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Journal of Community Medicine & Public Health

Research Article

Abi Ghosn J, et al. J Community Med Public Health 4: 197.
DOI: 10.29011/2577-2228.100097

CT Scan Findings of COVID-19 Infection and its Utility as Screening Tool in Lebanon

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Citation: Abi Ghosn J, Trad F, Berberi J, Hijazi M, Dib J, et al. (2020) CT Scan Findings of COVID-19 Infection and its Utility as Screening Tool in Lebanon. J Community Med Public Health 4: 197. DOI: 10.29011/2577-2228.100097

Received Date: October 26, 2020; **Accepted Date:** November 09, 2020; **Published Date:** November 16, 2020

Abstract

Rationale and objectives: Emerging evidence is increasingly supporting the COVID-19 diagnostic capacity of CT scan. This study aims to examine the applicability of chest CT scan for the diagnosis of COVID-19 and to determine the association between CT scan manifestations and COVID-19 infection.

Patients and Methods: A retrospective study of hospital records included all patients who underwent a CT scan and RT PCR for suspected COVID-19 infection presenting to the Rafic Hariri University Hospital (RHUH) in Beirut, Lebanon between 6 March and 17 April 2020.

Results: 881 patients were included in the study. COVID-19 patients were significantly more likely to be older (p value= 0.008), have moderate and severe criteria (p value <0.001), be hospitalized (p value<0.001), and die (p value= 0.004). Various CT findings were significantly associated with RT PCR results, including bilateral lesions (p value <0.0001), both round and non-round ground glass opacities (GGO), mixed consolidation and GGO, as well as crazy paving. Ancillary CT scan findings correlated with confirmed COVID-19 cases included subpleural line, septal thickening, reverse halo, and pleural thickening. The clinical applicability of chest CT scans for the diagnosis of COVID-19 was most evident in patients with moderate to severe criteria. CT scan had a sensitivity of 69.6% and a specificity of 63.7% for COVID-19, as confirmed by RT PCR.

Conclusion: Chest CT shows potential as a first-line diagnostic tool for COVID-19, particularly for moderate to severe cases. Establishing disease-specific imaging patterns and reliable indicators is critical for the accurate diagnosis of COVID-19 through chest CT.

Keywords: 2019-ncov; Chest CT; COVID-19; Novel coronavirus; RT-PCR; SARS-COV-2

Introduction

The end of 2019 saw the identification of a novel coronavirus, SARS-COV-2, the seventh member of the family of coronaviruses known to infect humans [1]. Since then, the virus has progressed into a global pandemic, causing more than 34 million cases worldwide and claiming the lives of more than 1 million individuals. Nucleic acid amplification tests, such as RT PCR, remain the golden standard of COVID-19 diagnosis [2]. However, despite the high specificity and sensitivity of amplifying viral RNA, false positives and false-negatives are still known to occur, leading to the missed diagnosis of COVID-19 cases [3].

Reliance on PCR results alone not being sufficient for the adequate detection of the novel virus, other methods were explored in order to supplement COVID-19 diagnosis. Combining clinical assessment of disease manifestations with RT PCR results was suggested to facilitate disease control [3]. While some researchers have looked to improve the diagnostic capacity of RT PCR [4], exploring the applicability of CT imaging for the detection of COVID-19 cases was of great interest. In fact, instances of negative RT PCR results in patients with high clinical suspicion of COVID-19 and imaging manifestations of viral pneumonia have been reported [5]. Investigation of CT scans for the diagnosis of COVID-19 have revealed chest CTs to have significantly superior sensitivity when compared to RT PCR [6,7]. Regardless, the sensitivity of CT scan has been questioned, particularly considering the overlap between CT findings correlated to COVID-19 and those exhibited by other respiratory diseases. As a result, both the WHO and the ACR do not recommend CT scans as first-line diagnostic tools for COVID-19 [8,9]. That being said, the absence of widespread testing or timely RT PCR results allowed for the conditional integration of chest imaging for the diagnosis of COVID-19, in addition to its role for the clinical guidance of treatment and therapeutic management of infected patients.

Further evidence on the clinical applicability of chest imaging, particularly CT scan, thus remains necessary in order to refine imaging-based COVID-19 diagnosis. The present study thus aimed to examine the association between CT scan manifestations in 881 patients presenting to the hospital with suspected COVID-19 infection who had undergone both chest CT scan and RCT PCR testing for SARS-Cov-2.

Methodology

Patient population

A retrospective analysis of data obtained from hospital records of patients who underwent a CT scan for suspected COVID-19 infection presenting to the Rafic Hariri University Hospital (RHUH) in Beirut, Lebanon between 6 March and 17 April, 2020 was undertaken. All patients who underwent CT scan for suspected COVID-19 pneumonia at RHUH were included in the analysis, with the exception of studies with severe motion artifacts and patients with unavailable PCR result. Institutional review board approval was obtained and patient consent was waived on the condition of gathering anonymized data from hospital records.

Measures and Statistical analysis

Patient and disease variables were retrospectively collected, including gender, age, severity criteria, hospital admission, and mortality. Criteria of severity were determined as follows: Patients were considered mild if they were less than 50 years old, previously healthy, presenting with upper respiratory tract symptoms (cough, fever, runny nose), and have normal CT scan. Moderate criteria were defined as patients aged more than 50 years, having CT findings of viral pneumonia, or with one or more comorbid conditions even with normal CT, or patients with lower respiratory tract symptoms as dyspnoea. Patients were considered severe requiring ICU admission if there was requirement of oxygen, mechanical ventilation whether invasive or non-invasive, ARDS, or shock requiring the use of vasopressors.

