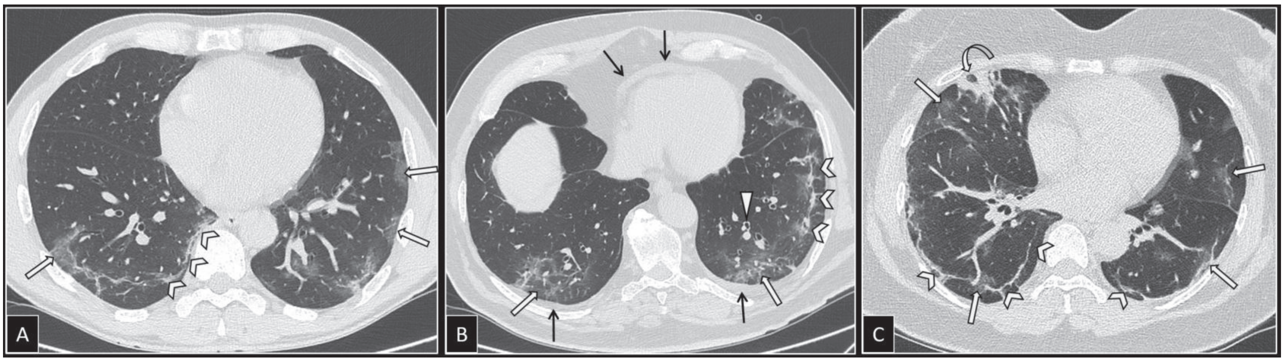

Fig. 1. *CT scans of 3 different laboratory confirmed COVID-19 patients (A, B, C), demonstrating bilateral and multilobar GGOs (arrows) and subpleural lines/bands (arrowheads), mostly located peripherally, posteriorly and in the lower zones. Small pericardial and pleural effusions (thin black arrows), as well as mild bronchial wall thickening (triangular arrowhead) can also be seen in patient B, while a consolidative infiltrate in the right middle lobe (curved arrow) is additionally seen in patient C.*

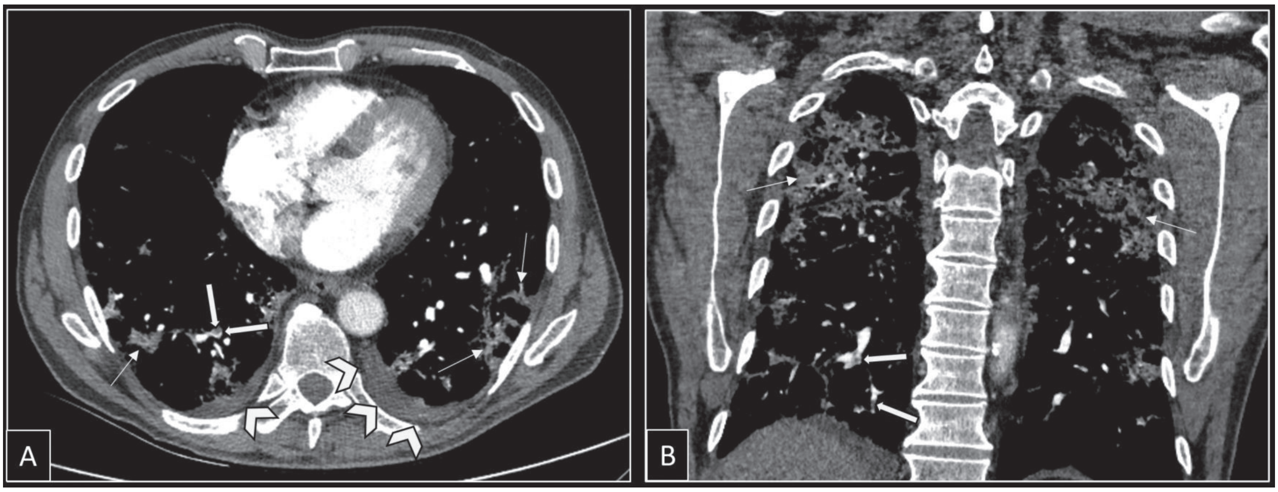

Fig. 2. *CT pulmonary angiogram scan of a laboratory confirmed COVID-19 patient, demonstrating pulmonary emboli in subsegmental branches of the pulmonary artery (thick arrows) in axial (**A**) and coronal plane (**B**). Bilateral pleural effusions (arrowheads) and consolidations (thin arrows) can also be seen.*

able, and were eventually included in the study only if the RT-PCR came back positive. Ultimately, the decision of which patients warranted imaging investigation was left to clinical judgment. As a general rule, and as long as the clinical situation of the patient allowed it, chest CT imaging was undertaken after the RT-PCR test results were made known in order to indicate the appropriate procedures for patient management.

