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Role of High Resolution Computed Tomography (HRCT) in predicting critical disease in corona virus disease

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ABSTRACT

Introduction: In the present study, we correlate the oxygen requirement of adult patients infected with COVID-19 virus with 25 CT severity score and estimate clinical outcome in the COVID-19 infected patients. *Materials and methods*: An observational case control study of 123 symptomatic COVID-19 positive patients presented to our hospital was collected for 3 months (August 2020 to Oct 2020). All patients underwent plain HRCT scan on TOSHIBA Activion 16 slice CT. The study was approved by Institutional Ethics Research review board and informed consents were obtained from all COVID-19 infected patients. *Results:* In our study, the Mean age of the patients ranged from 51-60 years (69.9% males, 30.1% females). CT severity score was correlated positively with the oxygen requirements as well as with other parameters i.e. age and sex. CT score of more than or equal to 18 was associated with an increased mortality risk and found to be predictive of death both in univariate (HR, 8.33; 95% CI, 3.19–21.73; $p < 0.0001$) and multivariate analysis (HR, 3.74; 95% CI, 1.10–12.77; $p = 0.0348$). *Conclusion:* The COVID-19 clinical severity is highly correlated with the 25-point CT severity score. Our findings imply that a chest CT grading system can help predict COVID-19 disease fate and has a strong relationship with oxygen demand and intubation.

Keywords: COVID-19, SARS-CoV-2, high-resolution computed tomography, CT severity score

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1. INTRODUCTION

SARS-CoV-2 has expanded into an global health emergency since its emergence, recently meeting the epidemiological criteria for the World Health Organization to declare it a pandemic (Yilmaz et al., 2021). According to the World Health Organization (WHO) data, the infection spread at an exponential rate in Italy, which, together with the United States, became one of the world's most serious epidemic hotspots (Thomas-Rüddel et al., 2021). CT has been demonstrated to have a high sensitivity in SARS-CoV-2 infected patients, which is why it is being used to improve patient care. These findings

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aroused major concerns regarding a possible clinico-radiological gap in asymptomatic persons, as well as clinical decision-making implications (Liu et al., 2020). The degree of disease can be determined based on imaging findings and clinical assessment, allowing for effective and prompt care in diseased patients (Leonardi et al., 2020; Meng et al., 2020).

To study lung involvement on chest CT scans, many studies employed visual and computerised quantitative analyses. This is the first study to look at the link between COVID-19 patients CT severity scores and their clinical symptoms. The CT severity score of the patients' were correlated with the severity of their clinical symptoms, i.e. oxygen requirement of COVID-19 positive adult patients, using a 25-point scale.

The most sensitive radiographic approach for diagnosing COVID-19 is high-resolution computed tomography (HRCT). HRCT reveals a variety of lung abnormalities, ranging from ground-glass opacities to consolidations and a variety of other radiological patterns. HRCT's specificity, on the other hand, is limited when it comes to discriminating various viruses (Li and Xia, 2020). The use of HRCT to measure lung injury has proven to be useful in determining prognostic implications in recent years (Yuan et al., 2020).

2. MATERIALS AND METHODS

Data collection

In this study, we included 123 individuals who were suspected of having COVID-19 infection and had undergone a chest HRCT scan. The study was approved by Institutional Ethics Research review board (NKPSIMS & RH and LMH / IEC-RADIOLOGY/ 03/2020) and informed consents were obtained from all COVID-19 infected patients. From August to October 2020, clinical and laboratory data were collected from a medical record system and analysed.

HRCT inspection

On the day of the patient's presentation, non-contrast HRCT scans with a TOSHIBA Activion 16 slice CT scanner were performed. In a supine position with a single breath hold, an HRCT scan was performed. The following were the scanning parameters: craniocaudally, tube voltage 120KV, tube current 100-600 mA - mA dose modulation, slice collimation 64 x 0.625 mm, width 0.625 x 0.625 mm, pitch (1), rotation time 0.5 s, scan length 60.00 – 1300.00 s

HRCT image analysis

The HRCT scans were examined first for classic COVID19 pneumonia abnormalities. The severity of the condition was then determined using the scoring system below (Chung et al., 2020). According to the 25 score CT severity score as described above in the table, involvement of less than 5 % of the lung lobe has a score of 1, involvement of 5-25 % of the lung lobe has a score of 2, involvement of 26-49% of the lung lobe has a score of 3, involvement of 50-75 % of the lung lobe has a score of 4 and involvement of more than 75 % of the lung lobe has a score of 5 (Table 1).