RT PCR tests were conducted according to patient risk profile, with low risk patients subjected to 1 PCR test while high risk patients subjected to two. Low risk patients were defined as symptomatic patients with no known contact with confirmed COVID-19 cases or typical CT findings. High risk patients were defined as symptomatic patients with known contact with confirmed COVID-19 cases or typical CT findings. CT findings were screened based on the criteria proposed in the Radiological Society of North America Expert Consensus Statement on Reporting Chest CT Findings Related to COVID-19 [10], and COVID-19 status (positive including typical, indeterminate and atypical or negative CT scan) was determined accordingly.

Chest CTs were conducted using low dose (DLP: 290 mGy/cm) unenhanced CT including the upper abdomen with 3 mm cuts (Germany, Phillips, 120 Kv, 80 mAs). CT scan findings were collected for all patients and subjected to statistical analysis in order to establish potential associations between CT scan observations and PCR results. Data was analysed using the Statistical Package for Social Sciences (SPSS) version 22 and were subjected to Chi-Square test or Fisher's Exact Test, as applicable.

Results

As shown in Table 1, 881 patients met the inclusion criteria and were included in this study. More than half of patients were male (64.6%), with predominately middle-aged patients observed (mean age 41.88 years of age). Mild cases were exhibited by 69.3% of patients, with only 3.7% showing severe COVID-19 criteria. Hospital admissions stood at 42%, with only 3 deaths noted in the patient population. Based on CT scan results, 41.5% had positive CT scan (Table 2), with 14.9% of patients were thought to have COVID-19 (typical findings) (Table 3). On the other hand, RT PCR tests when done confirmed cases of COVID-19 among 15.7% of patients.

Variable	All patients	N
Gender N (%)		
Male	569 (64.6%)	881
Female	312 (35.4%)	
Age (mean ± SD)	41.88 (17.88)	881
Severity		
Mild	593 (69.3%)	856
Moderate	231 (27.0%)	
Severe	32 (3.7%)	
Admission to hospital		
Yes	370 (42.0%)	881
No	511 (58.0%)	
Death		
Yes	3 (0.3%)	881
No	878 (99.7%)	
CT result		
Negative	515 (58.5%)	881
Positive	366 (41.5%)	
RT PCR COVID-19		
Negative	743 (84.3%)	881
Positive	138 (15.7%)	
RT PCR TB		
Yes	5 (0.6%)	881
No	876 (99.4%)	
COVID-19: Coronavirus Disease 2019; CT: Computed Tomography; RT PCR: Reverse Transcriptase Polymerase Chain Reaction; SD: Standard Deviation; TB: Tuberculosis.		

Table 1: Demographic and clinical characteristics of 881 patients who underwent a CT scan for suspected COVID-19 infection presenting to the Rafic Hariri University Hospital (RHUH).

Data was subjected to statistical analysis in order to establish the factors associated with positive PCR results (Table 2). COVID-19 patients were significantly more likely to be older than patients with negative PCR results (p value= 0.008). Moderate and severe cases were significantly more frequent among COVID-19 cases (p value <0.001), 92.8% of whom were admitted to the hospital compared to only 32.6% of their non-infected counterparts (p value<0.001). Mortality rates varied between the two study groups, with no deaths reported in the non-infected patient population compared to 3 (2.2%) in the COVID-19 group (p value= 0.004).

Variables	PCR results		P value
	Negative (N= 743)	Positive (N= 138)	
Gender N (%)			**0.680‡**
Male	482 (64.9%)	87 (63.0%)	
Female	261 (35.1%)	51 (37.0%)	
Age (mean ± SD)	41.21 ± 17.33	45.52 ± 18.54	**0.008□**
Criteria of severity			**<0.001‡**
Mild	549 (73.9%)	44 (31.9%)	
Moderate	149 (20.1%)	82 (59.4%)	
severe	22 (3.0%)	10 (7.2%)	
Admission to hospital			**<0.001‡**
Yes	242 (32.6%)	128 (92.8%)	
No	500 (67.3%)	10 (7.2%)	
Death			**0.004ɸ**
Yes	0 (0.0%)	3 (2.2%)	
No	743 (100%)	135 (97.8%)	
CT result			**<0.001‡**
Positive	270 (36.3%)	96 (69.6%)	
Negative	473 (63.3%)	42 (30.4%)	
RT PCR TB			**0.426ɸ**
Yes	5 (0.7%)	0 (0.0%)	
No	738 (99.3%)	138 (100.0%)	
COVID-19: Coronavirus Disease 2019; CT: Computed Tomography; RT PCR: Reverse Transcriptase Polymerase Chain Reaction; SD: Standard Deviation; TB: Tuberculosis; ‡: chi square; □ : t test; ɸ: Fisher's exact test.			

Table 2: Predictors of PCR results among patients undergoing CT scan for suspected COVID-19 infection at Rafic Hariri University Hospital (RHUH).

Most importantly, a highly significant correlation could be established between CT findings indicative of COVID-19 infection and PCR-confirmed COVID-19 infection (p value <0.001). Table 3 shows observed CT scan findings and their frequency among all presenting patients. Atelectatic bands were the most frequently noted ancillary finding in the CT scan (26.2%), followed by incidental subpleural nodule (19.0%). In regard to lesion presentation, the majority of observations (unilateral, bilateral, peripheral, focal, posterior, etc.) appeared comparably in the patient population. It can be noted that multilobar lesions seemed to have higher occurrences (20.9%), with the upper and lower lobes most frequently affected (22.7% and 27%, respectively). Emphysema could be suggested in 13.1% of cases, while an examination of opacity characteristics showed non-round GGO in 22% of CT scans.

