Shereen Farghaly, Gamal Agmy, Sahar Hassany, Shimaa Farghaly, Marwa Makboul, Lamees Mohammed Bakkar

Faculty of Medicine, Assiut University Hospital, Assiut, Egypt

Relation of high resolution pulmonary CT findings and clinical condition of COVID-19 patients

Abstract

Introduction: At present, chest computed tomography (CT) is accepted as a tool for assessment COVID-19 patients. However, there are few data about the relationship between initial imaging results at presentation and the presence of systemic inflammatory mediators and outcome in patients with COVID-19. The aim of study is to evaluate the relation of initial high resolution computed tomography (HRCT) chest findings to inflammatory indices and clinical course of COVID-19 patients during hospitalization.

Material and methods: This is a retrospective cohort study carried out on 108 confirmed COVID-19 patients. Demographic, laboratory and radiological data were recorded from patients medical records. Based on predominant HRCT density, patients were classified into either normal, ground glass opacity (GGO) and consolidation groups. By HRCT score, patients were classified into either no infilteration, $\leq 50\%$ infilteration and $> 50\%$ infilteration groups. Comparison between clinical and laboratory parameters were observed among the groups.

Results: More hypoxemia, higher inflammatory indices (CRP, d-dimer, ferritin), more requirement of ventilatory support and more mortality rate were observed in consolidation group compared to GGO ($p < 0.05$) and in patients with HRCT score $> 50\%$ compared to $\leq 50\%$ infilteration group ($p < 0.05$).

Conclusions: Consolidation pattern and high CT chest quantitative score are associated with elevated inflammatory indices and poor outcome in COVID-19 patients. HRCT chest can be used for risk stratification of COVID-19 patients.

Key words: COVID-19, HRCT, CT scores

Adv Respir Med. 2022; 90: 28–36

Introduction

Coronavirus disease 2019 has now become a global public health problem. Globally 8 525 042 cases and 456 973 deaths have been reported till July 2020 [1]. Imaging plays an important role in the diagnosis and management of COVID-19 pneumonia. Computed tomography (CT) is considered the first-line imaging modality in highly suspected cases and is helpful for monitoring imaging changes during treatment. Therefore, CT has been identified as an efficient clinical diagnostic tool for people with suspected COVID-19 [2]. It has potential for identifying people with COVID-19 pneumonia even their COVID swab is negative [3, 4]. The findings on CT images may reflect the severity of disease. There is little known about the relationship between initial imaging results at presentation and the presence of systemic inflammatory mediators and outcome in patients with COVID-19.

Aim of study

The purpose of this study was to evaluate the relation of initial chest CT findings to inflammatory indices and clinical course of COVID-19 patients during hospitalization.

Material and methods

Study design

This is a retrospective cohort study carried out on patients with confirmed COVID-19 hospitalized at El Rajhi hospital, Assiut university

Address for correspondence: Shereen Farghaly, Chest Department, Faculty of Medicine at Assiut University Hospital, e-mail: shereen@aun.edu.eg

DOI: 10.5603/ARM.a2022.0003 | Received: 26.01.2021 | | ISSN 2451–4934 | e-ISSN 2543–6031

hospital. All cases hospitalized with confirmed COVID-19 who do chest high resolution computed tomography (HRCT) on admission were included in the study between the period of June, 2020 and November 30, 2020. The ethics committee of Faculty of Medicine of Assiut University approved this study (No. 17300523).

Inclusion criteria

Patients diagnosed with confirmed COVID-19 pneumonia based on laboratory-confirmed COVID-19 [5] and who do HRCT chest within 24 hours of admission.

All the following patients data will be recorded.

Patient data were collected from stored computer data and patients' medical records

1. Demographic and clinical data

Demographic data were collected included age, gender, body mass index, duration of disease at presentation, smoking status and comorbidities were recorded. Common clinical symptoms and oxygen saturation at time of admission were all recorded. Data about the need of ventilatory support either noninvasive ventilation (NIV) or mechanical ventilation (MV) at admission and data about patient mortality rate were also recorded.

2. Laboratory data

Laboratory investigation including differential complete blood (CBC) count and inflammatory profile [C-reactive protein (CRP), d-dimer and serum ferritin] were recorded. Venous blood samples were collected from all patients within 24 hours of admission under restrict sterilized conditions.

3. HRCT data

- **CT protocol**

As a protocol in our hospital, HRCT chest done for all COVID-19 patients within 24 hours of admission. CT chest examination without intravenous contrast in a supine position was done for all patients, using a 64-channel Multi-detector CT scanner (Toshiba, Japan) Aquilion machine with 16 × 1.2 mm collimation, 120–140 kV, tube current 150–280 mA, all transverse images were reconstructed to 0.625 mm-slice images. CT images were acquired from the level of diaphragm to lung apices in a caudo-cranial direction.

- **CT chest image interpretation**

Multi-planar reconstruction (MPR) was used for image analysis after transferring images to a Vitrea Vital Image (VPMC-Revision C). CT images were reviewed by two radiologists with more than 10 years' experience in imaging.

For each patient, a CT scan was evaluated for the following:

1. The number of lobes affected.
2. Unilateral or bilateral involvement.
3. Lesion density: the predominant HRCT patterns defined by the Fleischner Society glossary [6] were as following normal, ground glass, or only consolidation (Figure 1, 2).
4. Lesion distribution: peripheral (sub-pleural, involve peripheral one-third of the lung), diffuse, or central (at lung hilum, involve central two-thirds of the lung).

- **HRCT scoreCT**

Severity score was calculated [7] by dividing both lungs into 5 lung zones [right upper lobe, right middle lobe, right lower lobe, left upper lobe (including lingula), and left lower lobe], regarding anatomical structures.

