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Research Article

Evaluation of the Relationship between Oxygenation Indices and the Extent of Radiographic Findings in Hospitalized COVID-19 Patients: A Cross-Sectional Study

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ABSTRACT

Background: Oxygenation indices are used to assess the condition of patients with pneumonia and ARDS. These indexes determine the status of patients as well as the mortality rate of respiratory diseases and the need for intubation. The aim of this study was to determine and compare oxygenation indices and the extent of radiographic findings in patients with COVID-19 in ICU at Shariati Hospital.

Methods: The present study was a cross-sectional study that was performed prospectively in the intensive care units of Shariati Hospital in Tehran. Patients admitted to the intensive care unit were examined if they met the inclusion criteria. Data were analysed by SPSS software version 26.

Results: In this study, 39 patients were evaluated. Of these, 35.9% were men and 64.1% were women. The mean age of the population was 62 ±17. On average, SpO2 and PaO2 were not significantly different based on pulmonary involvement, severity of pulmonary involvement and also the pattern of pulmonary involvement ($p > 0.05$). No significant relationship was found between the severity of ARDS and the parameters of pulmonary involvement severity on CT scan ($p > 0.05$).

Conclusion: It seems that there is no significant relationship between oxygenation indices and the extent of radiographic findings in hospitalized patients with COVID-19. Also, the severity of ARDS has no significant relationship with the extent of radiographic findings (CT scan). Oxygen saturation should be used as an adjunct when considering a CT scan of the lung, but should not be used as the sole means of diagnosis.

Introduction

In line with the emergence of the coronavirus pandemic since December 2019 [1–3], various achievements have been made in the fields of prevention, diagnosis, and treatment of infections caused by this disease. COVID-19 patients who are referred to a hospital may present more severe symptoms such as dyspnea, pneumonia [4], and eventually acute respiratory distress syndrome (ARDS) [5].

ARDS is a serious health condition in hospitalized patients (more likely in critical care settings) [6]. Typically, ARDS is characterized by dyspnea, low blood oxygen saturation, noncardiogenic pulmonary edema, and severe hypoxia [7]. Acute respiratory distress syndrome (ARDS) is classified as mild (PaO2/FIO2 200 mm Hg), moderate (PaO2/FIO2 200 mm Hg), or severe

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(PaO2/FIO2 100 mm Hg), with four ancillary variables for severe ARDS: radiographic severity, respiratory system compliance (40 mL/cm H2O), and positive end-expiratory pressure (10 cm H2O).

A chest CT scan is used to diagnose ARDS, and its involvement is in the form of bilateral heterogeneous infiltration more in the gravity-dependent areas of the lung [8]. Although a chest CT scan is not a suitable diagnostic method for COVID-19, it does show disease progression and complications and is extremely useful in the management of hospitalized patients. Pulmonary involvement in CT scan is in the form of double-sided ground-glass opacity (GGO) in the environment and rules of the lung and subpleural opacity, which is curved [9].

It is reported that, In COVID-19 patients, the PaO2 to FIO2 ratio is higher compared to H1N1 flu patients [10]. It is also more common in men and the elderly, and a GGO is common in its chest CT scan [11]. The aim of this study is to determine the relationship between oxygenation indices and the extent of radiographic findings in hospitalized COVID-19 patients.

Methods

Study design

This study was designed as a prospective cross-sectional study. It was approved by The Institutional Review Board (IRB) of Tehran University of Medical Sciences (IR.TUMS.MEDICINE.REC.1399.696).

Setting

The present study conducted in Shariati hospital, Tehran, Iran. Eligible patients who admitted to ICU were screened (January to December 2021).

Participants (patients)

After primary screening, patients who meet the inclusion criteria were included in this study. Patients were selected by a random sampling method.

Inclusion criteria: Patients with a diagnosis of COVID-19 (confirmed by real-time PCR or according to the infection disease practitioner), the age of patients between 18 and 75 years old, hospitalized in the special care unit for COVID-19. Exclusion criteria: rejection of the diagnosis of COVID-19 by an infectious disease specialist; pregnant women; patients over 75 years old; critically ill patients who were intubated at the time of admission to the ICU.

