Is There a Correlation Between Pulmonary Inflammation Index With COVID-19 Disease Severity and Outcome?

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Abstract

Background: The radiologic pulmonary inflammatory index (PII) may be used as an early predictor of inflammation as laboratory assessments in COVID-19 cases. The purpose of this study was to compare the clinical and radiological features between cases of COVID-19 necessitating admittance to the intensive care unit (ICU) and those who did not, and to correlate the PII with other inflammatory markers and outcomes.

Patients and methods: 72 patients consecutively admitted with confirmed COVID-19. Their electronic records were retrospectively revised and the demographic, clinical, laboratory (complete blood count, C- reactive protein, D dimer, and serum ferritin), High resolution computed tomography (HRCT) data, PII, and the outcomes of the patients were analyzed.

Results: They were 50/50%, males/females, with mean age 47.1 ± 16.8 years. During their stay, 15.3% necessitated ICU admittance, 68% cured and discharged, 9 cases referred and 6.9% died. The baseline lesions identified were ground-glass opacification recognized in (93%), higher PII and >3 lobes affection was considerably recorded in those who required ICU admittance (P= 0.041 and 0.013). There was a mild positive correlation between PII with age (r=0.264, P=0.031) and other prognostic inflammatory indicators as ferritin (r=0.225, P=0.048), D Dimer (r=0.271, P=0.043), and serum creatinine.

Conclusions: The use of PII together with clinical and laboratory data may be valuable in defining the inflammatory state of COVID-19. This may allow clinicians to avoid the progression of the illness and improve the cure rates by proper early intervention.

Keywords: COVID-19; coronavirus disease; SARS-CoV-2; Chest HRCT; Pulmonary inflammation index; Ferritin; CRP; severity; ICU; outcomes.

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Background

The clinical presentations of COVID-19 range from asymptomatic cases to mild, moderate, and severe forms rapidly progressing to hospital admission, septicemia, or even death in 4–15% of cases **(Wang et al., 2020).** So, it is crucial to detect the COVID-19 disease and its severity as early as possible**.** Due to the low sensitivity of PCR, several patients with COVID-19 may not be recognized and may not gain proper management in time.

Recently the use of HRCT, as a routine imaging tool for the diagnosis of COVID- 19 pneumonia, is comparatively simple to implement a fast diagnosis. As recently reported, chest CT demonstrates typical radiographic features in almost all COVID-19 cases **(Chung et al., 2020)** even with cases with preliminary negative PCR results **(Huang et al, 2020; Xie et al., 2020; Ai et al., 2020)** and the radiologic pulmonary inflammatory index (PII) may be used as an early predictor of inflammation as laboratory assessments **(Wu et al., 2020).**The objective of the current work was to compare the clinical and radiological features between the cases of COVID-19 necessitating admittance in the intensive care unit (ICU) and those who did not, and to correlate the radiological pulmonary inflammation index (PII) with the other inflammatory indices and outcome.

Patients and methods

This study included all patients consecutively admitted to Aswan university hospital during the period from April to June 2020. All cases had confirmed COVID-19 infection based on PCR and received standardized treatment protocols of the Egyptian Ministry of Health and Population-based on disease severity. We excluded children, pregnant females, and those with negative PCR results from this study. The electronic records of the patients were retrospectively revised and the demographic data, clinical manifestations, presence of comorbid diseases, laboratory investigations including [complete blood count (Sysmex XN-1000-Japan), C-reactive protein (CRP) (Beckman Coulter AU480), D dimer, serum ferritin (Vidas–Biomerieux-France)], and radiological topographies based on HRCT findings, moreover the outcomes of these patients (ICU admission, death, recovery, and referral) were analyzed.

Chest HRCT

HRCT examination was performed ~~on~~ all the population under study using standard protocol via Toshiba 160- slice CT scanner, aquilion TM prime, Japan. Non-contrast scans were obtained at full inspiration from the apex to the base of the lung in supine subjects. The acquisition parameters were as follows: Sequential mode, 1-mm collimation, and 10-mm interval, 180-260 mA average tube current (depending on a body built), and 120-140 kV tube voltage.