Based on the percentage of lobe involvement in CT images, a score was given for each lung lobe:

— Score 0: 0% involvement;
— Score 1: less than 5% involvement;
— Score 2: 5% to less than 25% involvement;
— Score 3: 25% to less than 50% involvement;
— Score 4: 50% to less than 75% involvement;
— Score 5: 75% or greater involvement.

The maximum CT score for both lungs is 25, and the summation of both lung scores provides a semi-quantitative evaluation of the total severity score. Then according to the percentage of whole lung involvement, patients were classified into 3 groups; no infilteration group (0%), ≤ 50% infilteration group and > 50% infilteration group (Figure 1, 2).

Statistical analysis

Statistical Package for the Social Sciences (SPSS-version 16) software (SPSS Inc., Chicago, IL, USA) was used for analysis of data. Continuous variables were presented as medians and interquartile range and compared by Mann-Whitney U test. Categoric variables were presented as numbers and percentages and were compared by chi-square test between the study groups. Two-sided p value < 0.05 was considered statistically significant.

Results

This study included 108 COVID-19 confirmed cases. Their median age was 48 (29–60) of whom 57.4% were males. Demographic data of

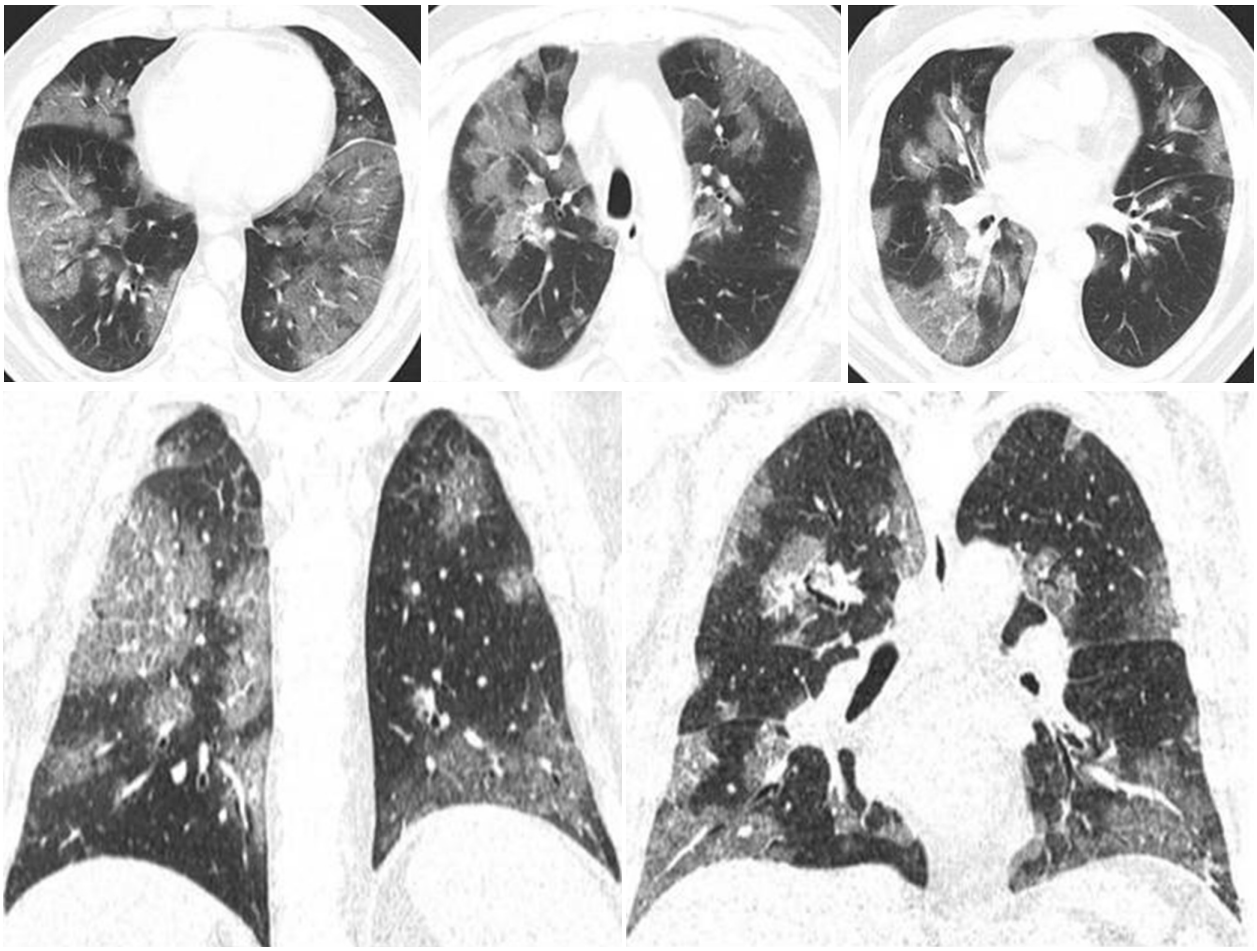

Figure 1. Male patient, 60 years old, was complaining of chest pain, dry cough and dyspnea and was confirmed to be COVID-19 by RT-PCR. These axial and coronal (lung window) non- contrast CT chest images show diffuse multifocal ground glass opacities involving both lungs. Both upper and lower lobes have score 5 (with ≥ 75% involvement), while middle lobe has score 4 with (50% to < 75% involvement), so total CT lung severity score is 24 with 96% of lung involvement

the study patients were presented in Table 1. By qualitative assessment of HRCT based on HRCT density, patients were classified into 3 groups either normal (10.2%), GGO (69.4%) and consolidation (20.4%) groups. By quantitative assessment of HRCT by HRCT score, patients were classified into either no infilteration (10.2%), ≤ 50% infilteration (65.7%) and > 50% infilteration (24.1%) groups. Comparison between clinical and laboratory parameters were observed among the groups.