CT examination procedure

All COVID-19 related CT examinations were conducted in a Philips Brilliance™ 64 CT scanner with a slice thickness of 1 mm, and a high-resolution CT algorithm. End-inspiration breath hold for the duration of the scanning was endorsed in individuals who could tolerate it depending on their clinical condition. Patients typically received a non-contrast chest CT, unless contrast administration was deemed necessary and crucial in their management (i.e. in order to exclude diagnosis such as suspected PE).

Imaging Analysis

Two radiologists (N.A.A. & A.T.), with 4 and 5 years of experience in interpreting chest CTs respectively, independently reviewed all chest CT images obtained and final decisions were reached by consensus. In cas-

Table 1. Imaging findings detected at initial chest CT scans in 79 patients

Imaging findings	Number of scans (%)
Ground glass opacities (GGOs) and consolidation(s)	
Absence of both GGOs and consolidation(s)	7 (8.8%)
Presence of either GGOs or consolidation(s)	72 (91.1%)
Presence of GGOs with or without consolidation(s)	71 (89.9%)
Presence of GGOs without consolidation(s)	31 (39.2%)
Presence of GGOs with consolidation(s)	40 (50.6%)
Presence of consolidation(s) without GGOs	1 (1.3%)
Presence of consolidation(s) with or without GGOs	41 (51.9%)
Intralobular and/or interlobular thickening	
Intralobular and/or interlobular thickening with or without GGOs	48 (60.7%)
Intralobular and/or interlobular thickening with GGOs (crazy paving pattern)	42 (53.1%)
Intralobular and/or interlobular thickening without GGOs	6 (7.6%)
Air bronchogram(s)	23 (29.1%)
Bronchial wall thickening	31 (39.2%)
Bronchial dilatation	32 (40.5%)
Vascular enlargement	37 (46.8%)
Subpleural line(s)/band(s)	44 (55.7%)
Pleural effusion(s)	15 (19%)
Pleural thickening	26 (32.9%)
Nodule(s)	16 (20.2%)
Halo sign	1 (1.3%)
Reverse halo sign	2 (2.5%)
Lymphadenopathy	20 (25.3%)
Pericardial effusion	3 (3.8%)
Other findings	
Pulmonary emphysema	10 (12.6%)
Coronary atherosclerosis	51 (64.5%)
No pulmonary parenchyma findings detected	3 (3.8%)

Table 2. Distribution characteristics of the imaging findings detected at initial chest CT scans in 79 patients

Localisation & Distribution	Number of scans (%)
Bilateral disease	68 (86%)
Unilateral disease	8 (8.8%)
Multilobar involvement	73 (92.4%)
Unilobar involvement	3 (3.8%)
Peripheral predominance	61 (77.2%)
Central predominance	2 (2.5%)
Neither peripheral or central predominance	13 (16.5%)
Upper zone predilection	6 (7.6%)
Lower zone predilection	39 (49.4%)
Neither upper or lower zone predilection	31 (39.2%)
Posterior predominance	44 (55.7%)
No pulmonary parenchymal findings detected	3 (3.8%)

Table 3. Total imaging extent of Covid-19 disease estimated on a visual assessment scale (CoVASc), in the initial scans of 79 patients

Visual assessment scale	Number of scans (%)
0%	3 (3.9%)
1-10%	14 (17.7%)
11-25%	19 (24%)
26-50%	25 (31.6%)
51-75%	14 (17.7%)
76-100%	4 (5.1%)

Table 4. Qualitative change at follow-up chest CT scans obtained in 14 patients.