All the cuts of CT were appraised by the use of a lung window, with a -500 HU window level and a 1500 HU window width. The CT images were revised by 2 specialists (pulmonologists) who were blinded to the clinical records of the cases. The CT imaging topographies were entirely evaluated, and the following findings were highlighted: ground-glass opacity (GGO), consolidation, crazy paving pattern, interlobular septal thickening, bronchial wall thickening, vascular enlargement, presence of halo sign, reverse halo sign, and pleural effusion in harmony with the typical morphologic descriptors built on the Fleischner Society Nomenclature Commission references and comparable studies **(Hansell et al., 2008; Schoen et al., 2019).** The assessment of the size and extent of lung affection was based on the number of segments affected by the disease: normally there are ten subdivisions in the left lung and ten subdivisions in the right lung (two segments were deliberated in the apicoposterior section of the left upper lobe and two segments were deliberated in the

inferior front section of the left lower lobe). According to the assessment standard proven by Chongqing Radiologist Association of China, the pulmonary inflammation index (PII) was accomplished for each case using the following formula: [PII = (distribution score + size score)/40*100 %]. This score uses lung opacification as a substitute for the determination of lungs extension of the disease **(Xie et al., 2020).**

Statistical analysis

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 22.0 (SPSS Inc., Chicago, IL, USA). A test for normality was done (Kolmogorov-Smirnov (K-S) test. Descriptive analyses were performed for categorical variables. Continuous variables were expressed as the mean ±SD, median, and compared using the independent samples t-test. Otherwise, the Mann–Whitney test was used. The proportions of categorical variables were compared using a chi-squared test. Pearson product-moment analysis was used to evaluate relations between variables. P-value < 0.05 was considered statistically significant.

Results

Clinical data of COVID-19 patients on admission

The current study described the characteristics of the COVID-19 cohort of 72 patients admitted to a single center. They were 50/50% males/ females, mean age was 47.1 ± 16.8 years. Most cases (48.6%) had a history of contact to positive cases. The mean duration of complaints was 4.3 ± 2.8 days before admission. 66.7% of the cases were isolated inwards, 18.1% requested home isolation, while 15.3% necessitated ICU admission. The recorded outcomes were: 49 (68%) of 72 patients discharged, 9 cases referred (12, 5%) and five (6.9%) cases died. Regarding the clinical severity of the disease (according to WHO), 50% of cases were moderate in severity. The associated comorbidities, clinical symptoms, and laboratory data were recorded in ***Table 1***.

CT chest conclusions

We found that 67 (93.1%) patients of the total study population had CT chest anomalies. The baseline lesions identified were ground-glass opacification identified in (67 cases, 93.1%), consolidation alone was observed in (16 cases, 22.2%), while combined consolidation and ground-glass opacification was identified in (16 cases, 22.2%); most of the lesions were bilateral and multi-focal. The most commonly affected part was the left lower division. Moreover, thickening of the inter-lobular septa was observed in (23 cases, 31.9%), vascular enlargement observed in (28, 38.9%), while one patient had pleural effusion, and the typical finding was “crazy paving sign” (19 cases, 26.4%) and “spider web sign” (12 cases, 16.6%), while halo sign was detected in (6 cases, 8.3%). The average PII value was (35.4 ± 14.7%) for all the cases ***Table 2***.

The determinants for ICU admission need and correlation with PII

We found that the cases that required ICU admittance presented mainly with dyspnea (81.8 vs. 37.7% of those non-requiring ICU, P = 0.009), tachypnea (P = 0.023), and had a higher rate of comorbidities (renal impairment, P = 0.016). This group had considerably lowered lymphocytes percentage (P = 0.002) and hemoglobin levels (P = 0.001), higher serum creatinine (P = 0.020), and ferritin (P = 0.034). There was an insignificant increase in CRP and D-Dimer levels. Regarding the radiological conclusions, > 3 lobes affection and higher PII were ominously recorded in those who required ICU admittance (P = 0.041 and P = 0.013) ***Table 3***.