Variables and outcomes

Patients' lab tests including CBC (hemoglobin, platelet, white blood cell, lymphocyte and neutrophil percentage), inflammatory factors including Erythrocyte Sedimentation Rate (ESR) and C-Reactive Protein (CRP) were extracted and recorded from their medical files. The blood sample was taken by the nurse and sent to the laboratory of Shariati Hospital. All patients were sent to the radiology department of Shariati Hospital for a chest Computed Tomography (CT) Scan upon admission to the ICU (no charge was imposed on the patients). The extent of lung involvement and the pattern of lung involvement were reported by two independent radiologists from the spiral chest CT scan, all of which were extracted and recorded from the patients' file reports.

Radiological findings consist of:

- Parenchymal abnormality

o Ground-glass opacification/opacity (GGO) and types of GGO, consolidation, reticular pattern, mixed pattern, and Honeycombing.

- Axial distribution of abnormalities (Subpleural (peripheral one third)/ Central (central two thirds)/Diffuse)
- Craniocaudal distribution (Apical/Basilar)
- Zonal involvement (left/right/both)

The main outcome of this project is to investigate and compare oxygenation indices, including SpO2, PaO2, based on the severity of pulmonary involvement (radiological finding) in patients with COVID-19 hospitalized in the intensive care unit.

Statistical methods

The collected data was analyzed after collection by SPSS version 26 software. The significance level of the data was considered less than 5% (P-value < 0.05). An independent paired t-test (or Mann-Whitney U) was used to compare the mean between the two groups of patients. In the case of a normal distribution, one-way analysis of variance (ANOVA) was used to compare average data across three groups. In case of a non-normal distribution, the Kruskal-Wallis H test (non-parametric) was used.

Results

39 patients were evaluated in this study. Of these, 35.9% were men and 64.1% were women. The average age of the population was 62.9±17.01 (Table 1).

According to the descriptive results (Table 1), the mean of the Berlin criteria (PF ratio) in this study was 144, which indicates moderate acute respiratory distress syndrome. The frequency of qualitative variables (nominal and categorial) is shown in (Table 2).

In terms of abnormal parenchymal tissue changes, 46.2% of patients had mixed pattern, 38.5% of patients had GGO pattern and 15.4% had CONSOLIDATION pattern. In terms of GGO type, 46.2% were pure GGO pattern, 17.9% were Crazy paving, 15% without GGO, 10.3% were GGO + smooth interlobular septal thickening, and 10.3% were Irregular lines and interfaces with architectural distortion + GGO.

In terms of axial distribution of abnormalities, 66.7% had subpleural involvement (peripheral one-third), 28.2% had a scattered pattern, and finally 5.1% had a central involvement pattern (central two-thirds).

Craniocaudal distribution was Basilar in 74.4% of cases and Apical in 25.6% of cases. 92.3% of cases of zonal involvement were bilateral (left and right), only 2 cases had left involvement and 1 case had right involvement.

Based on the results of comparing two oxygenation indices based on the severity of pulmonary involvement and patterns of pulmonary involvement in CT scan, no significant difference was found. In fact, mean SpO2 and PaO2 were not significantly different based on pulmonary involvement, severity of pulmonary involvement, and pattern of pulmonary involvement ($p>0.05$).

The comparison of PF ratio and SF ratio also showed no statistically significant difference based on the type of pulmonary involvement, severity of involvement and pattern of pulmonary involvement (Table 3).

To compare the oxygenation indices based on the severity of respiratory distress, the Kruskal-Wallis H test was used (Table 4).

The results of the chi-square test (Table 5) to investigate the relationship between the severity of ARDS and the parameters of the severity of pulmonary involvement in CT scan also showed no statistically significant difference ($p>0.05$).

Table 1- Basic and demographic information of patients hospitalized in the intensive care unit

	Min	Max	Mean	SD
Age (years)	18	73	62.92	17.01
White Blood Cell (WBC)	3600	74601	11207.97	11719.94
Lymphocyte %	2	26	9.56	5.48
Neutrophil %	60	98	84.18	7.84
Hb (g/dl)	5.8	16.3	12.105	3.114
Platelet	13000	493000	203307.69	124035.25
ESR	8	133	60.08	34.02
CRP (mg/dl)	4	169	74.45	37.03
PaO2	43	129	73.59	18.21
SPO2 (%)	58	100	93.05	6.97
FIO2	21	100	67.44	29.69
ZONAL score	1	24	13.85	7.30
FLOW of oxygen	0	12	6.41	3.94
PF ratio	43	328.5	144.52	97.44
SF ratio	59.7	457.1	181.08	111.43