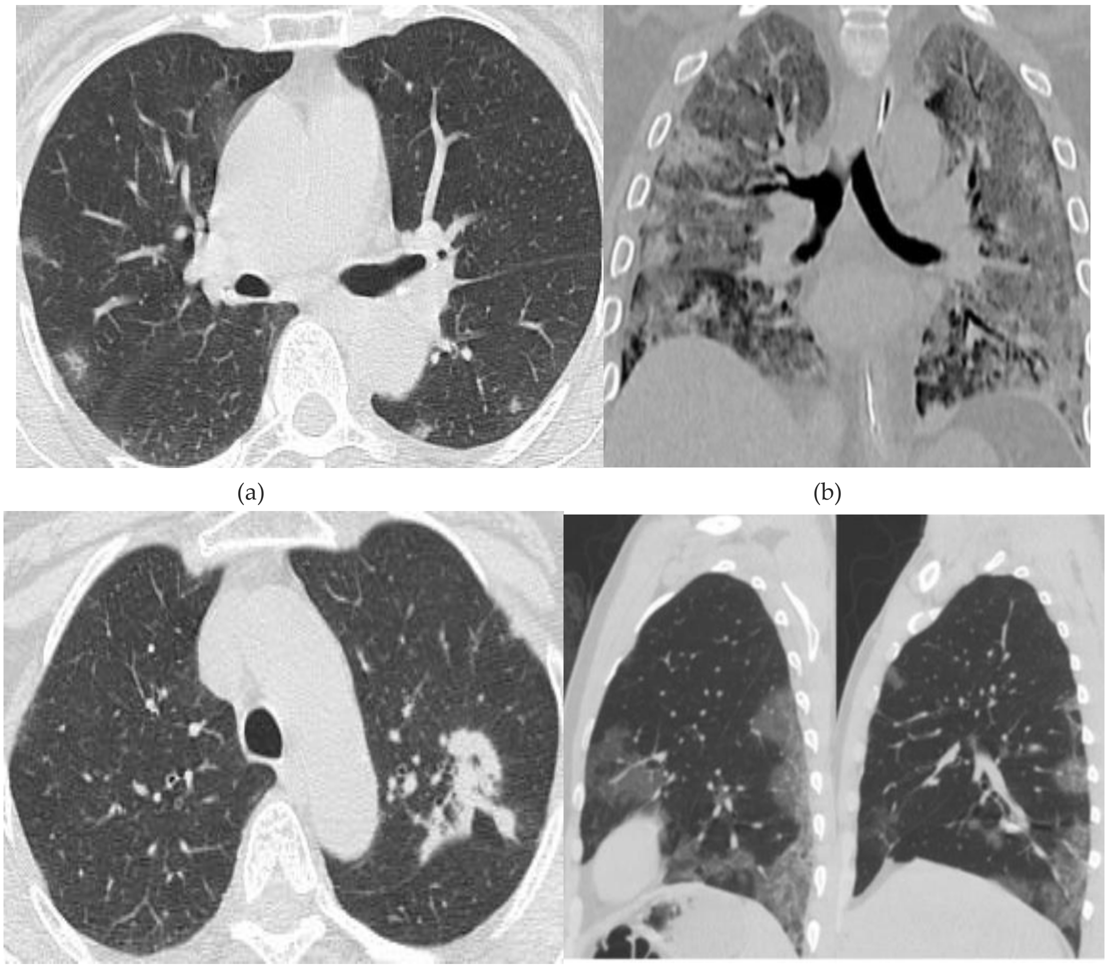
Table1 Percentage of involvement of lobe.

Percentage of involvement of lobe	Score
Less than 5%	1
5%-25%	2
26%-49%	3
50%-75%	4
＞75%	5

A score of less than or equal to 7 indicates a mild category of COVID-19 infection, score of 8-17 indicates a moderate category and a score of more than or equal to 18 indicates sever category of the infection (Table 2). Inclusion criterion include all patients clinically suspected or diagnosed with COVID – 19 on RTPCR and referred to the Department of Radio-diagnosis and who were willing to undergo HRCT Chest during the study period. Exclusion criteria included pregnant females and those not willing to undergo the scan. CT images in axial, coronal and sagittal sections in COVID 19 positive patients showing severity of disease in different patients (Figure 1).