Qualitative change	Number of scans (%)
Increase in extent of disease	10/14 (71.4%)
No significant imaging differentiation	2/14 (14.3%)
Decrease in extent of disease	2/14 (14.3%)

es of disagreement in their interpretations, a third radiologist with 27 years of experience (N.O.) adjudged a final decision. Taking into consideration findings previously described and categorised in recent literature [6-17], and according to the Fleischner Society definitions [18], CT images from all initial scans were evaluated for the presence of: consolidations (**Figs. 1-3**); GGOs (**Figs. 1, 3**); consolidations superimposed on GGOs (**Figs. 1, 3**); intralobular or interlobular thickening; crazy paving pattern (**Fig. 3**); air bronchograms (**Fig. 3b**); in-lesion bronchial wall thickening (**Fig. 1b, 3a**), bronchial dilatation (**Fig. 3b**) and vascular enlargement (**Fig. 4**); pleural effusion(s) (**Fig. 1b, 2, 3b**); pleural thickening; subpleural line(s)/band(s) (**Fig.1**); nodule(s); halo sign; reversed halo sign; lymphadenopathy; pericardial effusion (**Fig. 1b**), as well as for incidental findings of pulmonary emphysema and coronary atherosclerosis. Moreover, unilateral or bilateral and unilobar or multilobar (more than one lobe) involvement; predominant distribution (peripheral/central and upper/lower zone); as well as posterior distribution predominance were noted (**Fig. 1**). Additionally, disease extent/severity was estimated based on a visual assessment scale that we named Co.V.A.Sc.

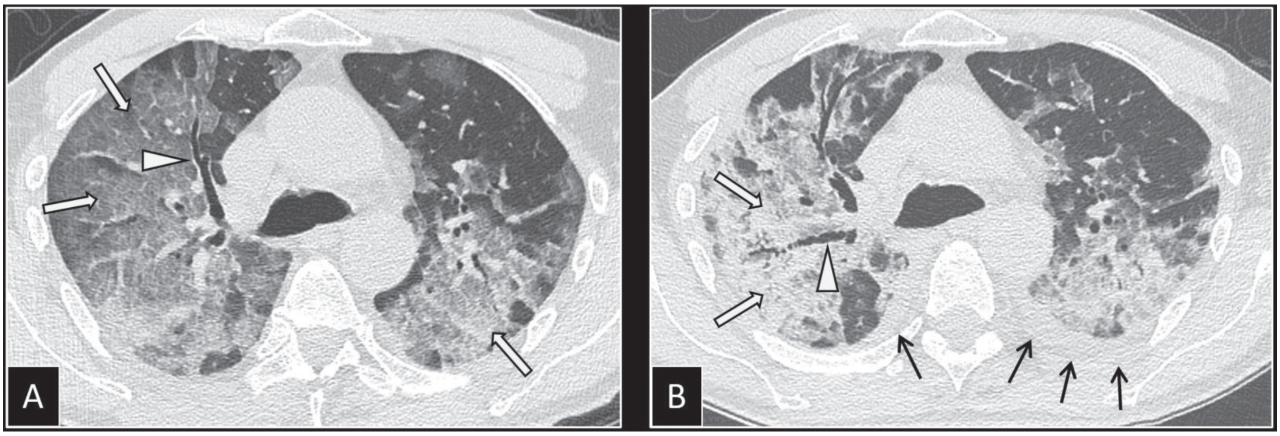

Fig. 3. *A) Initial CT scan of a laboratory confirmed COVID-19 patient showcasing bilateral and multilobar "ground glass" opacities with superimposed interlobular septal thickening (crazy paving pattern) (arrows) along with mild bronchial wall thickening (triangular arrowhead).* ***B****) Follow-up CT obtained 8 days later in the same patient demonstrates that the previous pattern has become consolidative (arrows) with traction bronchiectasis within (triangular arrowhead). Pleural effusions have developed as well (thin black arrows).*

(Covid Visual Assessment Scale); a scale that roughly estimates the percentage of pulmonary parenchyma affected by Covid-19 disease, as seen on chest CT, when both lungs are evaluated as a whole (0%, 1-10%, 11-25%, 26-50%, 51-75%, >75%). At last, follow-up CTs acquired in a total of 14 of these patients were examined in order to estimate disease progression, regression or stability. Those were obtained within 1-16 days (mean time 6.85 ± 3.88) after the initial CT study.

Results

A total of 93 CT scans in 79 consecutive RT-PCR confirmed COVID-19 infected patients were evaluated.