		Yes
Lesion	Unilateral	162 (18.4%)
	Bilateral	170 (19.3%)
	Peripheral	180 (20.4%)
	Central	80 (9.1%)
	Peripheral+central	157 (17.8%)
	Diffuse	55 (6.2%)
	Patchy	215 (24.4%)
	Ill defined	160 (18.2%)
	Anterior	203 (23%)
	Posterior	251 (28.5%)
	Focal	160 (18.2%)
	Multiple	172 (19.5%)
Appearance	Typical	131 (14.9%)
	Indeterminate	136 (15.4%)
	Atypical	99 (11.2%)
Lobes affected	Single lobe	150 (17.0%)
	Multilobar	184 (20.9%)
Location of lobe affected	Upper lobe	200 (22.7%)
	Middle lobe	134 (15.2%)
	Lower lobe	238 (27.0%)
Percentage of lung affected	<5%	192 (21.8%)
	5-25%	110 (12.5%)
	26-49%	29 (3.3%)
	50-75%	22 (2.5%)
	>75%	13 (1.5%)
Opacity characteristics	Round GGO	108 (12.3%)
	Non-round GGO	194 (22.0%)
	Extensive GGO	31 (3.5%)
	Mixed consolidation + GGO	94 (10.7%)
	Consolidation + halo	45 (5.1%)
	Consolidation – halo	72 (8.2%)
	Crazy paving	59 (6.7%)

Ancillary findings	Subpleural line	36 (4.1%)
	Septal thickening	82 (9.3%)
	Reverse halo	23 (2.6%)
	Solid nodule + halo	47 (5.3%)
	Solid nodule – halo	29 (3.3%)
	Micronodular/ tree in bud	41 (4.7%)
	Reticulo-nodular	29 (3.3%)
	Incidental subpleural nodule	167 (19%)
	Air bronchograms	89 (10.1%)
	Bronchus distortion	15 (1.7%)
	Bronchial wall thickening	68 (7.7%)
	Bronchiectasis	18 (2.0%)
	Cavitations	11 (1.2%)
	Microvascular dilation	46 (5.2%)
	Vacuolar sign	40 (4.5%)
	Subpleural fibrotic bands	40 (4.5%)
	Atelectatic bands	231 (26.2%)
	Parenchymal calcifications	9 (1.0%)
	Lymph nodes >1cm	51 (5.8%)
	Unilateral effusion	22 (2.5%)
	Bilateral effusion	30 (3.4%)
	Pericardial effusion	7 (0.8%)
	Pleural thickening	79 (9.0%)
	Pleural calcifications	7 (0.8%)
	Pleural retraction	25 (2.8%)
	Pneumothorax	3 (0.3%)
	Cardiomegaly	57 (6.5%)
	Emphysema	115 (13.1%)

Table 3: Chest CT findings among the 881 included patients.

Seeing as CT scan findings seemed to be correlated with PCR results, we then attempted to establish the potential association between each observed CT manifestation and PCR results in all patients. This was followed by a sub-analysis including only patients with CT scans indicative of COVID-19 (Table 4). Most lesion manifestations were significantly associated with PCR results.

		All patients		P value	Positive CT scan		P value
		Negative PCR (N= 743)	Positive PCR (N= 138)		Negative PCR (N=270)	Positive PCR (N=96)	
Lesion	Unilateral	141 (19.0%)	21 (15.2%)	0.295‡	129 (47.8%)	21 (21.9%)	**<0.0001**‡
	Bilateral	106 (14.3%)	64 (46.4%)	<0.0001‡	105 (38.9%)	64 (66.7%)	<0.0001‡
	Peripheral	130 (17.5%)	50 (36.2%)	<0.0001‡	126 (46.7%)	50 (52.1%)	0.362‡
	Central	60 (8.1%)	20 (14.5%)	0.016‡	57 (21.1%)	20 (20.8%)	0.954‡
	Peripheral + central	102 (13.7%)	55 (39.9%)	<0.0001‡	99 (36.7%)	55 (57.3%)	<0.0001‡
	Diffuse	33 (4.4%)	22 (15.9%)	**<0.0001**‡	32 (11.9%)	22 (22.9%)	**0.009**‡
	Patchy	152 (56.3%)	62 (64.6%)	0.157‡	152 (56.3%)	62 (64.6%)	0.157‡
	Ill Defined	112 (15.1%)	48 (34.8%)	**<0.0001**‡	109 (40.4%)	48 (50.0%)	0.102‡
	Anterior	140 (18.8%)	63 (45.7%)	**<0.0001**‡	138 (51.1%)	63 (65.6%)	**0.014**‡
	Posterior	165 (22.2%)	86 (62.3%)	**<0.0001**‡	162 (60.0%)	86 (89.6%)	**<0.0001**‡
	Focal	134 (18.0%)	26 (18.8%)	0.822‡	130 (48.1%)	26 (27.1%)	**0.001**‡
	Multiple	108 (14.5%)	64 (46.4%)	**<0.0001**‡	107 (39.6%)	64 (66.7%)	**<0.0001**‡
Appearance	Typical	61 (8.2%)	70 (50.7%)	**<0.0001**‡	61 (22.6%)	70 (72.9%)	**<0.0001**‡
	Indeterminate	116 (15.6%)	20 (14.5%)	0.738‡	116 (43.0%)	20 (20.8%)	**<0.0001**‡
	Atypical	93 (12.5%)	6 (4.3%)	**0.005**ϕ	93 (34.4%)	6 (6.3%)	**<0.0001**‡
Lobes Affected	Single lobe	128 (17.2%)	22 (15.9%)	0.712‡	124 (45.9%)	22 (22.9%)	**<0.0001**‡
	Multilobar	118 (15.9%)	66 (47.8%)	**<0.0001**‡	117 (43.3%)	66 (68.8%)	**<0.0001**‡
Location of Lobe Affected	Upper lobe	136 (18.3%)	64 (46.4%)	**<0.0001**‡	132 (48.9%)	64 (66.7%)	**0.003**‡
	Middle lobe	85 (11.4%)	49 (35.5%)	**<0.0001**‡	83 (30.7%)	49 (51.0%)	**<0.0001**‡
	Lower lobe	158 (21.3%)	80 (58.0%)	**<0.0001**‡	157 (58.1%)	80 (83.3%)	**<0.0001**‡
Percentage of Lung Affected	<5%	165 (22.2%)	27 (19.6%)	0.469‡	165 (61.1%)	27 (28.1%)	**<0.0001**‡
	5-25%	67 (9.0%)	43 (31.2%)	**<0.0001**‡	67 (24.8%)	43 (44.8%)	**<0.0001**‡
	26-49%	13 (1.7%)	16 (11.6%)	**<0.0001**‡	13 (4.8%)	16 (16.7%)	**<0.0001**‡
	50-75%	16 (2.2%)	6 (4.3%)	0.129ϕ	16 (5.9%)	6 (6.3%)	0.909ϕ
	>75%	9 (1.2%)	4 (2.9%)	0.131ϕ	9 (3.3%)	4 (4.2%)	0.458ϕ