Table 2 Sum of the scores of each lobe indicating the overall severity

Total score	Severity (category)
Less than or equal to 7	Mild
8 to 17	Moderate
More than or equal to 18	Severe



(a) (b) (c) (d)

Figure 1 (a) Axial section of HRCT chest scan shows mild ground glass opacities involving bilateral lung parenchyma. (b) Coronal section shows the severity of illness is indicated by a diffuse crazy–paving pattern with patches of consolidation in the periphery. (c) Axial section of HRCT chest scan shows Focal areas of Consolidation in the left lower lobe. (d) Sagittal thin-section of HRCT chest scan shows bilateral peripheral ground glass opacities of moderate severity.

Statistical analysis

Microsoft Excel and Epi Info software were used to conduct the analysis. For quantitative data, the description was made in the form of Mean +/- SD (or median), whereas for qualitative data, the description was made in the form of Frequencies (percent) when comparing categorical variables (i.e. examining the relationship between qualitative and quantitative variables), the ANOVA, T, and two proportion Z tests were utilised.

3. RESULTS

There were 123 patients in our study suspected of having COVID-19 infection. The RT-PCR tests and chest HRCT scan had been completed by all suspected patients. Eventually, following information was collected from the study population: Age, Gender, Maximum Oxygen requirement, need for Intubation and ICU admission. The research population was 51-60 years old on average [range 21-80 years, 86 males (69.9%), 37 females (30.1%)]. The age was then separated into six categories: (21-30, 31-40, 41-50, 51-60, 61-70 and 71-80 years). 59 (48%) of the 123 patients did not require oxygen support. The remaining 64 patients received O2 supplementation in the following manner: 21 patients (17.1%) needed a nasal cannula, 9 patients (7.3%) needed a facemask, 5 patients (4.1%) needed a non-breather mask, 10 patients (8.1%) needed BiPAP or a High Flow Nasal Cannula (HFNC), and 18 (14.6%) needed intubation.

Correlation between the CT severity and clinical parameters

Gender and Age

Our findings revealed a significant (p0.05) relationship between CT severity score and male gender. Maximum i.e. 30 (24.4%) belonged to age group of 51-60, followed by 24 (19.5 %) in age group 21-30 years, 23(18.7%) belonged to 61-70 years, 19(15.4%) study subjects belonged to 41-50 years age group, 18(14.6%) belonged to 31-40 years and minimum 9 (7.3%) in 71-80 years (Table 3).

Table 3 Age wise distribution of study subjects

AGE		
Age	Frequency	Percent
21-30	24	19.5
31-40	18	14.6
41-50	19	15.4
51-60	30	24.4
61-70	23	18.7
71-80	9	7.3
Total	123	100.0

Maximum 30 (24.4%) study subjects belonged to age group of 51-60, followed by 24 (19.5 %) in age group 21-30 years, 23(18.7%) belonged to 61-70 years, 19(15.4%) study subjects in age group 41-50 years,18(14.6%) belonged to 31-40 years and minimum 9 (7.3%) in 71-80 years (Figure 2). 86 (69.9%) study subjects were males and 37 (30.1%) were females (Table 4).

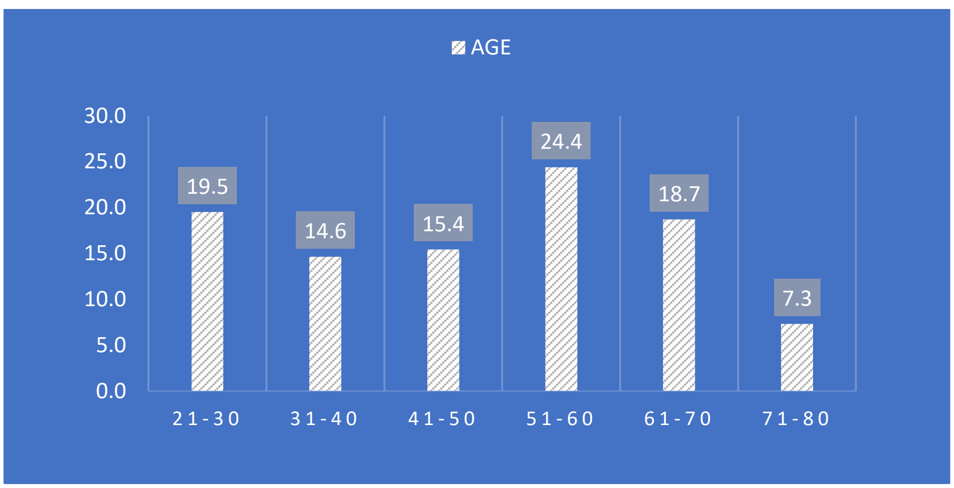


Figure 2 Age wise distribution of study subjects.