Based on HRCT density, no statistically significant differences were reported in duration of complaint and clinical symptoms except dypnea ($p = 0.014$). Respiratory rate at presentation was significantly higher in consolidation group compared to both GGO and normal groups [38 (30–44) vs. 29 (25–38), $p = 0.013$; 38 (30–44) vs. 24 (20–30), $p = 0.009$ respectively] and in GGO compared to normal group ($p = 0.016$). Also spO_2 at presentation was significantly lower in consolidation that both other groups [68 (60–72) vs. 92 (80–97), $p < 0.001$; 68 (60–72) vs. 98 (97–98)] and in GGO than normal group ($p < 0.001$) (Table 2). Regarding laboratory and inflammatory markers, neutrophils were significantly higher in consolidation than GGO and in GGO than normal group [7.4 (4.7–10.6) vs. 2.8 (1.7–6.4), $p < 0.001$; 2.8 (1.7–6.4) vs. 1.64 (1.4–2.2), $p = 0.016$ respectively]. Also inflammatory indices (CRP, D-dimer, ferritin) were significantly higher in consolidation group than both GGO [70 (32.7–247) vs. 21.8 (6.8–100), $p = 0.002$; 0.6 (1.9–5.9) vs. 0.5 (0.2–1.02), $p < 0.001$; 944 (676––2882) vs. 285 (126–728), $p < 0.001$ respectively] and normal groups [70 (32.7–247) vs. 3.3 (1.3–4.6), $p < 0.001$; 0.6 (1.9–5.9) vs. 0.3 (0.2–0.5), $p < 0.001$; 944 (676–2882) vs. 73.3 (28.2–314.7), $p < 0.001$ respectively]. Ground glass opacity group also reported higher CRP and ferritin compared to normal group ($p < 0.001$, $p = 0014$ re-

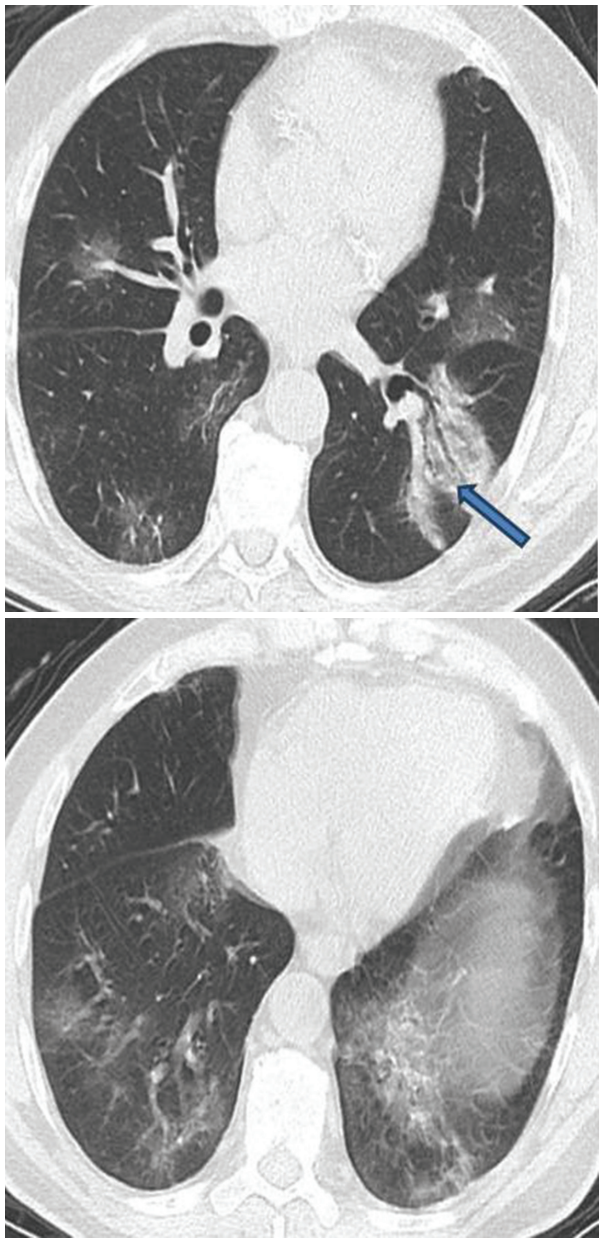

Figure 2. Female patient, 55 years old, was complaining of fever, dry cough and dyspnea and was confirmed to be COVID-19 by RT-PCR. These axial non-contrast CT chest images (lung window) show multifocal ground glass opacities involving both lower lobes as well as area of consolidation with air-bronchogramat anterior segment of left lower lobe (blue arrow). Right lower lobe has score 4 (50% to < 75% involvement), It lower lobe has score 5 with (with ≥ 75% involvement so total CT lung severity score is 9 with 36 % of lung involvement

Table 1. Demographic criteria of COVID-19 patients (n = 108)

Item	
Age [median (IQR)]	48 (29-60)
Gender %:	
Male	62 (57.4%)
Female	46 (42.6%)
Smoking habit %	
Smoker	23 (21.3%)
Comorborbidities %	61 (56.5%)
DM	38 (35.2%)
HTN	29 (26.9%)
IHD	14 (13%)
Underlying LD	5 (4.2%)
Admission ward %	
Isolation ward	73 (67.6%)
ICU	34 (32.4%)
Mechanical support %	
No mechanical support	72 (66.7%)
NIV	27(25%)
MV	9 (8.3%)
HRCT distribution	
Unilateral	3(2.8%)
Bilateral	94(87%)
HRCT density	
Normal	11 (10.2%)
GGO	75 (69.4%)
Consolidation	22 (20.4%)
HRCT quantitative scores	
No infilteration	11 (10.2%)
≤ 50% infilteration	74 (68.5%)
> 50% infilteration	22 (20.3%)

