Role of chest radiograph in predicting the need for ventilator support in COVID-19 patients

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Background. COVID-19 disease, a pandemic for more than two years, has major morbidity and mortality related to pulmonary involvement. Chest radiography is the main imaging tool for critically ill patients. As the availability of arterial blood gas analysis is limited in the Level I and II healthcare centres, which are major partners in providing healthcare in resource-limited times, we planned the present study.
Objective. To assess the role of chest radiography in predicting the need for oxygen/ventilator support in critically ill COVID-19 patients.
Methods. This hospital-based, retrospective study included 135 patients who needed oxygen/ventilator support and had optimal-quality chest radiographs at admission. All the chest X-rays were evaluated and a severity score was calculated on a predesigned pro forma. Statistical evaluation of the data obtained was done using appropriate tools and methods.
Results. Males outnumbered females, with a mean age of 54.35 ± 14.49 years. More than 72% of patients included in our study needed ventilator support while the rest needed oxygen support. There was a significant statistical correlation between the chest radiograph severity score and SPO_2/PaO_2 levels in our study. Using a cut-off value >8 for the chest radiograph severity score in predicting the need for ventilator support in a Covid-19 patient, the sensitivity, specificity and accuracy was 85.7%, 92.5% and 89.5%, respectively.
Conclusions. Chest radiography remains the mainstay of imaging in critically ill COVID-19 patients when they are on multiple life-support systems. Though arterial blood gas analysis is the gold standard tool for assessing the need for oxygen/ventilator support in these patients, the severity score obtained from the initial chest radiograph at the time of admission may also be used as a screening tool. Chest radiography may predict the need for oxygen/ventilator support, allowing time for patients to be moved to an appropriate-level healthcare centre, thus limiting morbidity and mortality.
Keywords. Chest radiography, ventilator, COVID-19.

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The COVID-19 disease caused by severe acute respiratory syndrome coronavirus II emerged in Wuhan, China, in December 2019 before becoming a global pandemic in March 2020.[1-3] Though both chest X-ray (CXR) and chest computed tomography (CCT) play a great role in the diagnosis of COVID-19 disease at all levels of severity, CXR remains the primary imaging modality.[1,3] COVID-19 disease varies clinically from symptom-free to severely ill patients, with pneumonia and death in a significant number.[4]

The gold standard tool for diagnosis of COVID-19 is reverse transcription-polymerase chain reaction (RT-PCR) of swab samples from the nasopharynx and oropharynx.[4] Non-ambulatory, critically ill patients on life-support devices cannot usually undergo CCT owing to many constraints. But CXR in such cases is not only cost effective but also saves time, provides quick results and can be repeated.[1] Hence, portable chest radiography has been considered as the investigation of choice in critically ill patients by the American College of Radiology and the Society of Thoracic Radiology.[3,5] Many institutes around the world are using portable chest radiography at triage level to assess severity of disease.[6]

Variable radiographic findings and degrees of lung parenchymal involvement have been observed on early chest radiographs in Covid-19 disease. Even though the overall sensitivity of CXR in diagnosing COVID-19 disease is only 69%, it nevertheless offers significant advantages in analysing clinical outcome at the hospital doorstep.[3]

In severely ill Covid-19 patients, the only investigating tool being utilised to establish the need for ventilatory support is arterial blood gas (ABG) analysis, which is not only an invasive and time-intensive procedure but also is of limited availability in peripheral areas, with Level I and II healthcare centres requiring highly skilled staff. Hence, in the present study, we assessed the utility of CXR in predicting the need for ventilatory support in severe COVID-19 disease that will help the clinician to start ventilatory support early and, in addition to other advantages of CXR, also avoid significant risk of contact with patients' secretions and blood products.