Table 4 Gender wise distribution of study subjects

SEX		
Sex	Frequency	Percent
Male	86	69.9
Female	37	30.1
Total	123	100

86 (69.9%) study subjects were males and 37 (30.1%) were females (Figure 3). In our study, 21(17.1%) patients belonged to negative group, 30(24.4%) patients belonged to mild group, 44(35.8%) belonged to moderate group and 28(22.8%) belonged to severe group (Table 5).

Table 5 Study participants were divided into groups based on the severity of their illness.

GRADE		
Grade	Frequency	Percent
Negative	21	17.1
Mild	30	24.4
Moderate	44	35.8
Severe	28	22.8
Total	123	100.0

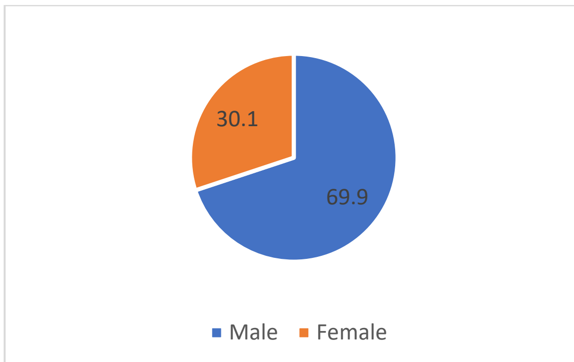


Figure 3 Study subjects distributed according on gender.

In our study, 21(17.1%) patients belonged to negative group, 30(24.4%) patients belonged to mild group, 44(35.8%) belonged to moderate group and 28(22.8%) belonged to severe group (Figure 4). In the mild category, each 2(6.7%) required nasal cannula and face mask whereas each of the 1 (3.3%) patient required non breather and HFNC/ BIPAP and 3(10%) required intubation only. 20 (70%) patients did not required oxygen in category. 22 (50 %) patients did not required oxygen, 13(29.5%) patients with moderate findings required nasal cannula, 1 (2.3%) required non breather and 2(4.5%) required HFNC/ BIPAP. Each 3(6.8%) patient required face mask and intubation. Each 2 (7.1%) patients from severity group required nasal cannula and face mask. 3(10%) required non breather, 11(39.3%) required intubation and 6(21.4%) required HFNC. 3(10.7%) did not required oxygen (Table 6).