There was a mild positive correlation between PII chest CT value with age (r=0.264, P=0.031) and other prognostic inflammatory markers as ferritin (r=0.225, P=0.048), D Dimer (r=0.271, P=0.043), and serum creatinine as shown in ***Table 4***.

Table 1. Demographic and clinical features of COVID-19 patients

	Description (n=72)
Gender, n (%)	
Male/female	36/36 (50/50)
Age, years	
Range	18 – 89
Mean ± SD	47.1 ± 16.8
Median (IQR)	47 (33 - 61.5)
Symptoms, n (%)	
Fever	48 (66.7)
Cough	49 (68.1)
Sputum	34 (47.2)
Dyspnea	32 (44.4)
Sore throat	14 (19.4)
Rhinorrhea	13 (18.1)
Diarrhea	27 (37.5)
Headache	27 (37.5)
Fatigue	30 (41.7)
Tachypnea	5 (6.9)
Bone ache	3 (4.2)
Anosmia, hyposmia	2 (2.8)
Disturbed conscious level	2 (2.8)
Loss of taste	2 (2.8)
Others	6 (8.3)
Duration of complaint, days	
Range	2 – 20
Mean ± SD	4.3 ± 2.8
Median (IQR)	4 (3 - 5)
Need for ICU admission, n (%)	11 (15.3)
Close contact case, n (%)	35 (48.6)
Comorbidities, n (%)	
Diabetes mellitus	24 (33.3)
Hypertension	17 (23.6)
Cardiac disease	6 (8.3)
Renal impairment	8 (11.1)
COVID-19 clinical severity	
Mild	27 (37.5)
Moderate	36 (50)
Severe, critical	9 (12.5)
Median (IQR)	6.3 (4.4 - 9)
Lymphocytes percentage (%)	
Range	4 – 55
Mean ± SD	26.7 ± 13.2
Median (IQR)	24 (15 - 39.9)
Absolute lymphocytic count (* 10^9 /L)	
Range	0.6 - 4.7
Mean ± SD	1.8 ± 1.1
Median (IQR)	1.6 (1 - 2.4)

Neutrophil percentage (%)	
Range	33.4 – 93
Mean ± SD	63.7 ± 15.4
Median (IQR)	66.8 (52 - 77)
Absolute neutrophils count (* 10^9 /L)	
Range	1.3 - 21.9
Mean ± SD	5.9 ± 4.8
Median (IQR)	4.3 (2.1 - 7.3)
HB (g/dl)	
Range	9 - 15.8
Mean ± SD	12.4 ± 1.4
Median (IQR)	12.3 (11.6 - 13.1)
Platelets (* 10^9 /L)	
Range	102 – 549
Mean ± SD	258.8 ± 85.9
Median (IQR)	259 (198.5 - 312)
C- reactive protein (mg/liter)	
Range	3.8 – 320
Mean ± SD	39.8 ± 43.9
Median (IQR)	32.5 (12.1 - 48.5)
D dimer (µg/L)	
Range	0.2 - 4.6
Mean ± SD	0.8 ± 0.7
Median (IQR)	0.7 (0.4 - 1)
Serum ferritin (ng/mL)	
Range	65 – 3417
Mean ± SD	412.8 ± 447.9
Median (IQR)	331 (180 - 510)
Creatinine (µmol/liter)	
Range	60 – 450
Mean ± SD	140.7 ± 78.6
Median (IQR)	117 2 - 160)

Table 2. Radiological topographies of the COVID-19 patients

Chest CT findings of the population under study	Frequency, n (%)
Normal CT chest	5 (6.9)
Presence of ground glass opacification	67 (93.1)
Distribution of lesions	
Peripheral lesions	47 (65.2)
Patchy lesions	20 (27.7)
Bilateral lesions	58 (80.6)
Multi-focal lesions	58 (80.6)
Uni-focal lesions	9 (12.5)
Number of lobes	
0	5(6.9)
1	4 (5.5)
2	8 (11.1)
3	12 (16.7)