Objectives

Our objectives were (*i*) to evaluate the spectrum of chest radiographic findings in predicting the need for ventilator support in COVID-19 patients; (*ii*) to evaluate the role of chest radiographs in conjunction with demographic details in determining the need for early ventilator support in COVID-19 patients; and (*iii*) to correlate chest radiographic findings with SPO_2/PaO_2 in COVID-19 patients needing early oxygen inhalation.

Materials and methods

This hospital-based, retrospective, cross-sectional study was conducted on 135 severely ill patients admitted to the intensive care unit of our institution over a period of 9 months, following approval from the institutional ethics committee using strict inclusion and exclusion criteria.

Inclusion criteria: Patients with COVID-19 infection showing positivity on the RT-PCR test who needed oxygen/ventilatory support and were positive with available chest radiograph.

Exclusion criteria: Patients with poor-quality chest radiographs, or who were pregnant.

The findings of the first CXR taken at the time of admission were used in our study. All CXRs were reported on by a radiologist with at least 3 years of experience in CXR interpretation. The CXR was divided into 3 zones (upper, middle and lower) and scoring was given from 0 - 3 depending on the percentage of involvement by consolidation or ground-glass opacity in that respective zone, i.e. a score 0 for no involvement, score 1 for one-third (<33%) involvement, 2 for one-third to two-thirds (34 - 66%) involvement, and 3 for two-thirds (66%) involvement. An additional score of 1 point was given for the presence of pleural effusion. Hence a maximum score of 10 could be given to each lung and a score of 20 for both (Fig. 1).

Appropriate statistical tests were applied after collection of data in a predesigned pro forma. Sensitivity, specificity, positive predictive value, negative predictive value and accuracy of values were calculated.

Observations and analysis (Figs 2 - 6)

Table 1 shows baseline characteristics among the study subjects. The majority of the subjects were male (60%). Mean age of the patients was 54 years. The CXR severity score was >8 in 104 cases out of 135 subjects, with 98 needing a ventilator and 37 oxygen support. Mean SPO_2 was 86% and mean PaO_2 was 79.88.

Table 2 and Fig. 7 describe the CXR severity score findings among the cases and their correlation with SPO_2 and PaO_2. Among the cases having an SPO_2 level of 91.35 ± 1.082 and PaO_2 level of 88.33 ± 1.826, the reported CXR severity score was <8 whereas cases having an SPO_2 level of 85.69 ± 4.950 and PaO_2 level of 78.88 ± 6.515, reported a CXR severity score >8. The difference was statistically significant ($p<0.01$).

Table 3 describes oxygen support and ventilator support for findings among the cases and the correlation with mean CXR severity score. Among the patients using oxygen support, the mean CXR severity score was 5.62 whereas patients on ventilator support had a mean CXR severity score of 12.04. The comparisons of oxygen support and ventilator support with mean chest radiograph severity scores were statistically significant ($p<0.01$).

Table 4 describes oxygen support and ventilator support findings among the cases and their correlation with CXR severity score using a cut-off value of 8. Among the subjects having <8 CXR severity score, 31 subjects required oxygen support and no subjects required ventilator support, whereas among the subjects having >8 CXR severity score, 6 subjects required oxygen support, and 98 subjects required ventilator support. This comparison of CXR severity score with oxygen and ventilator support using a cut-off value of 8 was statistically significant ($p<0.01$).