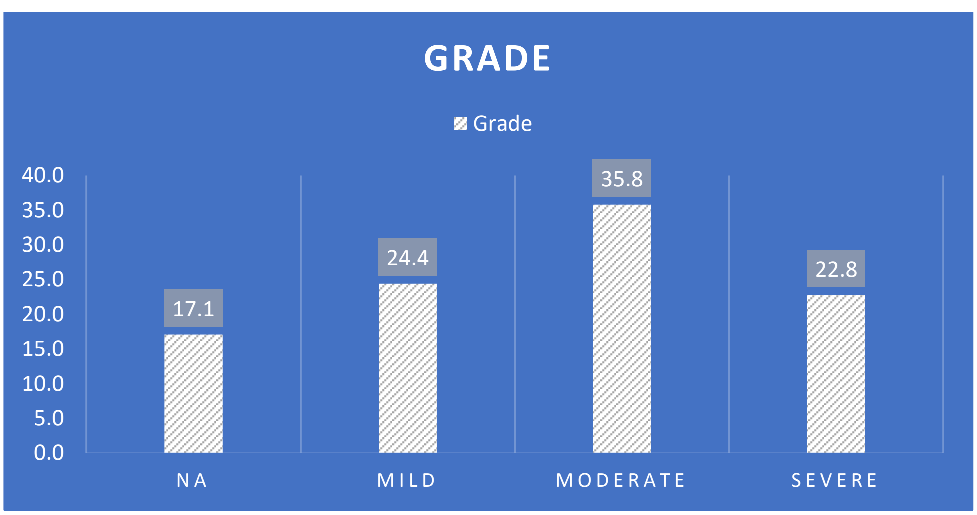


Figure 4 Distribution of study subjects according to severity of disease

Table 6 Oxygen requirement (Maximum) in each severity category

GRADE		None	Nasal cannula	Facemask	Nonrebreather	Intubation	HFNC/BIPAP
Negative	Count	13	4	2	0	1	1
	% within GRADE	61.9%	19.00%	9.50%	0.00%	4.80%	4.80%
	% of Total	10.6%	3.30%	1.60%	0.00%	0.80%	0.80%
ild	Count	21	2	2	1	3	1
	% within GRADE	70.0%	6.70%	6.70%	3.30%	10.00%	3.30%
	% of Total	17.1%	1.60%	1.60%	0.80%	2.40%	0.80%
Moderate	Count	22	13	3	1	3	2
	% within GRADE	50.0%	29.50%	6.80%	2.30%	6.80%	4.50%
	% of Total	17.9%	10.60%	2.40%	0.80%	2.40%	1.60%
Severe	Count	3	2	2	3	11	6
	% within GRADE	10.7%	7.10%	7.10%	10.70%	39.30%	21.40%
	% of Total	2.4%	1.60%	1.60%	2.40%	8.90%	4.90%
Total	Count	59	21	9	5	18	10
	% within GRADE	48.0%	17.10%	7.30%	4.10%	14.60%	8.10%
	% of Total	48.0%	17.10%	7.30%	4.10%	14.60%	8.10%

37(43%) males did not have the requirement of oxygen. 20 (23.3%) males needed Nasal Cannula, 6(7.0%) needed Face mask, 5(5.8%) needed Non breather mask, 11 (12.8%) needed Intubation and 7 (8.1%) needed HFNC/BIPAP. Whereas 1(2.7%) female needed Nasal Cannula, 3(8.1%) needed Face mask, 7(18.9%) needed Intubation and 3 (8.1%) needed HFNC/BIPAP. 22(59%) of females did not have the requirement of oxygen (Table 7).

Table 7 Gender wise oxygen requirement (maximum) in each severity category

SEX		NONE	Nasal cannula	Facemask	Non breather	Intubation	HFNC/ BIPAP
Male	Count	37	20	6	5	11	7
	% within SEX	43.0%	23.30%	7.00%	5.80%	12.80%	8.10%
	% of Total	30.1%	16.30%	4.90%	4.10%	8.90%	5.70%
Female	Count	22	1	3	0	7	3
	% within SEX	59.5%	2.70%	8.10%	0.00%	18.90%	8.10%
	% of Total	17.9%	0.80%	2.40%	0.00%	5.70%	2.40%
Total	Count	59	21	9	5	18	10
	% within SEX	48.0%	17.10%	7.30%	4.10%	14.60%	8.10%

	% of Total	48.0%	17.10%	7.30%	4.10%	14.60%	8.10%

In 21-30 years age group, 4(17.7%) patients needed nasal cannula, 1(4.2%) required facemask and 2(8.3%) needed HFNC/BIPAB. 17(70.8%) patients did not required oxygen in 21 to 30 years age group. In 31 to 40 years age group, each of the 3(16.7%) patients needed nasal cannula and face mask whereas each 1(5.6%) patients needed non breather, HFNC and intubation. 9(50%) patients did not required oxygen in 31-40years age group. In 41 to 50 years, 3 (15.8%) patients needed nasal cannula, only 1(5.3%) required face mask and 6(31.6%) needed intubation. 9(47.4%) patients did not require oxygen. In 51 to 60 years age group, 7(23.3%) patients needed nasal cannula, 2(6.7%) required facemask, only one patient needed non breather, 3 (10%) required HFNC and 7(23.3%) needed intubation.10 (33.3%) patients dint have requirement of oxygen in this group.

In 61 to 70 years, each of the 2(8.7%) study subjects needed nasal cannula, face mask and non-breather. Each 4(17.4%) patients required HFNC and intubation. 8(34.8%) patients did not require oxygen. In 71 to 80 years age group, 2(22.2%) patients required nasal cannula and only one patient required non breather. 6(66.7%) patients did not require oxygen in this group (Table 8).