BMI — body mass index; DM — diabetes mellitus; GGO — ground glass opacity; HRCT — high resolution computed tomography; HTN — hypertension; ICU — intensive care unit; IHD — ischemic heart disease; IQR — interquartile range; LD — lung disease; MV — mechanical ventilation

spectively) (Table 2). Consolidation pattern was also associated with higher rate of ventilatory support either NIV (54.5% vs. 20%) or MV (18.5% vs. 0%) (Figure 3A). Mortality rate was also significantly higher in consolidation group compared to GGO group (45.5% vs. 17.3%). On the other hand, neither ventilatory support nor mortality was reported in the normal group (Figure 4A).

Based on HRCT scores, no statistically significant different were also reported in duration of complaint and clinical symptoms except dypnea ($p = 0.001$). Reapiratory rate at presentation was also significatly higher in > 50% infilteration group compared to both ≤ 50% infilteration and no infilteration groups [38 (28–40) vs. 30 (25–35), $p < 0.001$; 38 (28–40) vs. 24 (20–30), $p = 0.004$ respectively] and in ≤ 50% group compared to normal [30 (25–35) vs. 24 (20–30), $p = 0.022$). Also spO_2 at presentation was significantly lower in > 50% than both other groups [66.5 (60–78.7)

Table 2. Clinical and laboratory variables among the study groups based on HRCT density (n = 108)

Variables	Normal (n = 11)	GGO (n = 75)	Consolidation (n = 22)	P1-value	P2-value	P3-value
Clinical variables						
Duration of complaint (days)	5 (4–7)	4 (3–6)	5 (3–7.3)	0.384	0.778	0.110
Cough (%)	2 (18.5)	16 (21.3)	8 (36.4)		0.311	
Chest pain (%)	0 (0)	9 (12)	3 (13.6)		0.455	
Dyspnea (%)	0 (0)	23 (30.7)	11 (50)		0.014*	
Fever (%)	10 (90.9%)	71 (94.7%)	21 (95.5%)		0.856	
RR (breath/min)	24 (20–30)	29 (25–38)	38 (30–44)	0.016*	0.009*	0.013*
SpO_2 % (room air)	98 (97–98)	92 (80–97)	68 (60–72)	< 0.001*	< 0.001*	< 0.001*
Laboratory variables						
Wbcs ($10^3/mm^3$)	4 (3–4.3)	5.2 (3.5–8.6)	11.7 (8.4–20.9)	0.024*	< 0.001*	< 0.001*
Neutrophils ($10^3/mm^3$)	1.64 (1.4–2.2)	2.8 (1.7–6.4)	7.4 (4.7–10.6)	0.016*	< 0.001*	< 0.001*
Lymphocytes ($10^3/mm^3$)	1.5 (1.4–1.9)	1.4 (1.1–1.8)	1.7 (1.1–4)	0.185	0.815	0.138
Hgb (gm/dL)	13.7 (12.9–14.6)	13.4 (12–14.1)	12.9 (10.7–14.3)	0.269	0.104	0.277
PLT ($10^3/mm^3$)	236 (208–286)	231 (182–285)	218 (164–288)	0.485	0.565	0.936
CRP (mg/L)	3.3 (1.3–4.6)	21.8 (6.8–100)	70 (32.7–247)	< 0.001*	< 0.001*	0.002*
D-dimer (mcg/mL)	0.3 (0.2–0.5)	0.5 (0.2–1.02)	0.6 (1.9–5.9)	0.079	< 0.001*	< 0.001*
Ferritin (ng/mL)	73.3 (28.2–314.7)	285 (126–728)	944 (676–2882)	0.014*	< 0.001*	< 0.001*

Data expressed as median (interquartile range) or percentage. CRP — c-reactive protein; GGO — ground glass opacity; Hgb — Hemoglobin; PLT — platelets; RR — respiratory rate; SpO_2 — oxygen saturation; WBCS — white blood cells. P1 compared between normal and GGO groups, P2 compared between normal and consolidation groups, P3 compared between GGO and consolidation groups. *Significant