Opacity characteristics	Round GGO	61 (8.2%)	47 (34.1%)	**<0.0001**‡	58 (21.5%)	47 (49.0%)	**<0.0001**‡
	Non-round GGO	123 (16.6%)	71 (51.4%)	**<0.0001**‡	122 (45.2%)	71 (74.0%)	**<0.0001**‡
	Extensive GGO	21 (2.8%)	10 (7.2%)	**0.010**‡	21 (7.8%)	10 (10.4%)	0.391‡
	Mixed consolidation + GG	62 (8.3%)	32 (23.2%)	**<0.0001**‡	57 (21.1%)	32 (33.3%)	**0.017**‡
	Consolidation + halo	37 (5.0%)	8 (5.8%)	0.689‡	36 (13.3%)	8 (8.3%)	0.196‡
	Consolidation – halo	58 (7.8%)	14 (10.1%)	0.357‡	57 (21.1%)	14 (14.6%)	0.165‡
	Crazy paving	27 (3.6%)	32 (23.2%)	**<0.0001**‡	26 (9.6%)	32 (33.3%)	**<0.0001**‡
	Subpleural line	16 (2.2%)	20 (14.5%)	**<0.0001**‡	16 (5.9%)	20 (20.8%)	**<0.0001**‡
	Septal thickening	43 (5.8%)	39 (28.3%)	**<0.0001**‡	42 (15.6%)	39 (40.6%)	**<0.0001**‡
	Reverse halo	13 (1.7%)	10 (7.2%)	**<0.0001**‡	13 (4.8%)	10 (10.4%)	0.052‡
	Solid nodule + halo	32 (4.3%)	15 (10.9%)	**0.002**‡	30 (11.1%)	15 (15.6%)	0.247‡
Ancillary findings	Solid nodule – halo	24 (3.2%)	5 (3.6%)	0.795$^{\phi}$	22 (8.1%)	5 (5.2%)	0.344$^{\phi}$
	Micronodular/ tree in bud	40 (5.4%)	1 (0.7%)	**0.014**$^{\phi}$	38 (14.1%)	1 (1.0%)	**<0.0001**$^{\phi}$
	Reticulo-nodular	27 (3.6%)	2 (1.4%)	0.295$^{\phi}$	25 (9.3%)	2 (2.1%)	**0.012**$^{\phi}$
	Incidental subpleural nodule	150 (20.2%)	17 (12.3%)	**0.030**‡	51 (18.9%)	9 (9.4%)	**0.031**‡
	Air bronchograms	73 (9.8%)	16 (11.6%)	0.527‡	71 (26.3%)	16 (16.7%)	0.057‡
	Bronchus distortion	9 (1.2%)	6 (4.3%)	**0.020**‡	8 (3.0%)	6 (6.3%)	0.149‡
	Bronchial wall thickening	47 (6.3%)	21 (15.2%)	**<0.0001**‡	43 (15.9%)	21 (21.9%)	0.188‡
	Bronchiectasis	15 (2.0%)	3 (2.2%)	0.753$^{\phi}$	14 (5.2%)	3 (3.1%)	0.306$^{\phi}$
	Cavitations	11 (1.5%)	0 (0.0%)	0.230$^{\phi}$	10 (3.7%)	0 (0.0%)	**0.046**$^{\phi}$
	Microvascular dilation	23 (3.1%)	23 (16.7%)	**<0.0001**‡	23 (8.5%)	23 (24.0%)	**<0.0001**‡
	Vacuolar sign	20 (2.7%)	20 (14.5%)	**<0.0001**‡	20 (7.4%)	20 (20.8%)	**<0.0001**‡
	Subpleural fibrotic bands	27 (3.6%)	13 (9.4%)	**0.003**‡	23 (8.5%)	12 (12.5%)	0.255‡
	Atelectatic bands	202 (27.2%)	29 (21.0%)	0.130‡	103 (38.1%)	24 (25.0%)	**0.020**‡
	Parenchymal calcifications	7 (0.9%)	2 (1.4%)	0.638$^{\phi}$	5 (1.9%)	2 (2.1%)	0.587$^{\phi}$
	Lymph nodes >1cm	47 (6.3%)	4 (2.9%)	0.162$^{\phi}$	38 (14.1%)	4 (4.2%)	**0.006**‡
	Unilateral effusion	20 (2.7%)	2 (1.4%)	0.557$^{\phi}$	17 (6.3%)	2 (2.1%)	0.005‡
	Bilateral effusion	29 (3.9%)	1 (0.7%)	**0.070**$^{\phi}$	24 (8.9%)	1 (1.0%)	**0.004**‡
	Pericardial effusion	6 (0.8%)	1 (0.7%)	0.920$^{\phi}$	5 (1.9%)	1 (1.0%)	0.504$^{\phi}$
	Pleural thickening	54 (7.3%)	25 (18.1%)	**<0.0001**‡	35 (13.0%)	24 (25.0%)	**0.006**‡
	Pleural calcifications	6 (0.8%)	1 (0.7%)	0.920$^{\phi}$	5 (1.9%)	1 (1.0%)	0.514$^{\phi}$
	Pleural retraction	11 (1.5%)	14 (10.1%)	**<0.0001**‡	10 (3.7%)	14 (14.6%)	**<0.0001**‡
	Pneumothorax	3 (0.4%)	0 (0.0%)	0.599$^{\phi}$	3 (1.1%)	0 (0.0%)	0.400$^{\phi}$
	Cardiomegaly	51 (6.9%)	6 (4.3%)	0.347$^{\phi}$	32 (11.9%)	6 (6.3%)	0.122$^{\phi}$
	Emphysema	100 (13.5%)	15 (10.9%)	0.407‡	76 (28.1%)	15 (15.6%)	**0.015**‡