Table 8 Age wise oxygen requirement in each severity category

AGE		None	Nasal canula	Facemask	Nonrebreather	HFNC/BIPAP	Intubation
21-30	Count	17	4	1	0	2	0
	% within AGE	70.8%	16.70%	4.20%	0.00%	8.30%	0.00%
	% of Total	13.8%	3.30%	0.80%	0.00%	1.60%	0.00%
31-40	Count	9	3	3	1	1	1
	% within AGE	50.0%	16.70%	16.70%	5.60%	5.60%	5.60%
	% of Total	7.3%	2.40%	2.40%	0.80%	0.80%	0.80%
41-50	Count	9	3	1	0	0	6
	% within AGE	47.4%	15.80%	5.30%	0.00%	0.00%	31.60%
	% of Total	7.3%	2.40%	0.80%	0.00%	0.00%	4.90%
51-60	Count	10	7	2	1	3	7
	% within AGE	33.3%	23.30%	6.70%	3.30%	10.00%	23.30%
	% of Total	8.1%	5.70%	1.60%	0.80%	2.40%	5.70%
61-70	Count	8	2	2	2	4	4
	% within AGE	34.8%	8.70%	8.70%	8.70%	17.40%	17.40%
	% of Total	6.5%	1.60%	1.60%	1.60%	3.30%	3.30%
71-80	Count	6	2	0	1	0	0
	% within AGE	66.7%	22.20%	0.00%	11.10%	0.00%	0.00%
	% of Total	4.9%	1.60%	0.00%	0.80%	0.00%	0.00%
Total	Count	59	21	9	5	10	18
	% within AGE	48.0%	17.10%	7.30%	4.10%	8.10%	14.60%
	% of Total	48.0%	17.10%	7.30%	4.10%	8.10%	14.60%

Each of the 2 patients required nasal cannula and facemask, each 1 patient required nasal cannula and HFNC in mild category.21 patients did not require oxygen in mild category (Table 9). Each of the 2 patients required nasal cannula and facemask, each 1 patient required nasal cannula and HFNC in mild category.21 patients did not require oxygen in mild category (Figure 5).

Table 9 Distribution of patients according to their requirement of oxygen in mild category

Mild Category	Frequency
None	21
Nasal cannula	2
Facemask	2
Non breather	1
Intubation	3
HFNC/BIPAP	1

13 patients required nasal cannula, each 3 patients required intubation and face mask, 2 patient required HFNC and 1 required non breather in moderate category. 22 patients did not require oxygen in moderate category (Table 10).

Table 10 Distribution of patients according to their requirement of oxygen in moderate category

Moderate category	Frequency
None	22
Nasal cannula	13
Facemask	3
Non breather	1
Intubation	3
HFNC/BIPAP	2

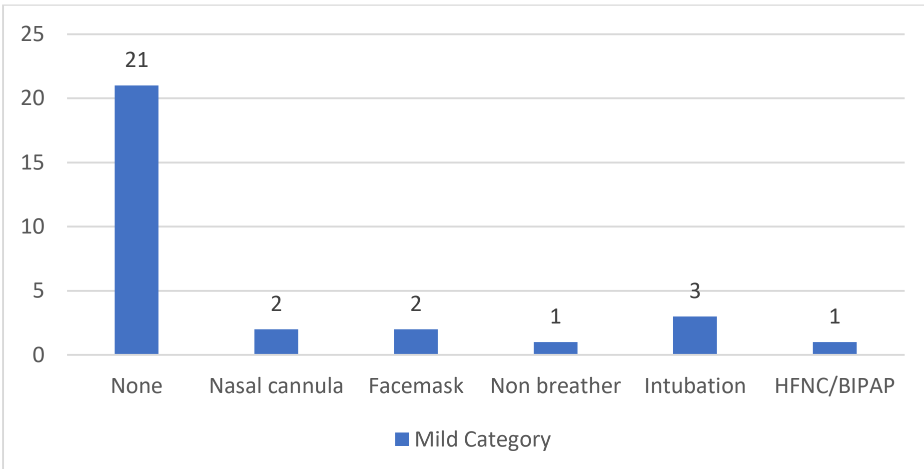


Figure 5 Distribution of patients according to their requirement of oxygen in mild category

13 patients required nasal cannula, each 3 patients required intubation and face mask, 2 patient required HFNC and 1 required non breather in moderate category.22 patients did not require oxygen in moderate category (Figure 6). Each of the 2 patients required nasal cannula and face mask, 3 required non breathers, 11 required intubation and 6 required HFNC. 3 patients did not require oxygen in severe category (Table 11).