Table 2- frequency of qualitative variables of patients at the beginning of ICU admission

		N	%
Parenchymal abnormality	GGO	15	38.5
	Consolidation	6	15.4
	Reticular pattern	0	0.0
	Mixed pattern	18	46.2
	Honeycombing	0	0.0
Type of GGO	Pure GGO	18	46.2
	GGO + smooth interlobular septal thickening	4	10.3
	Crazy paving: GGO + intralobular lines	7	17.9
	Irregular lines and interfaces with architectural distortion + GGO	4	10.3
	No GGO	6	15.4%
Axial distribution of abnormalities	Subpleural (peripheral one third)	26	66.7%
	Central (central two thirds)	2	5.1%
	Diffuse	11	28.2%
Craniocaudal distribution	Apical	10	25.6%
	Basilar	29	74.4%
Zonal involvement	RT	1	2.6%
	LT	2	5.1%
	BOTH	36	92.3%
Rt	0%-25%	14	35.9%
	25%-50%	12	30.8%
	50%-75%	9	23.1%
	75%-100%	4	10.3%
Lt	0%-25%	15	38.5%
	25%-50%	10	25.6%
	50%-75%	11	28.2
	75%-100%	3	7.7

Table 3- Comparison of oxygenation indices SF ratio and PF ratio based on different parameters of pulmonary involvement

		PF ratio			SF ratio		
		Mean	SD	P value	Mean	SD	P value
Sex	Male	152.50	97.99	0.27	190.52	114.96	0.34
	Female	130.28	98.44		164.24	106.87	
Parenchymal abnormality	GGO	143.77	104.04	0.93	169.02	107.62	0.91
	CONSOLIDATION	126.78	61.54		186.22	94.94	
	MIXED PATTERN	151.07	105.07		189.42	123.91	
Type of GGO	Pure GGO	175.06	112.13	0.20	212.15	124.72	0.069
	GGO + smooth interlobular septal thickening	66.32	20.96		94.45	33.50	
	Crazy paving: GGO + intralobular lines	140.78	110.33		180.59	123.62	
	Irregular lines and interfaces with architectural distortion + GGO	118.50	51.18		121.07	42.08	
	No GGO	126.78	61.54		186.22	94.94	
Axial distribution of abnormalities	Subpleural (peripheral one third)	147.03	105.20	0.73	181.16	119.28	0.78
	Central (central two thirds)	155.00	49.50		186.00	8.49	
	Diffuse	136.71	89.81		180.01	107.72	
Craniocaudal distribution	Apical	176.14	128.99	0.30	212.38	142.12	0.48
	Basilar	133.62	84.02		170.29	99.44	
Zonal involvement	Rt	180.00	.	0.70	198.00	.	0.61
	LT	118.50	72.83		140.50	67.18	
	BOTH	144.99	100.42		182.87	115.09	
Rt	0%-25%	183.49	116.54	0.23	229.30	130.48	0.10
	25%-50%	146.47	106.27		178.14	123.39	
	50%-75%	89.23	27.67		122.34	42.10	
	75%-100%	126.72	35.76		153.31	26.16	
Lt	0%-25%	196.40	126.32	0.30	233.88	141.47	0.18
	25%-50%	115.47	73.12		147.53	90.67	
	50%-75%	109.36	47.64		149.78	69.76	
	75%-100%	110.95	20.67		143.75	21.86	

Table 4- Comparison of indices of patients based on severity of respiratory distress