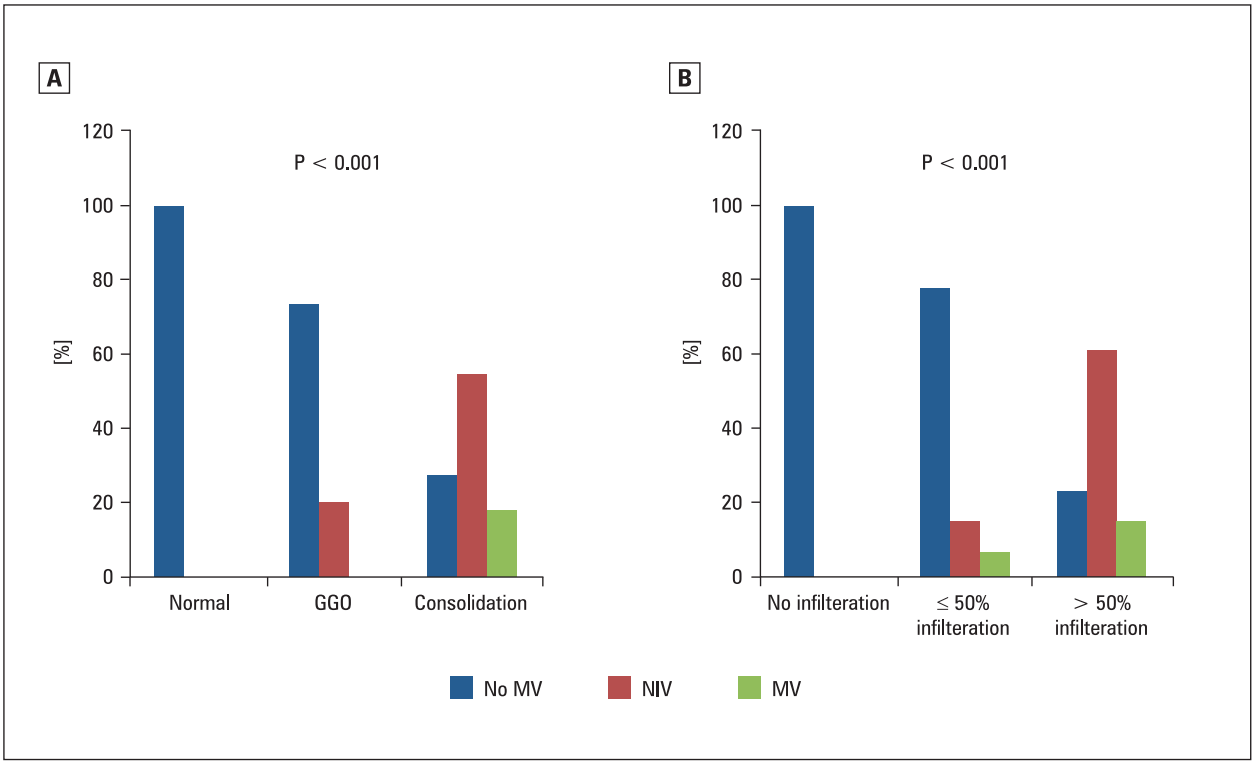

Figure 3. Mechanical ventilatory support among the studied groups. **A.** Mechanical ventilatory support among the study groups based on HRCT denisty ($p < 0.001$); **B.** mechanical ventilatory support among the study groups based on HRCT quantitative scores ($p < 0.001$)

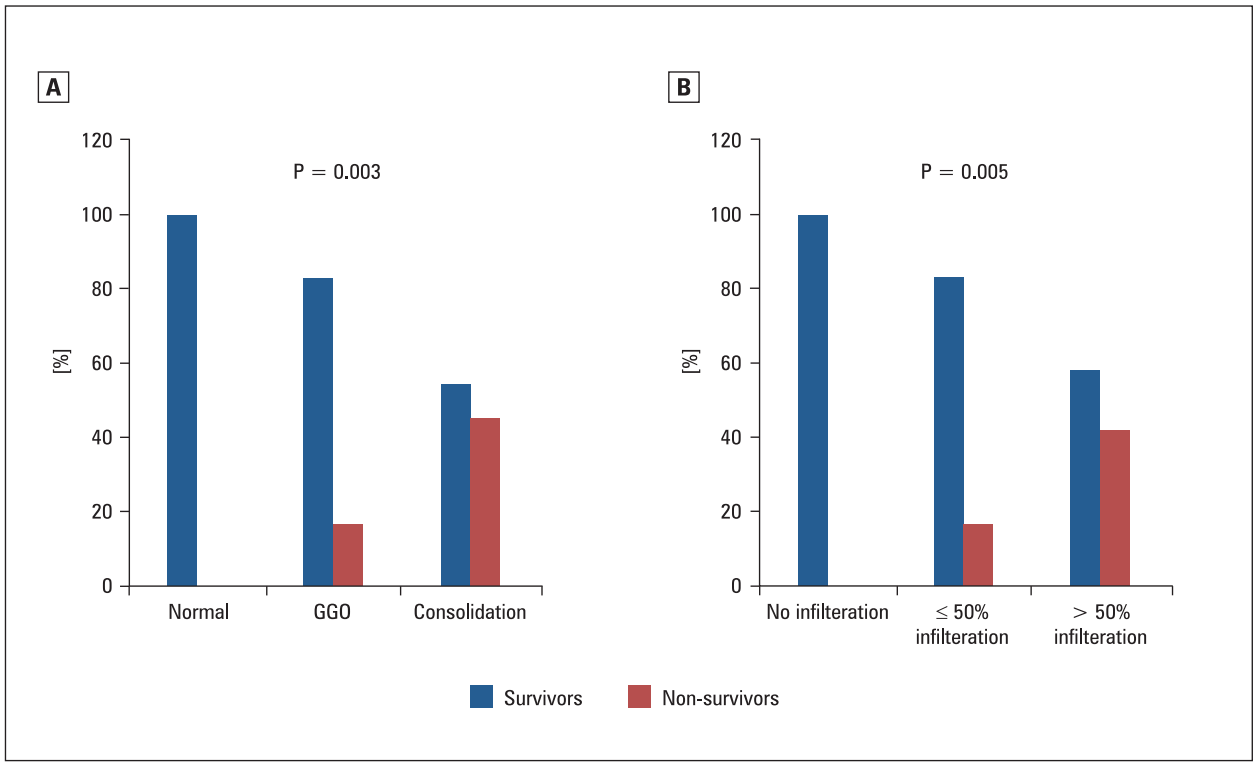

Figure 4. Mortality rate among the sudy groups. **A.** Mortality rate among the study groups based on HRCT density (p = 0.003); **B.** mortality rate among the study groups based on HRCT quantitative scores (p = 0.005)