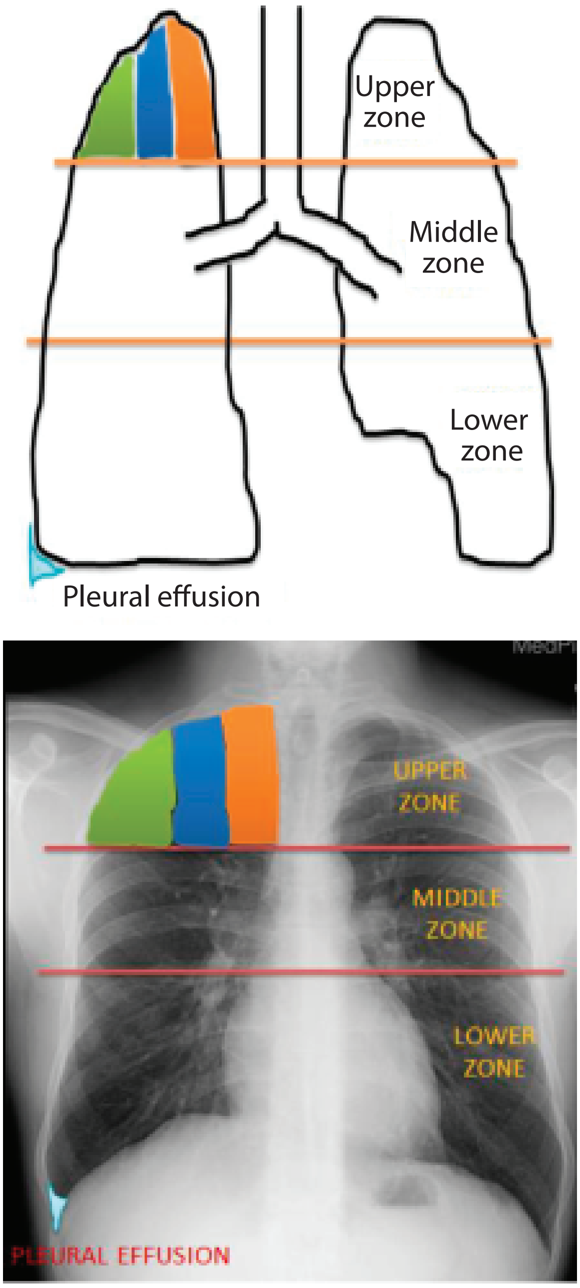

Fig. 1. Schematic diagram and corresponding chest radiograph showing arbitrary division of three lung zones and percentage of involvement by consolidation or ground-glass opacity of that respective zone, i.e. score 1 for one-third (33%) involvement (shown by green colour), 2 for one-third to two-thirds (34 - 66%) involvement (blue colour) and 3 for two-thirds (66%) involvement (shown by orange colour). A score of point one is given for presence of pleural effusion for each side (shown by sky-blue colour).

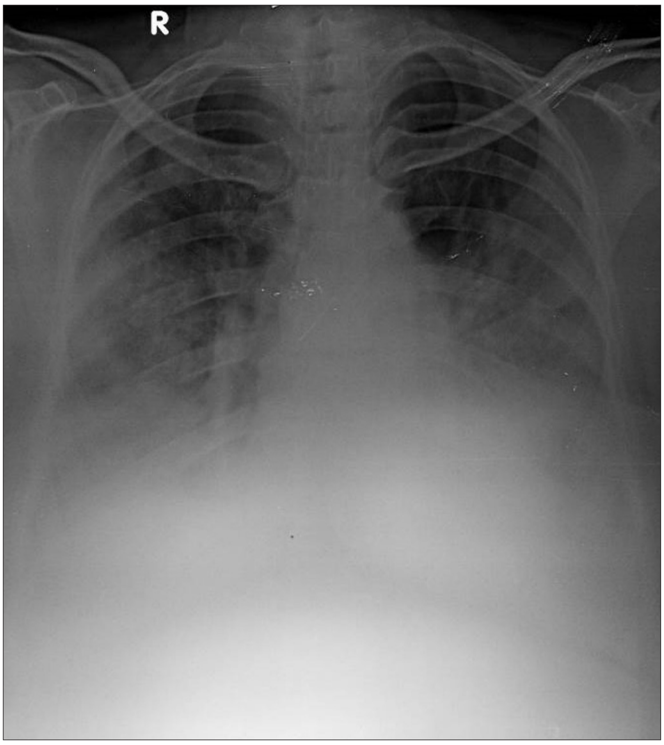

Fig. 2. Chest radiograph showing opacity involving two-thirds (67%) area of bilateral middle and lower lung zones with obscuration of bilateral costophrenic angles, representing chest radiograph severity score of 14. This patient required ventilatory support.