4	7 (9.7)
5	36 (50)
≤ 3	27 (37.5)
> 3	43 (59.7)
Left upper lobe	47 (65.3)
Left lower lobe	59 (81.9)
Right upper lobe	52 (72.2)
Right middle lobe	44 (61.1)
Right lower lobe	60 (83.3)
Bilateral upper lobes	40 (55.6)
Bilateral lower lobes	56 (77.8)
Ground glass opacification + consolidation	16 (22.2)
Consolidation without ground glass opacification	16 (22.2)
Crazy paving pattern	19 (26.4)
Vascular enlargement	28 (38.9)
Thickening of the inter-lobular septa	23 (31.9)
Bronchial wall thickening	5(6.9)
Air bronchogram	16 (22.2)
Air trapping sign	2 (2.8)
Reverse halo sign	3 (4.2)
Presence of a halo sign	6 (8.3)
Spider web sign	12(16.6)
Pleural effusion	1(1.3)
Pulmonary Inflammation Index in chest CT (%)	
Range	5 - 57.5
Mean ± SD	35.4 ± 14.7
Median (IQR)	37.5 (25 - 50)

Table 3. Comparisons between groups according to the necessity for ICU admittance

	ICU admission		
	Yes (n=11)	**No (n=61)**	
Gender, n (%)			
Male/female	8/3 (72.7/27.3)	28/33 (45.9/54.1)	0.101
Age, years			
Range	36 - 89	18 – 77	
Mean ± SD	54.4 ± 14.4	45.8 ± 17	
Median (IQR)	55 (45 - 58)	46 (33 - 62)	0.141
Clinical symptoms, n (%)			
Fever	9 (81.8)	39 (63.9)	0.316
Cough	10 (90.9)	39 (63.9)	0.093
Sputum	7 (63.6)	27 (44.3)	0.236
Dyspnea	9 (81.8)	23 (37.7)	**0.009**
Sore throat	4 (36.4)	10 (16.4)	0.207
Rhinorrhea	1 (9.1)	12 (19.7)	0.676
Diarrhea	7 (63.6)	20 (32.8)	0.088
Headache	2 (18.2)	25 (41)	0.191
Fatigue	2 (18.2)	28 (45.9)	0.107
Tachypnea	3 (27.3)	2 (3.3)	**0.023**

Bone ache	1 (9.1)	2 (3.3)	0.397
Anosmia, hyposmia	0 (0)	2 (3.3)	1.000
Disturbed level of consciousness	1 (9.1)	1 (1.6)	0.284
Loss of taste	0 (0)	2 (3.3)	1.000
Others	1 (9.1)	5 (8.2)	1.000
Duration of complaints (Days)			
Range	3 - 13	2 – 20	
Mean ± SD	5.5 ± 3.1	4.1 ± 2.7	
Median (IQR)	4 (4 - 6)	4 (3 - 4)	**0.028**
Close contact case, n (%)	3 (27.3)	32 (52.5)	0.124
Comorbidities, n (%)			
Diabetes Mellitus	5 (45.5)	19 (31.1)	0.488
Hypertension	3 (27.3)	14 (23)	0.714
Cardiac disease	1 (9.1)	5 (8.2)	1.000
Renal impairment	4 (36.4)	4 (6.6)	0.016
WBC (* 10^9 /L)			
Range	3.2 - 14	3.2 - 24.8	
Mean ± SD	7.2 ± 3.1	7.5 ± 4.3	
Median (IQR)	6.5 (5.3 - 9)	6.1 (4.3 - 9.1)	0.876
Lymphocytes percentage (%)			
Range	10 - 38	4 – 55	
Mean ± SD	16.3 ± 8.3	28.6 ± 13	
Median (IQR)	15 (11 - 18)	26.3 (18.7 - 40)	**0.002**
Absolute lymphocytic count (* 10^9 /L)			
Mean ± SD	0.8 ± 0.3	1.9 ± 1.1	
Median (IQR)	0.8 (0.6 - 1)	1.7 (1 - 2.6)	0.214
Neutrophil percentage (%)			
Range	69 - 81	33.4 – 93	
Mean ± SD	75 ± 8.5	63.2 ± 15.5	
Median (IQR)	75 (69 - 81)	65 (52 - 76)	0.316
Absolute neutrophils count (* 10^9 /L)			
Mean ± SD	3.7 ± 1.3	6.1 ± 4.9	
Median (IQR)	3.7 (2.8 - 4.6)	4.3 (2.1 - 7.8)	0.742
Hemoglobin (g/dl)			
Mean ± SD	11 ± 1.2	12.6 ± 1.3	
Median (IQR)	11.7 (10 - 12)	12.8 (11.8 - 13.2)	**0.001**
Platelets (* 10^9 /L)			
Mean ± SD	224.8 ± 83.7	264.9 ± 85.6	
Median (IQR)	236 (120 - 310)	263 (199 - 312)	0.280
C reactive protein (mg/liter)			
Mean ± SD	71.8 ± 87.9	34 ± 27.8	
Median (IQR)	45 (23 - 102)	32 (12 - 45)	0.066
D dimer (mg/liter)			
Range	0.3 - 4.6	0.2 - 2.8	
Mean ± SD	1.3 ± 1.4	0.7 ± 0.5	
Median (IQR)	0.9 (0.4 - 1.3)	0.7 (0.4 - 0.9)	0.161
Serum ferritin (ng/ml)			
Mean ± SD	552.3 ± 299.9	391 ± 465.4	
Median (IQR)	513 (312 - 727)	321 (176 - 448)	**0.034**