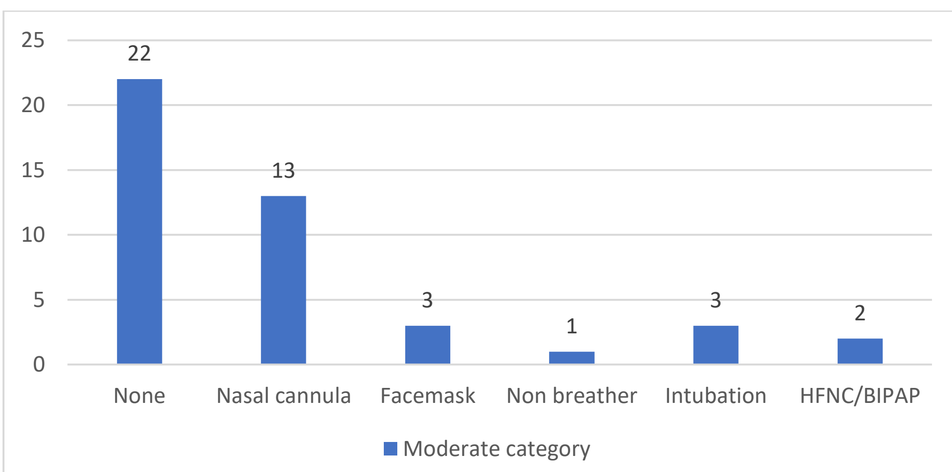


Figure 6 Distribution of patients according to their requirement of oxygen in moderate category

Table 11 Distribution of patients according to their requirement of oxygen in severe category

Severe category	Frequency
None	3
Nasal cannula	2
Facemask	2
Non breather	3
Intubation	11
HFNC/BIPAP	6

Each of the 2 patients required nasal cannula and face mask, 3 required non breathers, 11 required intubation and 6 required HFNC.3 patients did not require oxygen in severe category (Figure 7). Comparison of survival rate between COVID-19 positive patients with CT score less than 18 and more than or equal to 18. The y-axis represents the percentage of those who survive, while the x-axis represents the length of the observation period (days). Out of the 123 patients, 20 patients (15.4 percent) died during follow-up period of 14.3 ± 4.3 days (range 1–24 days), 16 of who had co-morbidities. Hypertension was diagnosed in 8/20 of the deaths (40%) and no substantial co-morbidities in 4/20 of the cases (20 percent). Patients above the age of 75 were found to have a substantially greater mortality rate (n = 12/36; 33.3 percent) than patients under the age of 75 (n = 8/94; 8.5 percent) (p = 0.0083) (Figure 8). The mortality rate among critically sick patients (9/9; 100 percent) was also found to be considerably greater than that of mild (3/79; 3.8 percent) and moderate (8/42; 19 percent) patients (p 0.0001 and p = 0.0091, respectively).

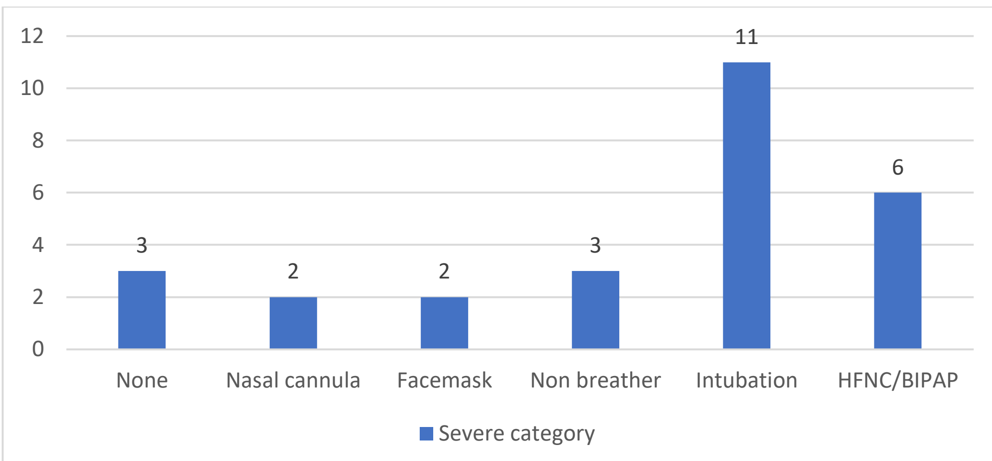


Figure 7 Distribution of patients according to their requirement of oxygen in severe category