‡: chi square; $^{\phi}$: Fisher's exact test.

Table 4: Correlation between PCR results and CT findings among all patients and patients with positive CT scan.

When considering only patients with positive CT scan, positive PCR results were significantly more likely to be obtained in patients who present bilateral lesions (p value <0.0001) that are both peripheral and central (p value <0.0001) or diffuse (p value 0.009). COVID-19 patients are more likely to have typically manifesting multiple lesions as opposed to those that are focal. In regards to affected regions, multilobar lesions were more frequently observed in COVID-19 patients, in whom manifestations mostly reflected 5% to 25% of lung volume being affected.

Opacity characteristics that seemed to be indicative of positive PCR results included both round and non-round GGO (Figure 1), mixed consolidation + GGO (Figure 2) as well as crazy paving (Figure 3). Ancillary CT scan findings correlated with confirmed COVID-19 cases included subpleural line, septal thickening, reverse halo (Figure 4), microvascular dilation (Figure 5), vacuolar signs (Figure 6), pleural thickening, and pleural retraction. When including all patients in the analysis, it seemed that the observation of certain CT scan manifestations, such as solid nodule + halo, bronchus distortion, bronchial wall thickening, and subpleural fibrotic bands could also be used for the diagnosis of COVID-19.

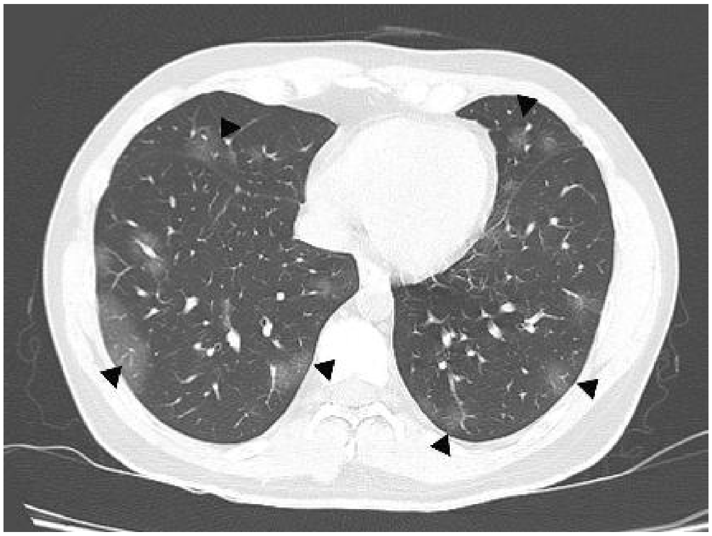

Figure 1: A case of COVID-19 pneumonia confirmed by RT-PCR. 34-year-old man, day 1 after symptom onset, with moderate severity criteria. Axial chest CT shows multiple peripheral ground-glass opacities (arrowheads) bilaterally. Time to conversion (i.e. time interval to have a negative PCR): 45 days.