Creatinine (µmol/liter)			
Mean ± SD	247.3 ± 135.4	124.3 ± 50.8	
Median (IQR)	260.5 (128.5 - 345)	113.5 (77.5 - 159.5)	**0.020**
Radiological Findings, n (%)			
Bilateral lesions	10 (90.9)	48 (78.7)	0.679
Multi-focal lesions	9 (81.8)	49 (80.3)	1.000
Number of lobes affected			
≤ 3	1 (9.1)	28 (45.9)	**0.041**
> 3	10 (90.9)	33 (54.1)	
PII chest CT value (%)			
Range	27.5 - 57.5	5 – 55	
Mean ± SD	45.5 ± 8.9	33.4 ± 14.9	
Median (IQR)	47.5 (37.5 - 52.5)	33.8 (24.5 - 46.3)	**0.013**
Clinical Severity, n (%)			
Mild	0 (0)	27 (44.3)	**<0.001**
Moderate	2 (18.2)	34 (55.7)	
Severe	9 (81.8)	0 (0)	

- *P < 0.05 was considered statistically significant (in bold)*

Statistical tests used: the independent samples t-test & Mann-Whitney U Test

Table 4. Correlation between Pulmonary inflammation index (PII) with clinical and laboratory prognostic parameters

Variables	**PII chest CT value** (%)	
	R	**P**
Age	0.264	**0.031***
Duration of complaints (Days)	-0.049	0.703
White blood cell count	0.138	0.264
Lymphocyte %	-0.212	0.084
Absolute lymphocytes count	0.148	0.368
Neutrophil %	-0.017	0.915
Absolute neutrophils count	0.019	0.917
Hemoglobin	-0.047	0.706
Platelet's count	-0.162	0.190
C reactive protein	0.209	0.090
D dimer	0.271	**0.043***
Serum ferritin	0.225	**0.048***
Creatinine	0.443	**0.001****

- *P < 0.05 was considered statistically significant (in bold)*

HRCT chest of a male patient, asthmatic, presented with fever, productive cough, dyspnea, and tachycardia of 3 days. He was diagnosed as COVID-19, admitted to ICU. The CT findings are multi-lobular bilateral GGO with consolidation, crazy paving pattern, PII= 60%. The patient rapidly deteriorated and died, **(Fig.1).**