Initial chest CT imaging findings and distribution

Data regarding the imaging findings and distribution characteristics of the 79 initial chest CTs of the cohort are presented in **Tables 1 and 2** respectively. Additionally, the most commonly encountered findings and distribution patterns are graphically represented in **Figs. 5 & 6** respectively.

Intravenous contrast was administered in only 6 (7.6%) initial CT scans, all of which in order to exclude suspected concomitant pulmonary embolism (PE). From the 6 patients undergoing a computed tomography pulmonary angiography (CTPA) as an initial investigation, PE was identified in 1 (16.7%) occurring bilaterally in lobar and segmental branches of the pulmonary artery.

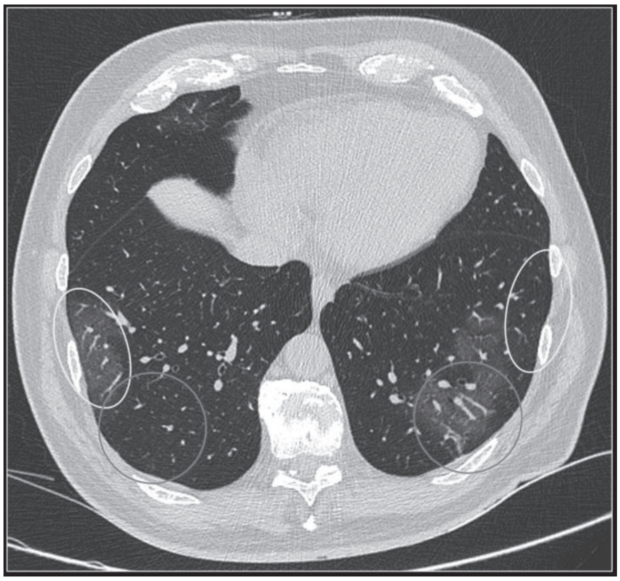

Fig. 4. *CT scan of a RT-PCR positive COVID-19 patient demonstrates mild vascular dilatation within "ground glass" opacities. Specifically, mild vascular dilatation can be seen in the affected part of the right lower lobe (white oval on the left) when compared to the corresponding unaffected part of the left lower lobe (white oval on the right). Similarly, vascular dilatation is noted in the affected part of the left lower lobe (grey circle on the right) when compared to the corresponding unaffected part of the right lower lobe (grey circle on the left).*

Severity of disease

The total imaging extent of disease (estimated by using

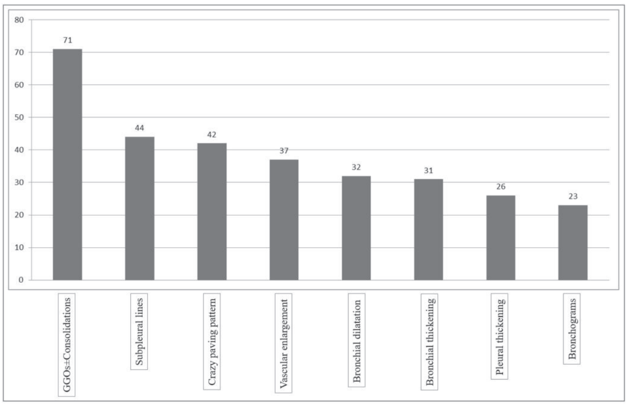

Fig. 5. *Graphical representation of the most common imaging findings/ patterns encountered in the 79 initial scans obtained. GGOs with or without consolidations, subpleural line(s)/band(s) and crazy paving pattern were the most typical imaging findings while common findings included in-lesion occurrence of vascular enlargement, bronchial dilatation and bronchial wall thickening, as well as the detection of pleural thickening and the presence of air bronchogram(s).*

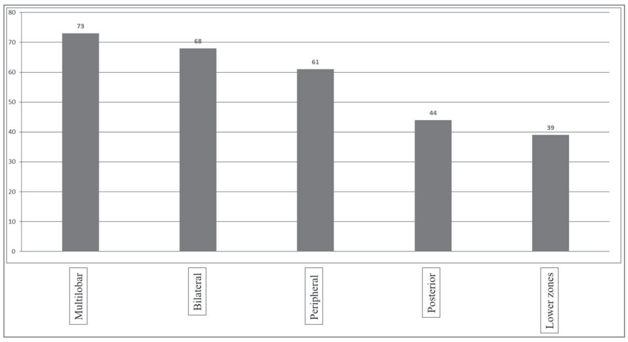

Fig. 6. *Graphical representation of the most common distribution patterns encountered in the 79 initial scans obtained. The disease most often affected multiple lobes and both lungs and was usually distributed peripherally, posteriorly and in the lower zones.*

the CoVASc) in the initial scans of the 79 patients included in this study is summarised in **Table 3**.