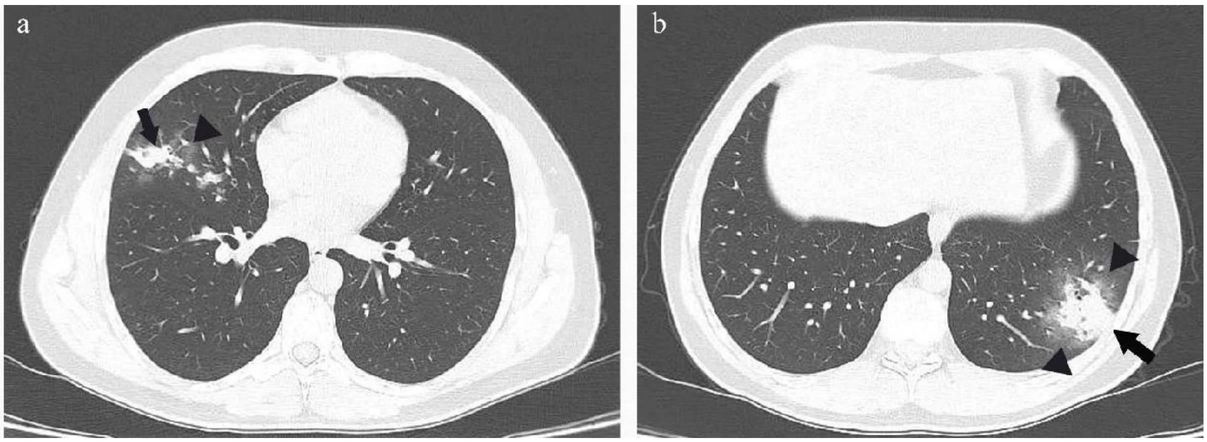

Figure 2: A case of COVID-19 pneumonia confirmed by RT-PCR. 45-year-old man, day 3 after symptom onset, with moderate severity criteria. A. Axial chest CT shows peripheral mixed consolidations (arrow) and GGO (arrowhead) in the middle lobe. B. Axial chest CT shows peripheral consolidations (arrow) surrounded by ground glass halo (arrowheads) in the left lower lobe.

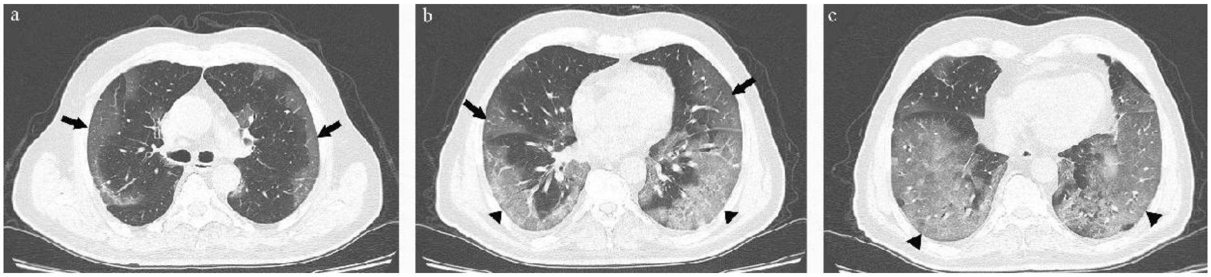

Figure 3: A case of COVID-19 pneumonia confirmed by RT-PCR. 72-year-old man, day 4 after symptom onset, with severe severity criteria. Axial chest CT shows bilateral diffuse subpleural ground-glass opacities (arrows) and crazy paving (arrowheads). Patient died 2 days later.

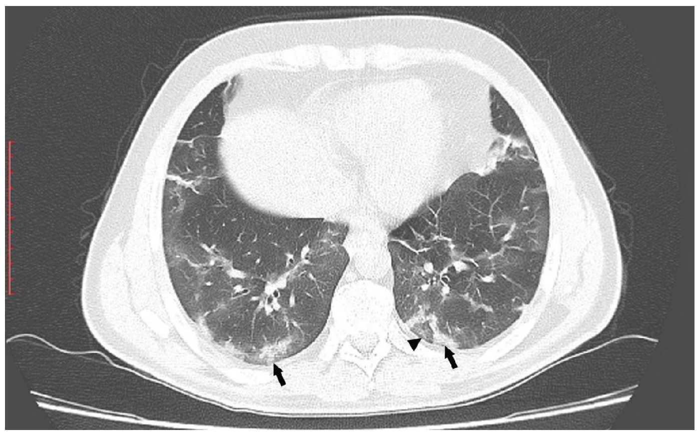

Figure 4: A case of COVID-19 pneumonia confirmed by RT-PCR. 45-year-old man, day 13 after symptom onset, with moderate severity criteria. Axial chest CT shows small bibasilar consolidations (arrows) with a reversed halo sign (arrowhead) seen on the left. Time to conversion: 26 days.

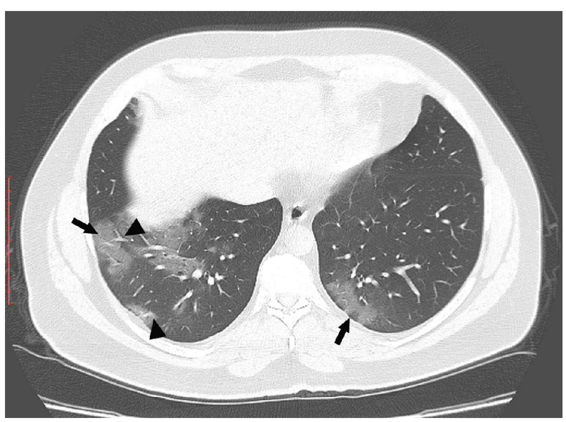

Figure 5: A case of COVID-19 pneumonia confirmed by RT-PCR. 38-year-old man, day 5 after symptom onset, with moderate severity criteria. Axial chest CT shows bilateral peripheral and central ground glass opacities (arrows) with microvascular dilatation (arrowheads). Time to conversion: 13 days.