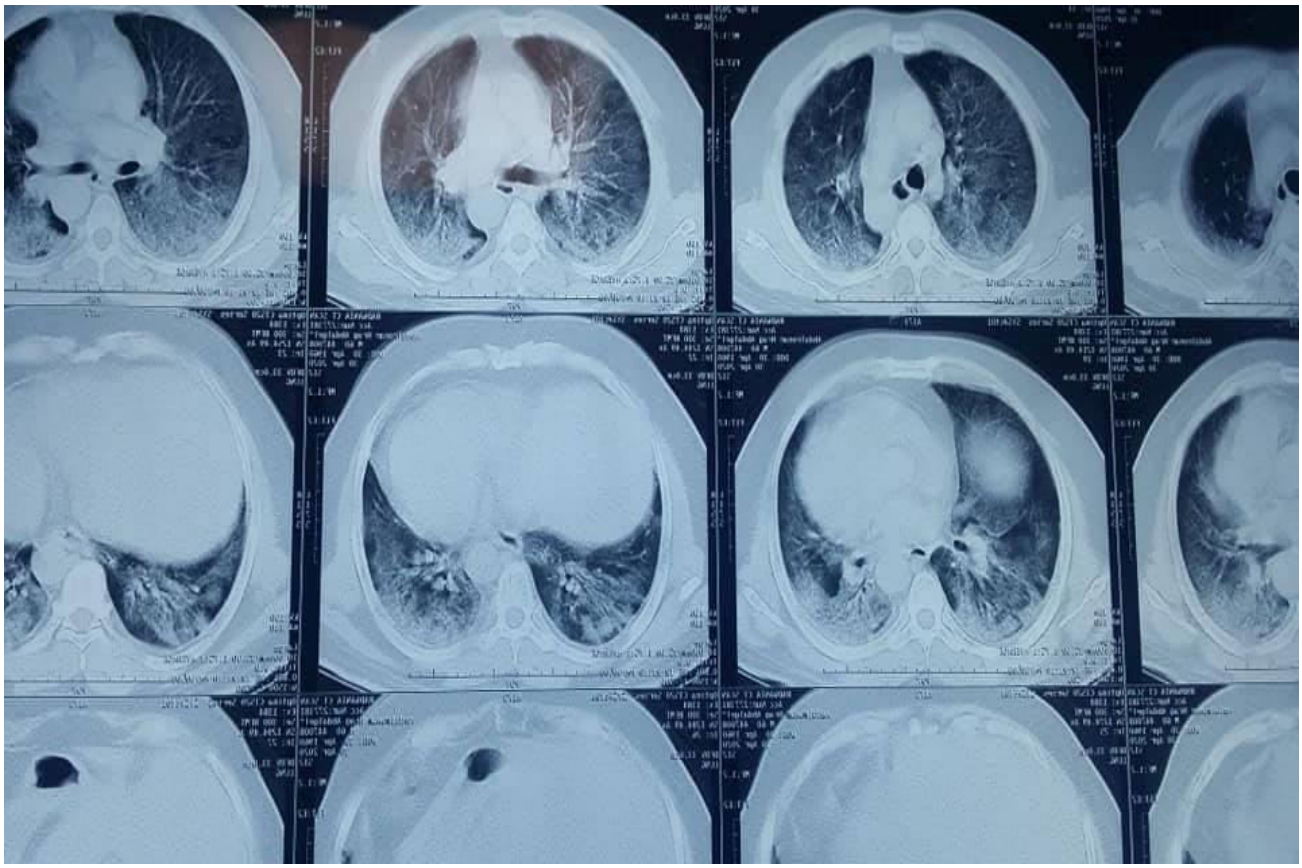

Fig.1. HRCT chest of a male patient, asthmatic, presented with fever, productive cough, dyspnea, tachycardia of 3 days. He was diagnosed as COVID-19, admitted to ICU. The CT findings are multi-lobular bilateral GGO with consolidation, crazy paving pattern, PII= 60%. The patient rapidly deteriorated and died.