Follow-up Chest CT

Follow-up CTs were acquired in a total of 14 patients and those were obtained within 1-16 days (mean time 6.85 ± 3.88 days) after the initial CT study. A CTPA was the imaging protocol performed in 7/14 patients (50%) and a non-contrast scan was performed in the remaining 7/14 (50%). All CTPA scans were preceded by a non-contrast end-inspiration chest CT scan. From the evaluation of the follow-up CTPA scans, PE was detected in 2/7 (28.6%), occurring in subsegmental branches of the pulmonary artery in both cases (**Fig. 2**).

Disease progression, regression or stability can be seen in **Table 4**. Increase in extent of disease was seen in 10/14 (71.4%) patients (**Fig. 3**), with increase of both consolidations and GGOs seen in 8/10 (80%) of these patients. The remaining 2/10 (20%) of these patients had presented with GGOs (without consolidations) in the initial scan and no consolidations occurred in follow-up scanning either. Furthermore, traction bronchiectasis occurred in 1/14 patients (7.1%); pleural effusions occurred as a new finding in 1/14 (**Fig. 3b**) and preexisting pleural effusion progressed in 1/14 patients (7.1%) demonstrating worsening on imaging. Crazy paving pattern did not occur as a new finding in the follow-up CTs performed but was already present in the initial scans of 5/10 (50%) patients displaying progression. Only 2/14 (14.3%) patients demonstrated no significant imaging differentiation. Their follow-up scans were obtained in order to exclude PE which wasn't identified in any of them either. Additionally, 2/14 (14.3%) patients demonstrated decrease in the total extent of disease, however with a cavitated lesion occurring in an area of previous consolidation in one of them (presumably due to secondary infection), and prominent bronchial dilatation identified in the other one.

Discussion

We thoroughly assessed the imaging characteristics in the initial chest CT scans of 79 consecutive RT-PCR confirmed COVID-19 pneumonia patients presenting to our hospital, as well as the follow-up chest CT scans obtained in 14 of those patients. The most typical imaging findings were GGOs with or without consolidations and GGOs with concomitant intralobular or interlobular thickening (crazy paving pattern), with the disease affecting both lungs, multiple lobes and most often being distributed peripherally, posteriorly and in lower zones. Another very often occurring finding was the presence of subpleural line(s)/band(s). Common findings included in-lesion occurrence of bronchial wall thickening, bronchial dilatation and vascular enlargement, as well as the detection of pleural thickening and the presence of air bronchogram(s). Less common findings were lymphadenopathy, pleural effusion(s) and nodule(s), while a pericardial effusion, the halo sign and the reversed halo sign were only rarely seen.

The majority of our findings are in keeping with the available literature. Specifically, a recently published systematic review of 919 patients [7] described GGOs occurring in 88% of patients, bilateral involvement in 87.5%, multilobar involvement in 78.8% and peripheral distribution in 76%. Additionally, posterior involvement has been seen in up to 80% of cases [7, 16] while a multicenter study [19] described lower predominance in 54.5% of cases. A crazy paving pattern has been described in 5-36% of cases [10, 13, 20] while other available publications have described its incidence to be 71% [21] and 75% [16]. Moreover, a review from Güneyli et al [17] found that air bronchogram(s) have been reported in 28-80% of patients; pleural thickening in up to 32%; vascular enlargement in 59-80% and bronchial dilatation in up to 52.5% [17, 19]. The reversed halo sign has been described in up to 5% of cases [10, 17], which is also in accordance with our findings, where 2 (2.5%) patients demonstrated its presence. Interestingly, one of them suffered from concomitant pulmonary embolism, hence the reversed halo sign in this case could have been the result of pulmonary infarction. Similarly, in keeping with our findings, the incidence of pericardial effusion has been described in up to 5% of patients [17].