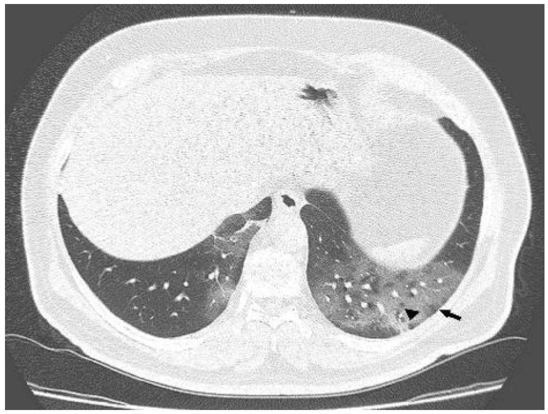

Figure 6: A case of COVID-19 pneumonia confirmed by RT-PCR. 60-year-old man, day 7 after symptom onset, with moderate severity criteria. Axial chest CT shows bilateral subpleural ground glass opacities (arrow) with vacuolar changes (arrowhead). Time to conversion: 12 days.

On the other hand, micronodular/ tree in bud manifestations (Figures 7 and 8), as well as reticulo-nodular manifestations, incidental subpleural nodules, atelectatic bands, cavitations, lymph nodes >1cm, bilateral effusion and emphysema were significantly indicative of negative PCR results.

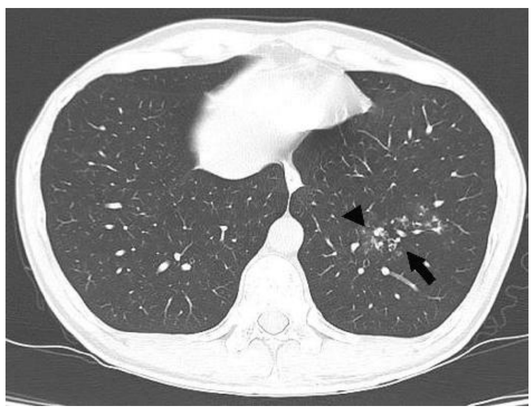

Figure 7: A case of negative COVID-19 RT-PCR. 33-year-old man, day 3 after symptom onset, with mild severity criteria. Axial chest CT shows micronodules (arrow) surrounded by minimal ground glass infiltrates (arrowhead) in the left lower lobe.

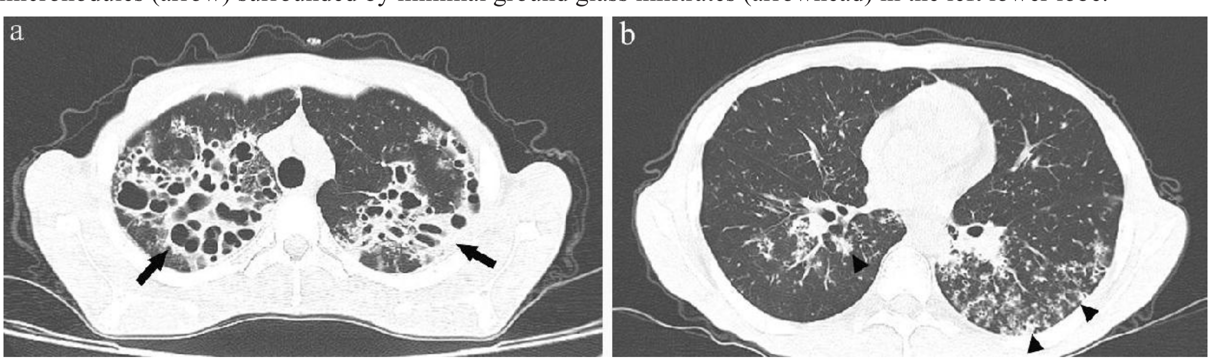

Figure 8: A case of negative COVID-19 RT-PCR. 29-year-old male, day 5 after symptom onset, with moderate severity criteria. Axial chest CT shows bilateral upper lobe parenchymal destruction, bronchiectasis and fibrosis (arrows) (image a) with tree in bud infiltrates (arrowheads) mainly in the apical segments of both lower lobes (image b). Tuberculosis PCR was positive. Final diagnosis: Active Tuberculosis.

The clinical applicability of using CT scans for the diagnosis of COVID-19 was further explored according to severity criteria (Table 5). Severity criteria was highly correlated with both PCR and CT scan results. Patients with moderate and severe criteria were significantly more likely to be positive for COVID-19 through RT PCR and CT scan. In fact, the diagnosis of patients with moderate and severe criteria that were diagnosed to be positive for COVID-19 through CT scan was later confirmed with RT PCR in 80% and 10.5% of the cases, respectively. On the other hand, CT scan seemed to be less practicable as a diagnostic tool in patients with mild criteria. Among the 881 included patients, chest CT scan had a sensitivity of 69.6% and a specificity of 63.7% for COVID-19, as confirmed by RT PCR.

		All patients* (N=856)		**P value**	**Positive CT scan**		**P value**
		Negative PCR (N= 720)	Positive PCR (N= 136)		Negative PCR (N= 261)	Positive PCR (N= 95)	
Symptom severity	Mild	549 (76.3%)	44 (32.4 %)	**<0.0001**‡	176 (67.4%)	9 (9.5%)	**<0.0001**‡
	Moderate	149 (20.7%)	82 (60.3%)		69 (26.4%)	76 (80.0%)	
	Severe	22 (3.1%)	10 (7.4 %)		16 (6.1%)	10 (10.5%)	
‡: chi square; *all patients for whom severity criteria were available in medical records (N=856).							

Table 5: Correlation between PCR results and the severity criteria among all patients and patients with positive CT scan.

The Positive Predictive Value (PPV) of CT scan is estimated at 53.4% for typical findings, 14.7% for indeterminate findings and 6.1% for atypical findings. The overall PPV is 26.2%. The PPV of the scan suggests that typical CT findings yield the most accurate diagnosis of COVID-19.