	ARDS severity						
	Mild		Moderate		Severe		P
	Mean	SD	Mean	SD	Mean	SD	value
Age	26.00	8.49	69.53	10.73	64.31	12.65	0.003
WBC	8330.00	4492.62	9475.79	4435.14	13984.44	17495.67	0.80
Hb	9.88	3.96	12.14	2.88	12.62	3.14	0.41
PLT	165250.00	204221.08	194315.79	126112.85	223500.00	103075.38	0.19
ESR	84.75	36.95	60.47	34.42	53.44	32.06	0.48
CRP	76.00	65.94	74.37	33.02	74.15	35.99	0.87
PaO2	78.25	11.21	77.53	19.58	67.75	17.14	0.36
SPO2	93.25	2.50	94.32	3.59	91.50	10.09	0.84
Total score of zonal involvement	9.25	2.87	14.63	7.30	14.06	7.95	0.39
NEUT	6974.50	4001.54	8293.26	4418.49	11826.14	15416.69	0.85
LYMPHO	708.50	332.79	676.53	330.18	1456.71	1590.16	0.29
PaO2	78.25	11.21	77.53	19.58	67.75	17.14	0.36
SPO2	93.25	2.50	94.32	3.59	91.50	10.09	0.84
PF ratio	372.62	53.36	159.56	50.05	69.64	18.40	<0.001
SF ratio	444.05	11.90	198.86	59.88	94.24	15.49	<0.001

Table 5- relationship between the severity of ARDS and the severity of pulmonary involvement in CT scan

		Mild		Moderate		Severe	
		N	%	N	%	N	%
Parenchymal abnormality	GGO	1	25.0%	7	36.8%	7	43.8%
	CONSOLIDATION	0	0.0%	4	21.1%	2	12.5%
	RETICULAR PATTERN	0	0.0%	0	0.0%	0	0.0%
	MIXED PATTERN	3	75.0%	8	42.1%	7	43.8%
	Honeycombing	0	0.0%	0	0.0%	0	0.0%
Type of GGO	Pure GGO	3	75.0%	10	52.6%	5	31.3%
	GGO + smooth interlobular septal thickening	0	0.0%	0	0.0%	4	25.0%
	Crazy paving: GGO + intralobular lines	1	25.0%	3	15.8%	3	18.8%
	Irregular lines and interfaces with architectural distortion + GGO	0	0.0%	2	10.5%	2	12.5%
	no GGO	0	0.0%	4	21.1%	2	12.5%
Axial distribution of abnormalities	Subpleural (peripheral one third)	3	75.0%	11	57.9%	12	75.0%
	Central (central two thirds)	0	0.0%	2	10.5%	0	0.0%
	diffuse	1	25.0%	6	31.6%	4	25.0%
Craniocaudal distribution	apical	2	50.0%	5	26.3%	3	18.8%
	basilar	2	50.0%	14	73.7%	13	81.3%
Zonal involvement	Rt	0	0.0%	1	5.3%	0	0.0%
	LT	0	0.0%	1	5.3%	1	6.3%
	BOTH	4	100.0%	17	89.5%	15	93.8%
RT	0%-25%	3	75.0%	7	36.8%	4	25.0%
	25%-50%	1	25.0%	5	26.3%	6	37.5%
	50%-75%	0	0.0%	4	21.1%	5	31.3%
	75%-100%	0	0.0%	3	15.8%	1	6.3%
LT	0%-25%	4	100.0%	6	31.6%	5	31.3%
	25%-50%	0	0.0%	4	21.1%	6	37.5%
	50%-75%	0	0.0%	7	36.8%	4	25.0%
	75%-100%	0	0.0%	2	10.5%	1	6.3%

Discussion

The present study aimed to determine the relationship between oxygenation indices and the extent of pulmonary involvement based on radiological findings (CT scan). According to the findings of this research, no significant relationship was found between the extent of pulmonary involvement and radiological findings (CT scan). Different oxygenation parameters such as PaO, SPO2 and PF ratio were not related to (statistically significant difference in pulmonary involvement pattern (unilateral/bilateral)) type of pulmonary involvement (GGO).

Based on the results of Dai et al. [12], the clinical performance of patients with COVID-19, mainly with epidemiological history and typical clinical symptoms, is very important in the diagnosis of COVID-19. While high-resolution CT provides the distribution of pulmonary involvement, shape, attenuation, and extent of pulmonary lesions, as well as some typical CT features of COVID-19 pneumonia, Therefore, the tool is for clinical use, but its relationship with oxygenation parameters is still disputed. However, Alinjad et al. suggested [13] that there is a significant inverse relationship between CT intensity score and capillary oxygen saturation (41%). In fact, it was shown that there is a significant inverse relationship between CT intensity score and capillary oxygen saturation, which is of great clinical importance. However, no such relationship was found in our study.