A case of 54 years-old male, passive smoker, complaining of shortness of breath, dry cough, and low-grade fever. He was diagnosed as COVID-19 based on clinical, radiologic, and laboratory findings, and he was advised to follow treatment protocol with home isolation. Two weeks later he developed high-grade fever (40°C), rapidly progressive dyspnea (grade III). A nasopharyngeal swab was done, and the PCR result was positive for COVID-19. And the patient was transferred to an isolation Hospital. His CT chest showed right soft tissue infiltrate with air bronchogram with ***PII 30%***. On room air, his oxygen saturation was 66% and on Venturi 50%, and his ABG improved: pH: 7.50, $PaCO_2$: 27, PaO_2: 68, HCO_3:23, SaO_2: 95. He received treatment and intermittent oxygen therapy and improved within one month, **(Fig.2).**

Fig.2. a case of 54 years-old male, passive smoker complaining from shortness of breath, dry cough, low-grade fever, PCR positive for COVID-19. His CT chest showed right soft tissue infiltrate with air bronchogram with PII 30%. On room air, his oxygen saturation was 66%, and on Venturi 50%. He received treatment and intermittent oxygen therapy and improved within one month.

The HRCT of a female patient 64 years old with a history of fever, dry cough, headache, and anosmia for 3 days. Nasopharyngeal swab PCR was positive for COVID-19. The PII of the HRCT chest was 5%. She was advised for home isolation and symptomatic treatment and completely improved in 10 days **(Fig.3).**

Fig. 3. HRCT of a female patient 64 years old with a history of fever, dry cough, headache, and anosmia for 3 days. Nasopharyngeal PCR was positive for COVID-19. Her PII of HRCT chest was 5%. She was advised for home isolation and symptomatic treatment and improved in 10 days

Discussion

We performed an inclusive study of the demographic, clinical, laboratory and radiological topographies of 72 consecutive Egyptian COVID-19 patients admitted to our hospital. The main findings of this study were the predominance of HRCT findings in the majority of COVID-19 cases with different disease severity. The use of radiologic PII seemed a very informative index of the state of inflammation and correlated with the prognostic parameters such as levels of serum ferritin and D dimer.

The median age in the study population was 47 years and it is well-matched with previous studies in China and United States **(Singh et al., 2020; Richardson et al, 2020).** There was also no obvious gender predilection in the current study. However, male predominance (up to 73%) was recorded repeatedly in several studies and was explained by more exposure to the virus in outdoor working men **(Huang et al., 2020a**).

Furthermore, it was reported that one-third of the positive COVID-19 cases had comorbidities including diabetes mellitus, hypertension, and cardiac problems similar to our results **(Huang et al., 2020b; Shi et al., 2020).**

Regarding the clinical severity of the disease**,** most of the cases included in the study presented with moderate COVID-19 disease severity similar to Zu and colleagues **(Zu et al., 2020).** As expected, the most common symptom among the studied population was cough (68.1), which is in harmony, with numerous reports **(Chen et al., 2020; Guan et al., 2020; Wu et al., 2020).** Diarrhea was evident in 37% of the cases comparable to reports recording that over 1/3 of the patients had symptoms suggesting gastro-intestinal affection such as diarrhea, nausea, and vomiting **(Zhang et al., 2020).**

In this study, like early published reports, 5 cases (6.9%) presented with normal CT chest and positive PCR results suggesting that PCR results can be positive even in cases presented with normal CT findings **(Ai et al., 2020).** The normal chest CT findings frequency ranged from 0.7% to 56%, varied according to the disease severity with the highest rates reported in those with asymptomatic or with mild presentations **(Sun et al., 2020).**

Regarding the HRCT chest topographic features, we found that multi-lobar affection was noted in 80.6%, bilateral lower lobes affection in 83.3%, and peripheral/sub-pleural affection in 65.2%. The common configurations were: ground-glass opacification, consolidation, crazy paving pattern, vascular enlargement & interlobular septal thickening and the uncommon CT patterns were: reverse halo sign, pleural effusion, spider web sign, air trapping sign & bronchial wall thickening. These results are universally approved with many published data **(Lomoro et al., 2020; Raptis et al., 2020; Salehi et al., 2020; Zu et al., 2020).**

In this study, more than half of the cases had multi-lobar affection and progression, and the right lung was more commonly involved. Even when a single section was affected, the right lung was commonly involved. In the right lung, the lower section was commonly affected, while the upper section was often involved in the left lung **(Awulachew et al., 2020).** This should specify that as the disease progress, the disease tends to distribute often all over both lung lobes.