Discussion

Consistently with the current clinical understanding of COVID-19, infected patients in this study presented as slightly older individuals with significantly higher rates in those with moderate and severe criteria, hospital admissions, and mortality. Age was previously noted as the most frequent predictor of COVID-19 diagnosis [11]. A recent meta-analysis found that COVID-19 patients were predominately males, who account for around 60% of patients, while the fatality rate seems to be around 5% [12]. Mortality among our patient population was relatively low at 2.2%, possibly due to the low proportion of patients with severe disease progression.

The use of chest CT for the diagnosis of COVID-19 is challenged by the fact that infected patients can present with a normal CT scan or with indeterminate or atypical features [10]. However, multiple studies have suggested the use of chest CT as a first line diagnostic tool in the COVID-19 pandemic. In the present study, CT scan results captured approximately 70% of PCR-confirmed COVID-19 cases. The sensitivity of chest CT was lower in our study (sensitivity 69.6%, specificity 63.7%) compared to those reported in the literature. In fact, when examining the clinical characteristics of hospitalized patients with SARS-COV-2, it was found that the incidence of abnormal chest CTs stood at 96.6% [13]. Similarly, a study comparing chest CT and RT PCR in terms of diagnostic sensitivity showed that chest CT could detect 98% of cases, compared to only 71% with RT PCR [6]. However, the role of selection bias should be explored in order to address the possible overestimation of CT scan diagnostic sensitivity for COVID-19. It is important to note that the lower sensitivity noted in our study could be due to the high number of mild to moderate cases of COVID-19, where CT scans are less efficient for the diagnosis of the disease. Regardless, all patients presenting to the ER were subjected to both PCR testing and CT scan, which considerably limits the possibility of selection bias.

Studies have established that the typical features of COVID-19 pneumonia are peripheral, focal or multifocal, bilateral, ground glass opacities with lower lobes predominance, and progression to crazy paving and consolidations [14-17]. Ground-Glass Opacity (GGO) and consolidations have been the most frequently and consistently cited typical COVID-19 CT imaging patterns [5,16,18,19], particularly in the subpleural region [16], similar to our study. In addition to this, our findings were similar to studies showing that COVID-19 patients were more likely to present with bilateral lesions [14], albeit with lower lobe involvement predominating the literature [14], unlike the present study where all lobe locations were involved.

On the other hand, complications such as pleural thickening were relatively frequent in our study 9% while in others they were cited to be rare [18]. Imaging findings have been shown to be dependent on disease severity [19], and inter-study variations are therefore to be expected in the absence of a standardized approach for the evaluation of chest CT imaging.

While not considered in our study, time from onset of symptoms also plays an important role in chest CT manifestations, with some becoming more frequent as the disease progresses [14]. Such examples include greater lung involvement, the “crazy-paving” pattern and the “reverse halo” sign [20], all of which were observed in the present study. Various other observations have been noted in COVID-19 patients, such as septal thickening, subpleural lines, and bronchus distortion [14], imaging patterns that were also reflected in our study.

While these features can guide the detection of viral pneumonia and facilitate patient triage in overburdened hospitals, they are also indicative of other aetiologies and cannot distinguish between viruses, thereby leading to misdiagnosis of COVID-19 cases [18]. It is thus important to base COVID-19 diagnosis on reliable CT scan manifestations of the disease, as reflected by the PPV of the diagnostic tool which was highest in this study when considering typical radiological findings only. Radiologist sensitivity to COVID-19 also plays an important role in the diagnosis of the disease based on chest CT [15], which highlights the need for the provision of evidence-based training in order to improve CT-based COVID-19 diagnosis. That being said, typical COVID-19 chest CT findings could prove useful in the diagnosis of patients with initially negative RT-PCR results [5].

The present study provides valuable insights but is not without limitations. Chest CT findings were not stratified according to disease severity and stage, or time from symptom onset. This prevents the ability to clearly delineate the appearance and significance of CT imaging patterns in specific patient populations. Prospective investigations of CT findings should thus be conducted among asymptomatic and symptomatic patients throughout the patient management journey. Through this, a more comprehensive understanding of chest CT manifestations and their clinical implications can be extricated, thus allowing the improvement of COVID-19 diagnosis and prognostication. Moreover, by establishing the sensitivity and comparability of chest CT and RT PCR for COVID-19 diagnosis, specific criteria for the detection of COVID-19 can be formulated and employed, thereby alleviating the burden of increasingly strained economies around the world.

Conclusion

Chest CT shows potential as a first-line diagnostic tool for COVID-19, particularly for moderate to severe cases, albeit with room for sensitivity improvement in Lebanon. Establishing disease-specific imaging patterns is critical for the improved diagnosis of COVID-19, particularly in light of the moderate RT PCR sensitivity and the superior PPV of typical COVID-19 radiological findings. GGO or mixed GGO and consolidations are among the most reliable indicators of COVID-19, with a variety of other manifestations such as subpleural line, septal thickening, crazy paving, reverse halo, microvascular dilation, vacuolar signs, pleural thickening and pleural retraction playing a potential role. Further investigations remain necessary to prove the clinical applicability and reliability of chest CT-based COVID-19 diagnosis in moderate to severe cases. Clinical follow up would also be interesting in order to establish the potential long term sequalae of COVID-19 and their radiological manifestations. Regardless, current evidence of CT scan’s diagnostic capacity along with the subpar specificity and sensitivity of RT PCR suggests that CT scan could be incorporated into daily clinical practice to support the diagnosis of suspected COVID-19 cases.

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