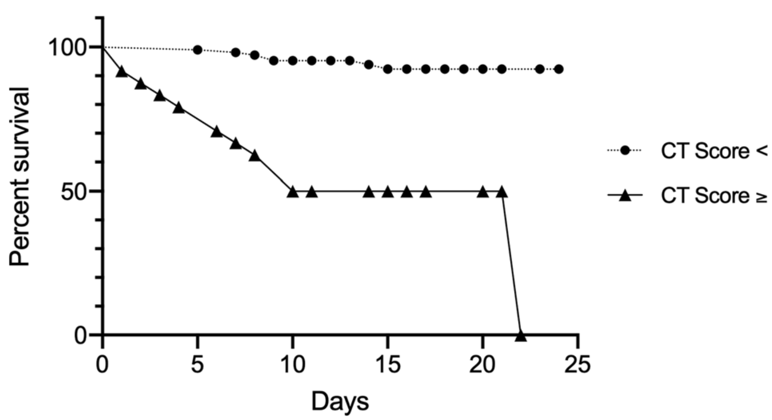


Figure 8 Survival curve

Oxygen requirement and outcome

13 out of 21 patients with negative scan results did not require oxygen support. 4/21 required a nasal cannula; 2/21 required a facemask; 0/21 required non-breather masks; 1/21 required BIPAP/HFNC; 1 required intubation. In the mild group, 21/30 patients

did not need oxygen, 2/30 needed a nasal cannula, 2/30 needed a facemask, 1/30 needed a non-breather mask, 1/30 needed BIPAP/HFNC, and 3/30 needed intubation. In the intermediate group, 22/44 patients did not need oxygen; 13/44 patients needed a nasal cannula; 3/44 patients needed a facemask; 1/44 patients needed a non-breather mask; 2/44 patients needed BiPAP/HFNC; and 3/44 patients needed intubation. Only three patients with severe HRCT scan findings did not require oxygen; two patients required a nasal cannula, two patients required a facemask, three patients required a non-breather mask, six patients required BiPAP/HFNC, and eleven patients required intubation. There was a statistically significant association between oxygen need and CT severity scores.

4. DISCUSSION

The appearance of Ground glass opacities with or without consolidatory changes, with a predominantly peripheral, basal and lower lobes distribution, as validated in our study, is the key feature of COVID-19 pneumonia. The high prevalence of Ground glass opacities is because of acute phase of diffuse alveolar damage. This is due to alveolar oedema, bacterial superinfection, and inflammatory changes in the interstitial space (Francone et al., 2020). Because of the diverse presentations of the disease's symptoms, which range from asymptomatic/subclinical forms to severe disease with ARDS or Multiorgan failure, the disease's clinical course is unpredictable (Huang et al., 2020).

The HRCT chest scan is a useful technique for determining the severity of an illness. The quantitative severity is determined using a visual software method that uses deep learning algorithms to quantify the percentage influencing lung volumes (as in our study) (Lessmann et al., 2020). Due to the lack of software in our investigation, we relied on visual assessment of each segment of the five lung lobes. COVID-19 infection severities were then classified using the overall CT severity score. Our sample had a male inclination and was of a significantly older age (mean 51-60 years). This is explained by the UAE's unique population characteristics, which include a high proportion of young male foreign workers (Tezcan-Unal, 2019). Many literatures stated that the risk factors such as HTN, DM, smoking, pulmonary and coronary artery diseases had a bad prognosis (Bhandari et al., 2020; Guan et al., 2020).

The presence of risk variables had no significant link with CT severity scores in our study, although there was a significant correlation (p 0.0001) between the risk factors and ICU admission. As the CT severity score raises, so does the oxygen need because of the virus's direct damage to the lung parenchyma, which causes severe inflammatory alterations in the alveolar wall, oxygen exchange is interrupted, resulting in ARDS, fibrosis and death. There are a few limitations in this research. The first is the requirement for a larger cohort in order to improve the accuracy of the results. Second, the severity of disease is subjectively assessed using CT images. This was minimised, however, by incorporating two radiologists in the decision-making process.

5. CONCLUSION

Patients with COVID-19 disease can benefit from CT scoring to stratify their risk and help in the prediction of outcome. The level of CT damage is strongly linked to a variety of illness factors, including clinical and laboratory results. Finally, our findings support the use of chest CT in patients with COVID-19 disease, further suggesting that it may be used as a quick and effective means to find patients with a low risk of illness.

Abbreviations

COVID-19 (Corona Virus disease), CRP (C-reactive protein), CT (Computed Tomography), GGO (Ground Glass Opacity), HRCT (High Resolution Computed Tomography), PACS (Picture Archiving and Communication Systems), RT-PCR (Reverse Transcription Polymerase Chain Reaction) and WHO (World Health Organization).

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Authors Contribution

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; gave final approval of the version to be published; and agree to be accountable for all aspects of the work.

Ethical Approval

The study was approved by Medical Ethics Committee of NKP Salve Institute of Medical Sciences and Research Centre with the letter number: (NKPSIMS &RC &LMH/IEC/03/2020).

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Conflicts of interest

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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