Previous studies have shown subpleural lines to occur in 20-28% of patients [17-20, 22] while bronchial wall thickening has been described in up to 28.7% of patients [19] and associated with more severe disease [20]. Nodules have been reported in 3–13% of patients [10, 17] which is less than what we observed in this study. However, nodules can be present due to a wide range of aetiologies. They could represent an atypical finding of the disease and/or could be attributed to an unrelated synchronous pathology (i.e. representing metastasis if identified in patients with an underlying malignancy, as was the case for 2/16 patients demonstrating nodules in this study). Additionally, we noted an increased prevalence of pleural effusion(s) (19%) compared to previously published literature describing it in up to 9.7% of cases [10, 23]. Although the authors assume the prevalence of pleural effusion(s) could also be associated with the patient's cardiac function, underlying cardiovascular status was not investigated for the purposes of this study. Furthermore, lymphadenopathy was detected in 25.3% of scans with most available literature describing it in only 8% of cases [10, 17] and one report (which included a small number of severely ill patients) observing it in six out of nine patients (66%) being imaged [24]. Since the majority of patients being scanned for COVID-19 pneumonia around the globe undertake a non-contrast CT scan, accurate assessment of lymphadenopathy can often prove challenging, especially in cases were lymph nodes are not surrounded by fat in order to be more clearly detected. This could partly lead to underdiagnosis and along with the variable size of lymph nodes (depending on their mediastinal location) they could both cause variability in assessment amongst studies and reviewers. Of interest, both lymphadenopathy and pleural effusion(s) are considered to indicate severe disease [25]. Furthermore, occurrence of the halo sign can also present great variability amongst studies, ranging from 18-80.6% of cases [17, 26]. The authors speculate that decreased incidence of the halo sign in this study could be attributed to the fact that it was evaluated as present only if the detected GGO was surrounding a discrete nodule, in contrast to many reviewers who might evaluate it as present in cases where small consolidative infiltrates are superimposed on, or surrounded by GGOs. On another note, coronary calcifications were an incidental finding in the vast majority of scans. Its high occurrence could be attributed to the fact that the disease will most likely significantly affect (hence eventually leading to CT imaging) older patients with underlying comorbidities. However, this assumption has not been confirmed. Studies performing a quantitative evaluation of coronary disease and examining its potential as an independent indicator of disease severity, outcome, morbidity and mortality, would be of interest.

Visual assessment based on the CoVASc, demonstrated that most patients suffered from a mild to moderate imaging extent of disease, meaning that less than 25% and less than 50% of the total lung parenchyma was respectively affected on imaging. Correlation of imaging extent of disease with the patient's clinical status and outcome of disease is merited.

In this study we found that from the 14 follow-up scans obtained, 10 patients demonstrated increase in extent of disease. Notably, 8/10 (80%) of them demonstrated increase of both consolidations and GGOs, which is in keeping with previously published literature observing that consolidations indicate disease progression [16]. In contrast to Pan et al. [12], observing that the crazy-paving pattern can signal progression or peak stage of the disease, other published studies [27-29] observed that the most common findings on follow-up CT were the increase of consolidations and the loss of crazy-paving pattern. In this study, crazy paving did not occur as a new finding in the 10 follow-up CTs demonstrating progression; however, in 5/10 (50%) of them it was already present in the initial examination. Nevertheless, accurate assessment of the evolution of disease in follow-up scans requires additional studies with a larger number of patients.

A total of 13 CTPA scans were performed in this retrospective study, six of which were obtained on initial presentation and seven as follow-up scans. Three of the 13 scans (23.1%) were positive for PE; two of those demonstrating PE in subsegmental branches and one in lobar and segmental branches. Recent studies have reported PE occurring in 32/106 (30%) [30] and in 37% [31] of patients undergoing CTPA. In any case, further research including larger patient cohorts is warranted, in order to verify the potential of a direct causative relation between PE and COVID-19 infection.

On another note, COVID-19 pneumonia can be difficult to differentiate from organising pneumonias (OP) as they can display a similar pattern [14]. As stated previously, in our study we had a high prevalence of bilateral, peripheral and basal GGOs, consolidations and subpleural lines/bands, all of which are also common OP findings. On the contrary, we did not frequently encounter the halo or reversed halo sign which are also commonly seen in OP. Of interest, the high occurrence of the OP pattern has implied that the use of corticosteroids could have a clinically important role in the management of COVID-19 disease [16].