In a study by Yang et al. in China, quantitative and semi-quantitative indicators of lung CT scan and their relationship with the clinical conditions of patients were evaluated. They reviewed the CT scan findings of 102 patients with COVID-19 infection and found that the total CT intensity score was significantly higher in patients with severe COVID-19 infection compared to mild cases. They also suggested that the CT intensity score can be used to assess the severity of pulmonary involvement [14]. Another study was conducted by Zhao et al. [15] Their study was conducted on 101 cases of patients with COVID-19 to investigate possible relationships between chest CT findings and the patients' clinical conditions. They showed that ground-glass opacities or mixed ground-glass opacities, consolidation, and vascular

enlargement are more common in patients. In our study, it was found that the most pulmonary pattern in the patients was mixed ground-glass opacities, followed by ground-glass opacities, and finally consolidation, which is also consistent with Zhao's study. Zhao et al. also suggested that the CT intensity score can help in evaluating the severity and extent of the disease.

In another study, Fang et al. [16] compared the results of the CT intensity score with the results of reverse transcription polymerase chain reaction (RT-PCR) in 51 patients with COVID-19 infection. They showed that the sensitivity of lung CT was higher than RT-PCR (98% versus 71%, respectively) and patients with higher CT scores had more severe infection in the following days. In our study, there was a significant correlation between the severity of ARDS and the severity of involvement in CT The lung scan was not found. The important point from the present study as well as the study by Fang et al. is that the parameters of lung involvement in the CT scan are clinically important. However, they may not have a significant relationship with the oxygenation parameters. Of course, this point It should also be noted that the measurement time of these parameters is also important.

Cheng et al [17] also evaluated the CT scan findings of patients suspected of having a COVID-19 infection and reported that radiological patterns of multifocal, peripheral, pure vitreous opacity (GGO), mixed GGO, or consolidation with partial predominance in the lower part of the lung in the first week of the disease can be considered as findings that are highly suspicious for confirming the infection of COVID-19. But they were not able to clarify whether there was a relationship between the CT scan findings and the clinical characteristics of the patients.

It is important to understand that COVID-19 infection often exhibits the characteristics of a slow radiological progression, peaking in the second week after the onset of symptoms. The second week of the disease period is the most critical week with the highest CT intensity score, the highest frequency of complications, and the lowest oxygen saturation. This is followed by a gradual regression in the third week [18]. It has also been found that the consolidation pattern alone, without GGO, appears more in the final stages of the disease [19].

Xiong et al. observed that COVID-19 infection was characterized by GGO on chest CT scan, which was associated with increased levels of CRP, ESR, and lactate dehydrogenase. In contrast to other studies, they failed to correlate any clinical characteristics with the severity of CT scan findings [20]. Based on these findings, a higher CT severity score is associated with more severe clinical complications in COVID-19 patients. Possibly, the association between higher CT intensity scores and hypoxia may help explain this problem. As a basic principle, people with an oxygen saturation level of less than 93% should undergo imaging procedures (such as a CT scan). The British guidelines recommend that pulse oximetry be used to screen and monitor people with shortness of breath, who are sick or at high risk of suspected COVID-19 [21].

It is suggested that oxygen saturation level alone is neither an exclusive nor a determining factor in the decision to consider CT lung imaging. When deciding to offer a CT scan of the lungs and other diagnostic methods, the general clinical condition and all the symptoms of the patient should be considered more carefully. However, this finding suggests that oxygen saturation should be used as an adjunctive factor when considering a chest CT scan but should not be used as an exclusive means of diagnosis. Finally, Komatipalli et al [22] found that people with higher CT scores required more oxygen during their disease and showed that oxygen saturation values decreased with increasing CT intensity scores.

Limitations

There were 3 major limitations in the present study. First, the sample size is very small. Therefore, it will be difficult to draw conclusions based on the findings of this research. Secondly, the follow-up of patients until discharge or death was not done in this study, which reduces the power of concluding (external validity) the relationship between oxygenation indices and the prognosis of patients. Finally, this study was a single center and just focused on patients admitted to critical care settings.

Conclusion

It seems that there is no significant relationship between oxygenation indices and the extent of radiographic findings in hospitalized corona patients. Also, the severity of ARDS has no significant relationship with the extent of radiographic findings (CT scan). It is suggested that oxygen saturation should be used as an adjunctive factor when considering a CT lung scan, but should not be used as an exclusive means of diagnosis.

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