vs. 92 (81–97), p < 0.001; 66.5 (60–78.7) vs. 98 (97–98), p < 0.001] and in ≤ 50% infilteration group than no infilteration group (p < 0.001) (Table 3). Regarding laboratory and inflammatory markers, neutrophils were significantly higher in > 50% infilteration group than both other groups [9.4 (7.03–13.5) vs. 2.6 (1.6–4.7), p < 0.001; 9.4 (7.03–13.5) vs. 1.64 (1.4–2.2), p < 0.001]. Also inflammatory indices (CRP, d-dimer, ferritin) were significantly higher in > 50% infilteration group than both ≤ 50% infilteration group [70 (33.4–214) vs. 21.5 (6.8–88.1), p = 0.002; 0.84 (0.5–2.1) vs. 0.89 (0.22–1.5), p < 0.008; 870 (369–1209) vs. 285 (88–728), p < 0.001 respectively] and no infilteration group [70 (33.4–214) vs. 3.3 (1.3––4.6), p < 0.001; 0.84 (0.5–2.1) vs. 0.3 (0.2–0.5), p < 0.001; 870 (369–1209) vs. 73.3 (28.2–314.7), p < 0.001 respectively] (Table 3). ≤ 50% infilteration group also reported higher CRP and ferritin compared to no infilteration group [21.5 (6.8––88.1) vs. 3.3 (1.3–4.6), p < 0.001; 285 (88–728) vs. 73.3 (28.2–314.7), p = 0.014 respectively] (Table 3). ≥ 50% infilteration group was also associated with higher rate of ventilatory support either NIV (61.5% vs. 15.5%) or MV (15.4% vs. 7%) (Figure 3B). Mortality rate was also significantly higher in this group compared to < 50% infilteration group (42.3% vs. 16.9%) (Figure 4B). On the other hand, neither ventilatory support nor mortality was reported in the no infilteration group.

Discussion

Early diagnosis of COVID-19 and detection of severity is crucial for disease treatment and control [8]. At present, CT chest is widely accepted as a tool for early diagnosis of COVID-19 patients [9]. However, there are few studies which assess the relation of imaging to inflammatory indices and the impact of CT chest on course and outcome of COVID-19 pneumonia during hospitalization. We aimed in this study to to evaluate the relation of initial chest CT findings to inflammatory indices and clinical course of COVID-19 patients during hospitalization.

For analysis of our study results, patients were classified based on HRCT density and on HRCT quantification scores. Based on HRCT predominant density findings, patients were classified into 3 groups either normal, GGO and consolidation groups. Based on HRCT scores, patients were classified into either no infilterations, ≤ 50% infilteration and > 50% infilteration groups. Comparison of clinical and laboratory parameters and outcome were observed among the study groups.

Table 3. Clinical and laboratory variables among the study groups based on HRCT quantitative scores (n = 108)

Variables	No infilteration (n = 11)	≤ 50% infilteration (n = 71)	> 50% infilteration (n = 26)	P1-value	P2- value	P3-value
Clinical variables						
Duration of complaint [days]	5 (4–7)	4 (3–6)	4 (3-7.3)	0.444	0.920	0.428
Cough [%]	2 (18.5)	15 (21.1)	5 (34.6)		0.345	
Chest pain [%]	0 (0)	10(14.1)	2 (7.7)		0.314	
Dyspnea [%]	0 (0)	19 (26.8)	55 (57.7)		0.001*	
Fever [%]	10 (90.9)	68 (95.8)	24 (92.3)		0.693	
RR [breath/min]	24 (20–30)	30 (25–35)	38 (28–40)	0.022*	0.004*	< 0.001*
SpO_2 % [room air]	98 (97–98)	92 (81–97)	66.5 (60–78.7)	< 0.001*	< 0.001*	< 0.001*
Laboratory variables						
Wbcs [10^3/mm^3]	4 (3–4.3)	4.9 (3.4–7.1)	13.7 (11.7–21.6)	0.056	< 0.001*	< 0.001*
Neutrophils [10^3/mm^3]	1.64 (1.4–2.2)	2.6 (1.6–4.7)	9.4 (7.03–13.5)	0.035*	< 0.001*	< 0.001*
Lymphocytes [10^3/mm^3]	1.5 (1.4-1.9)	1.4 (1.1-1.8)	1.6 (1.1-3.3)	0.185	0.986	0.285
Hgb [gm/dl]	13.7 (12.9–14.6)	13 (11.8–14.1)	13.5(11.5–14.2)	0.198	0.246	0.914
PLT [10^3/mm^3]	236 (208–286)	231 (182–285)	218 (164–288)	0.387	0.864	0.520
CRP [mg/L]	3.3 (1.3–4.6)	21.5 (6.8–88.1)	70 (33.4–214)	< 0.001*	< 0.001*	0.002*
D-dimer [mcg/mL]	0.3 (0.2–0.5)	0.89 (0.22– 1.5)	0.84 (0.5–2.1)	0.088	< 0.001*	0.008*
Ferritin [ng/mL]	73.3 (28.2–314.7)	285 (88–728)	870 (369–1209)	0.014*	< 0.001*	< 0.001*

Data expressed as median (interquartile range) or percentage. CRP — c-reactive protein; Hgb — Hemoglobin; PLT — platelets; RR — respiratory rate; SpO_2 — oxygen saturation; WBCS — white blood cells. P1 compared between no infilteration and ≤ 50% infilteration groups, P2 compared between no infilteration and > 50% infilteration groups, P3 compared between ≤50% infilteration and >50% infiltertion groups. *Significant

Since the emerging of COVID-19 pandemics, it has observed that GGO opacities and consolidation are common initial CT findings in COVID-19 patients [10, 11] and this is consistent with our study. GGO may be an indicator of interstitial alveolar edema [12]. As the disease progresses, more diffuse alveolar edema and exudates are formed with lymphocytes infilteration forming the consolidation pattern with acute respiratory distress syndrome (ARDS) picture [13, 14]. These findings likely correlate pathologically with an exudative and proliferative acute-phase of COVID-19 pneumonia [12].