Besides the role of HRCT in the detection of COVID-19, it also plays an essential role in the proper stratification and management of the disease. As with other types of pneumonia, there was a definite association between disease severity & chest CT topographies. Intensive care unit (ICU) cases on admittance often presented with bilateral multi-lobar and sub-segmental consolidations, compared with the non-severe cases that presented with bilateral GGOs and consolidation **(Huang et al., 2020a).** Chest CT might be used as a monitor to detect the evolution of the coronavirus disease as patients with severe illness most commonly report bilateral and multi-lobar affection (**Duan & Qin, 2020; (Sabri et al., 2020; Salehi et al., 2020; Shi et al., 2020; Song et al., 2020).**

We found that the cases that required ICU admittance presented mainly with dyspnea, fatigue and had a higher rate of comorbidities, lower lymphocytes percentage, and hemoglobin levels while higher serum creatinine, D Dimer, and ferritin. Decreased lymphocytes percentage on admittance was linked with worse consequences in cases with COVID-19 **(Huang & Pranata, 2020)** and lymphopenia, in addition to the serum levels of D dimer, CRP, ferritin were considered as important factors in the hazard stratification of the severe and fatal form of COVID-19 in hospitalized cases **(Velavan & Meyer, 2020)** and high serum ferritin alone might be

considered as a forecaster of poor outcome **(Mehta et al., 2020; Hussein et al., 2021).**

Cases with comorbid disorders signified more severe clinical signs compared to paralleled to those without any comorbid disorder **(Huang et al., 2020b).** There is a strong relationship between the need for admittance to the intensive care unit and an elevated score of qSOFA, higher levels of CRP, and pro-calcitonin levels **(Almazeedi et al., 2020; Hussein et al., 2021).**

The levels of CRP were increased in cases with COVID-19 and it has been revealed that survivors had greater levels compared with non-survivors, indicating a strong correspondence with the severity & prognosis of the disease **(Ruan et al., 2020).** This was similar to the results of this study but the difference did not reach the level of significance (median 45 vs. 32, p = 0.066). This may be attributed to the small number of ICU admitted patients in this cohort (only 11 cases).

A slight increase of the D-Dimer level was also noticed in this study in ICU cases (1.3±1.4 vs. 0.7±0.5). Greater levels of D-dimer may help in efficient differentiation between mild and severe cases of COVID-19 disorder **(Zhang et al., 2020)** and may be used as a mirror for the identification of disease progression toward unfavorable outcomes and even death **(Bashash et al., 2020; Zhou et al., 2020).**

We used the PII to quantify the lung lesions in patients with COVID-19 and found that the PII was ominously higher in cases requiring ICU admittance. The PII was positively correlated with age, D Dimer, serum ferritin, and creatinine. These findings may suggest the value of the PII as an independent index of early inflammation before clinical deterioration and it may predict the evolution from mild to severe infection **(Wan et al., 2020).** Similar substantial correlations were observed between the degree of pulmonary inflammation and the main clinical symptoms and laboratory markers in COVID-19 patients **(Wu et al., 2020).**

Conclusions

We suggest the use of PII together with clinical and laboratory data as valuable in determining the inflammatory status of COVID-19. It was correlated to inflammatory markers such as D dimer, ferritin even before clinical deterioration. This may allow clinicians to avoid the advance of the disease by proper early intervention and improve cure rates.

Study's limitations

This study had some limitations. Firstly, its retrospective design and the short duration for the collection of our records, secondly, we did not perform a follow-up CT to explore the radiology evolution of our cases, which might aid in the judgment of the course of the disease. Thirdly, it's a single-center study with a limited number of patients to identify the outcome. Finally, the inter-observer bias presented in the CT interpretation.

Abbreviations: PII; pulmonary inflammatory index, HRCT; high resolution computed tomography.

Declarations:

Ethical approval: the study was approved by the Ministry of Health and Population and ethical committee Faculty of Medicine, Aswan University, Egypt.

The study is registered in clinicaltrial.gov ID: NCT04479293

Approval and consent to participate: written consent was taken from all patients

Consent for publication: All authors have read and approved the final draft of the manuscript and approved the submission

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Availability of data and materials statement:
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request

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