Limitations of this study include the absence of correlation between imaging findings and extent of disease with clinical severity and outcome of disease. Further limitations include the small sample size of follow-up CTs and CTPAs performed and the variability of the timing of the initial and the follow up CTs. Additionally, imaging findings on initial scans can vary, depending on the patient's stage of disease at the time of initial scanning. Furthermore, there was no correlation between the day/stage of the initial CT scan and the onset of symptoms.

Conclusion

To conclude, typical imaging manifestations of the disease include bilateral multilobar GGOs with or without consolidation(s) and/or concomitant interlobular or intralobular septal thickening (crazy paving pattern), distributed mainly peripherally, posteriorly and in the lower zones. These findings further confirm formerly published radiological patterns of COVID-19 pneumonia. However, awareness should be raised regarding the prevalence of more subtle findings such as the frequently occurring subpleural line(s)/band(s) more often noted in this study than previously described. Finally, further research is necessary in order to detect a possible connection between certain imaging findings, disease severity, clinical status and disease outcome. **R**

Funding

This project did not receive any specific funding.

Ethical approval

The institutional review board of the hospital (UGHA) waived the requirement to obtain written informed due to retrospective study.

Conflict of interest

The authors declared no conflicts of interest.

References

1. Mayo Clinic. Coronavirus disease 2019 (COVID-19). Available via https://www.mayoclinic.org/diseases-conditions/coronavirus/symptoms-causes/syc-20479963. Published April 14, 2020. Accessed May 15, 2020.
2. World Health Organization. Q&A on coronaviruses (COVID-19) Available via https://www.who.int/news-room/q-a-detail/q-a-coronaviruses. Published April 17, 2020. Accessed May 15, 2020.
3. Stockholm: European Centre for Disease Prevention and Control. Guidance for wearing and removing personal protective equipment in healthcare settings for the care of patients with suspected or confirmed COVID-19. Available via https://www.ecdc.europa.eu/sites/default/files/documents/COVID-19-guidance-wearing-and-removing-personal-protective-equipment-healthcare-settings-updated.pdf. Published February 2020. Accessed May 16, 2020.
4. Centers for Disease Control and Prevention. How COVID-19 Spreads. Available via https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/how-covid-spreads.html. Updated June 16, 2020. Accessed May 16, 2020.
5. Yang Y, Yang M, Shen C, et al. Evaluating the accuracy of different respiratory specimens in the laboratory diagnosis and monitoring the viral shedding of 2019-nCoV infections. medRxiv 2020. doi.org/10.1101/2020.02.11.20021493. Published February 17, 2020. Accessed May 16, 2020.
6. Ai T, Yang Z, Hou H, et al. Correlation of chest CT and RT-PCR testing in Coronavirus disease 2019 (COVID-19) in China: A report of 1014 cases. *Radiology* 2020; 296(2): E32-E40.
7. Salehi S, Abedi A, Balakrishnan S, et al. Coronavirus disease 2019 (COVID-19): A systematic review of imaging findings in 919 patients. *AJR Am J Roentgenol* 2020; 215(1): 87-93.
8. Simpson S, Kay FU, Abbara S, et al. Radiological Society of North America Expert Consensus Statement on Reporting Chest CT Findings Related to COVID-19. Endorsed by the Society of Thoracic Radiology, the American College of Radiology, and RSNA - Secondary Publication. *J Thorac Imaging* 2020; 35(4): 219-227.
9. Revel MP, Parkar AP, Prosch H, et al. COVID-19 patients and the radiology department - advice from the European Society of Radiology (ESR) and the European Society of Thoracic Imaging (ESTI). *Eur Radiol* 2020; 30: 4903–4909.
10. Ye Z, Zhang Y, Wang Y, et al. Chest CT manifestations of new coronavirus disease 2019 (COVID-19): a pictorial review. *Eur Radiol* 2020; 30(8): 4381-4389.
11. Bai HX, Hsieh B, Xiong Z, et al. Performance of radiologists in differentiating COVID-19 from Non-COVID-19 viral pneumonia at chest CT. *Radiology* 2020; 296(2): E46-E54.
12. Pan F, Ye T, Sun P, et al. Time course of lung changes at chest CT during recovery from Coronavirus disease 2019 (COVID-19). *Radiology* 2020; 295(3): 715-721.
13. Bernheim A, Mei X, Huang M, et al. Chest CT findings in Coronavirus disease-19 (COVID-19): Relationship to duration of infection. *Radiology* 2020; 295(3): 200463.
14. Kong W, Agarwal PP. Chest imaging appearance of COVID-19 infection. *Radiology*: *Cardiothoracic Imaging* 2020; 2(1):e200028. 0200028. Published February 13, 2020. Accessed May 18, 2020.
15. Chung M, Bernheim A, Mei X, et al. CT Imaging features of 2019 Novel Coronavirus (2019-nCoV). *Radiology* 2020; 295(1): 202-207.
16. Song F, Shi N, Shan F, et al. Emerging 2019 Novel Coronavirus (2019-nCoV) Pneumonia. *Radiology* 2020; 295(1): 210-217.
17. Güneyli S, Atçeken Z, Doğan H, et al. Radiological approach to COVID-19 pneumonia with an emphasis on chest CT. Diagn *Interv Radiol* 2020; 26(4): 323-332.
18. Hansell DM, Bankier AA, MacMahon H, et al. Fleischner Society: glossary of terms for thoracic imaging. *Radiology* 2008; 246(3): 697-722.
19. Zhao W, Zhong Z, Xie X, et al. Relation between chest CT findings and clinical conditions of Coronavirus disease (COVID-19) pneumonia: A multicenter study. *AJR Am J Roentgenol* 2020; 214(5): 1072-1077.