Clinically, more hypoxemia was reported in consolidation group patients compared to GGO group. The main mechanism of hypoxemia in consolidation is the development of intrapulmonary shunting due to extensive alveolar exudates or alveolar collapse [15]. Lamy et al. [16] in a previous study carried out on ARDS patients found strong correlation between gas exchange abnormalities and pathological changes.

Regarding laboratory markers, we observed significantly higher inflammatory indices (CRP, d-dimer, ferritin) in consolidation pattern patients than GGO group. Wu et al. [17] applied pulmonary inflammtion index based on type and density of lung abnormalities on CT chest and showed that this index correlated significantly with seum CRP, procalcitonin in addition to lymphocyte and monocyte count ($p < 0.05$). Thus it can be suggested that the patients with the worst laboratory findings are also expected to have worse CT infilterations [18].

The poor course observed in our consolidation group was observed in previous studies. Previous studies found that patients with viral pneumonias with consolidations pattern in lung CT had more severe clinical courses than those with GGO [19, 20]. In addition, some reports [21, 10, 11] described consolidation pattern to be more common in severe and critically ill COVID-19 patients and that intensive care unit (ICU) patients had more consolidation on admission than non-ICU on chest CT [22].

By quantitative CT assessement scores, the present observed that patients with HRCT score > 50% were associated with more hypoxemia and higher inflammatory indices. The more extensive pneumonia on chest CT was significantly correlated with the derangement in gas exchange [23].

As viruses spread through the respiratory mucosa and infect other cells, they induce a series of immune responses and cytokine storm that affect peripheral WBCs and inflammatory cells [24, 25]. We significantly found that > 50% infilteration associated with higher neutrophils count and higher inflammatory indices level. These results were consistent with those of another study [26]. Levels of neutrophils and C-reactive protein may be correlated to the cytokine storm induced by viral infection [27]. By applying baseline quantititaive CT score in their study, Cheng et al. [28] showed significant CT score correlations with CRP, LDH and ESR without evidence of coinfection. This implies that chest CT quantification score can be used as marker of COVID-19 severity.

We observed poor prognosis with more mortality rate in > 50% infilteration group than other groups. This was consistent with that of a previous report, in which severe patients had a larger total lung CT score than non-severe patients [29]. Previous investigations into severe acute respiratory syndrome and middle-east respiratory syndrome reported the number of involved lung segments might be used as a predictor of disease severity and poor outcome [30, 31]. Quantitative chest CT score in COVID-19 is also correlated with pneumonia severity index which is a known index of community acquired pneumonia severity [32].

Conclusions

Consolidation pattern and high CT chest quantitative score are associated with elevated inflammatory indices and poor outcome in COVID-19 patients. HRCT chest can be used for risk stratification of COVID-19 patients. More future studies are recommended to evaluate combined qualitative and quantitative CT chest assessment in COVID-19 pneumonia.

Limitation of the study

First, this a retrospective study so accurate timing to ventilatory support cannot be documented. Second, no data about changes of HRCT during hospitalization which could affect outcome of disease.

Conflict od interests

None declared.

References

1. World Health Organization. Coronavirus disease (COVID-19) Situation Report – 152. https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200620-covid-19-sitrep-152.pdf (June 20, 2020).
2. China National Health Commission website. Notice on issuing a new coronavirus infected pneumonia diagnosis and treatment plan (trial version 5). bgs.satcm.gov.cn/zhengcewenjian/2020-02-06/12847.html (February 18, 2020).
3. Huang P, Liu T, Huang L, et al. Use of chest CT in combination with negative RT-PCR assay for the 2019 novel coronavirus but high clinical suspicion. Radiology. 2020; 295(1): 22–23, doi: 10.1148/radiol.2020200330, indexed in Pubmed: 32049600.
4. Xie X, Zhong Z, Zhao W, et al. Chest CT for typical coronavirus disease 2019 (COVID-19) pneumonia: relationship to negative RT-PCR testing. Radiology. 2020; 296(2): E41–E45, doi: 10.1148/radiol.2020200343, indexed in Pubmed: 32049601.
5. World Health Organization. Clinical management of severe acute respiratory infection when novel coronavirus (nCoV) infection is suspected: interim guidance. 2020.
6. Hansell DM, Bankier AA, MacMahon H, et al. Fleischner Society: glossary of terms for thoracic imaging. Radiology. 2008; 246(3): 697–722, doi: 10.1148/radiol.2462070712, indexed in Pubmed: 18195376.
7. Li K, Fang Y, Li W, et al. CT image visual quantitative evaluation and clinical classification of coronavirus disease (COVID-19). Eur Radiol. 2020; 30(8): 4407–4416, doi: 10.1007/s00330-020-06817-6, indexed in Pubmed: 32215691.
8. Ai T, Yang Z, Hou H, et al. Correlation of chest CT and RT-PCR testing for coronavirus disease 2019 (COVID-19) in China: a report of 1014 cases. Radiology. 2020; 296(2): E32–E40, doi: 10.1148/radiol.2020200642, indexed in Pubmed: 32101510.
9. Zhao D, Yao F, Wang L, et al. A comparative study on the clinical features of coronavirus 2019 (COVID-19) pneumonia with other pneumonias. Clin Infect Dis. 2020; 71(15): 756–761, doi: 10.1093/cid/ciaa247, indexed in Pubmed: 32161968.
10. 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, doi: 10.1097/RLI.0000000000000672, indexed in Pubmed: 32118615.
11. Pan Y, Guan H, Zhou S, et al. Imaging changes in patients with 2019-nCov. Eur Radiol. 2020; 30(7): 3612–3613, doi: 10.1007/s00330-020-06713-z, indexed in Pubmed: 32025790.
12. Tian S, Hu W, Niu Li, et al. Pulmonary pathology of early-phase 2019 novel coronavirus (COVID-19) pneumonia in two patients with lung cancer. J Thorac Oncol. 2020; 15(5): 700–704, doi: 10.1016/j.jtho.2020.02.010, indexed in Pubmed: 32114094.
13. Franquet T. Imaging of pulmonary viral pneumonia. Radiology. 2011; 260(1): 18–39, doi: 10.1148/radiol.11092149, indexed in Pubmed: 21697307.
14. Xu Z, Shi L, Wang Y, et al. Pathological findings of COVID-19 associated with acute respiratory distress syndrome. Lancet Respir Med. 2020; 8(4): 420–422, doi: 10.1016/S2213-2600(20)30076-X, indexed in Pubmed: 32085846.
15. Gattinoni L, Coppola S, Cressoni M, et al. COVID-19 does not lead to a „typical" acute respiratory distress syndrome. Am J Respir Crit Care Med. 2020; 201(10): 1299–1300, doi: 10.1164/rccm.202003-0817LE, indexed in Pubmed: 32228035.
16. Lamy M, Fallat RJ, Koeniger E, et al. Pathologic features and mechanisms of hypoxemia in adult respiratory distress syndrome. Am Rev Respir Dis. 1976; 114(2): 267–284, doi: 10.1164/arrd.1976.114.2.267, indexed in Pubmed: 788563.
17. 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, doi: 10.1097/RLI.0000000000000670, indexed in Pubmed: 32091414.
18. Pan Y, Guan H, Zhou S, et al. Initial CT findings and temporal changes in patients with the novel coronavirus pneumonia (2019-nCoV): a study of 63 patients in Wuhan, China. Eur Radiol. 2020; 30(6): 3306–3309, doi: 10.1007/s00330-020-06731-x, indexed in Pubmed: 32055945.

19. Grinblat L, Shulman H, Glickman A, et al. Severe acute respiratory syndrome: radiographic review of 40 probable cases in Toronto, Canada. Radiology. 2003; 228(3): 802–809, doi: 10.1148/radiol.2283030671, indexed in Pubmed: 12853655.
20. Gattinoni L, Caironi P, Cressoni M, et al. Lung recruitment in patients with the acute respiratory distress syndrome. N Engl J Med. 2006; 354(17): 1775–1786, doi: 10.1056/nejmoa052052, indexed in Pubmed: 16641394.
21. Zu ZiY, Jiang MDi, Xu PP, et al. Coronavirus disease 2019 (COVID-19): a perspective from China. Radiology. 2020; 296(2): E15–E25, doi: 10.1148/radiol.2020200490, indexed in Pubmed: 32083985.
22. Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet. 2020; 395(10223): 497–506, doi: 10.1016/S0140-6736(20)30183-5, indexed in Pubmed: 31986264.
23. Staples CA, Müller NL, Vedal S, et al. Usual interstitial pneumonia: correlation of CT with clinical, functional, and radiologic findings. Radiology. 1987; 162(2): 377–381, doi: 10.1148/radiology.162.2.3797650, indexed in Pubmed: 3797650.
24. Gambotto A, Barratt-Boyes SM, de Jong MD, et al. Human infection with highly pathogenic H5N1 influenza virus. Lancet. 2008; 371(9622): 1464–1475, doi: 10.1016/S0140-6736(08)60627-3, indexed in Pubmed: 18440429.
25. Lau SKP, Lau CCY, Chan KH, et al. Delayed induction of proinflammatory cytokines and suppression of innate antiviral response by the novel Middle East respiratory syndrome coronavirus: implications for pathogenesis and treatment. J Gen Virol. 2013; 94(Pt 12): 2679–2690, doi: 10.1099/vir.0.055533-0, indexed in Pubmed: 24077366.
26. Feng Z, Yu Q, Yao S, et al. Early prediction of disease progression in 2019 novel coronavirus pneumonia patients outside Wuhan with CT and clinical characteristics. MedRxiv. 2020, doi: 10.1101/2020.02.19.20025296.
27. Wang D, Hu Bo, Hu C, et al. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China. JAMA. 2020; 323(11): 1061––1069, doi: 10.1001/jama.2020.1585, indexed in Pubmed: 32031570.
28. Cheng Z, Qin Le, Cao Q, et al. Quantitative computed tomography of the coronavirus disease 2019 (COVID-19) pneumonia. Radiol Infect Dis. 2020; 7(2): 55–61, doi: 10.1016/j.jrid.2020.04.004, indexed in Pubmed: 32346594.
29. Zhang JJ, Dong X, Cao YY, et al. Clinical characteristics of 140 patients infected with SARS-CoV-2 in Wuhan, China. Allergy. 2020; 75(7): 1730–1741, doi: 10.1111/all.14238, indexed in Pubmed: 32077115.
30. Lee KS. Pneumonia associated with 2019 novel coronavirus: can computed tomographic findings help predict the prognosis of the disease? Korean J Radiol. 2020; 21(3): 257–258, doi: 10.3348/kjr.2020.0096, indexed in Pubmed: 32056396.
31. Ko SF, Lee TY, Huang CC, et al. Severe acute respiratory syndrome: prognostic implications of chest radiographic findings in 52 patients. Radiology. 2004; 233(1): 173–181, doi: 10.1148/radiol.2323031547, indexed in Pubmed: 15273329.
32. Sun D, Li X, Guo D, et al. CT quantitative analysis and its relationship with clinical features for assessing the severity of patients with COVID-19. Korean J Radiol. 2020; 21(7): 859–868, doi: 10.3348/kjr.2020.0293, indexed in Pubmed: 32524786.