20. Li K, Wu J, Wu F, Guo D, et al. The clinical and chest CT features associated with severe and critical COVID-19 pneumonia. *Invest Radiol* 2020; 55(6): 327-331.
21. Li Y, Xia L. Coronavirus Disease 2019 (COVID-19): Role of chest CT in diagnosis and management. *AJR Am J Roentgenol* 2020; 214(6): 1280-1286.
22. Wu J, Wu X, Zeng W, et al. Chest CT findings in patients with Coronavirus disease 2019 and its relationship with clinical features. *Invest Radiol* 2020; 55(5): 257-261.
23. Zhou S, Wang Y, Zhu T, et al. CT Features of Coronavirus disease 2019 (COVID-19) pneumonia in 62 patients in Wuhan, China. *AJR Am J Roentgenol* 2020; 214(6): 1287-1294.
24. Valette X, du Cheyron D, Goursaud S. Mediastinal lymphadenopathy in patients with severe COVID-19. *Lancet Infect Dis* 2020; 20(11): 1230.
25. Li K, Wu J, Wu F, et al. The clinical and chest CT features associated with severe and critical COVID-19 pneumonia. *Invest Radiol* 2020; 55(6): 327-331.
26. Wang J, Xu Z, Wang J, et al. CT characteristics of patients infected with 2019 novel coronavirus: association with clinical type. *Clin Radiol* 2020; 75(6): 408-414.
27. Fang Y, Zhang H, Xu Y, et al. CT manifestations of two cases of 2019 Novel Coronavirus (2019-nCoV) pneumonia. *Radiology* 2020; 295(1): 208-209.
28. Lei J, Li J, Li X, et al. CT Imaging of the 2019 Novel Coronavirus (2019-nCoV) pneumonia. *Radiology* 2020; 295(1): 18.
29. Shi H, Han X, Zheng C. Evolution of CT manifestations in a patient recovered from 2019 Novel Coronavirus (2019-nCoV) pneumonia in Wuhan, China. *Radiology* 2020; 295(1): 20.
30. Leonard-Lorant I, Delabranche X, Severac F, et al. Acute pulmonary embolism in COVID-19 patients on CT Angiography and relationship to D-Dimer levels. *Radiology* 2020; 296(3): E189-E191.
31. Kaminetzky M, Moore W, Fansiwala K, et al. Pulmonary embolism on CTPA in COVID-19 patients. *Radiol Cardiothorac Imaging* 2020; 2(4): e200308.

READY - MADE CITATION

Arkoudis NA, Tsochatzis A, Argentos S, Kontopoulou C, Mademli M, Spiliopoulos S, Oikonomopoulos N. CT in patients with COVID-19: Imaging patterns, disease extent and evolution; our experience in a Greek reference University Hospital. *Hell J Radiol* 2021; 6(1): 2-12.