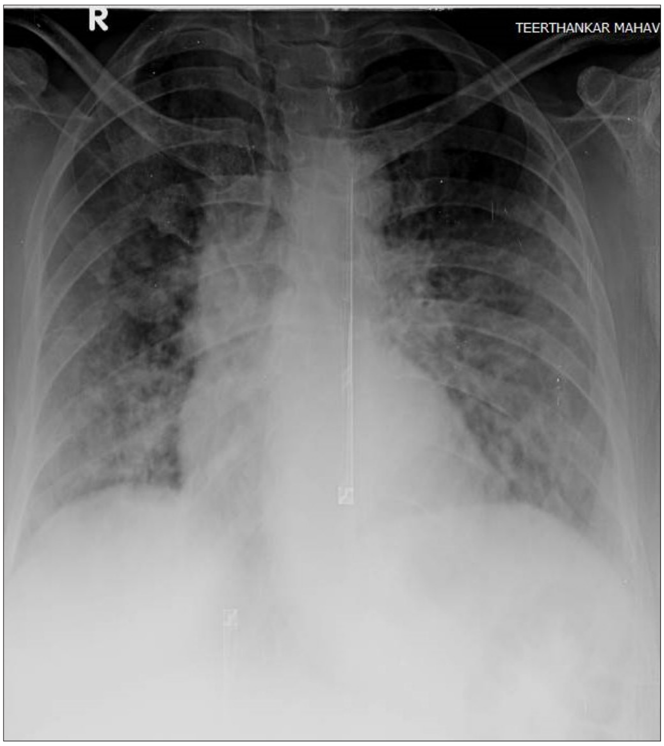

Fig. 3. Chest radiograph showing opacity involving more than 33% but less than 66% area of the bilateral middle lung zones and more than two-thirds (67%) area of bilateral lower lung zones without obscuration of bilateral costophrenic angles, representing chest radiograph severity score of 10. This patient required ventilatory support.

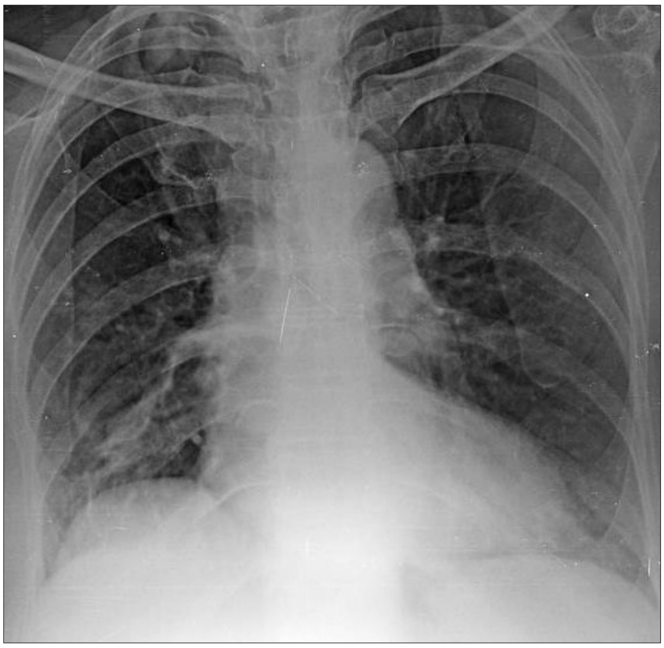

Fig. 4. Chest radiograph showing opacity involving less than 33% area of the right upper lung zone and more than 33% but less than 66% area of right lower lung zone with right-sided pleural effusion, representing chest radiograph severity score of 4. This patient did not require ventilatory support.

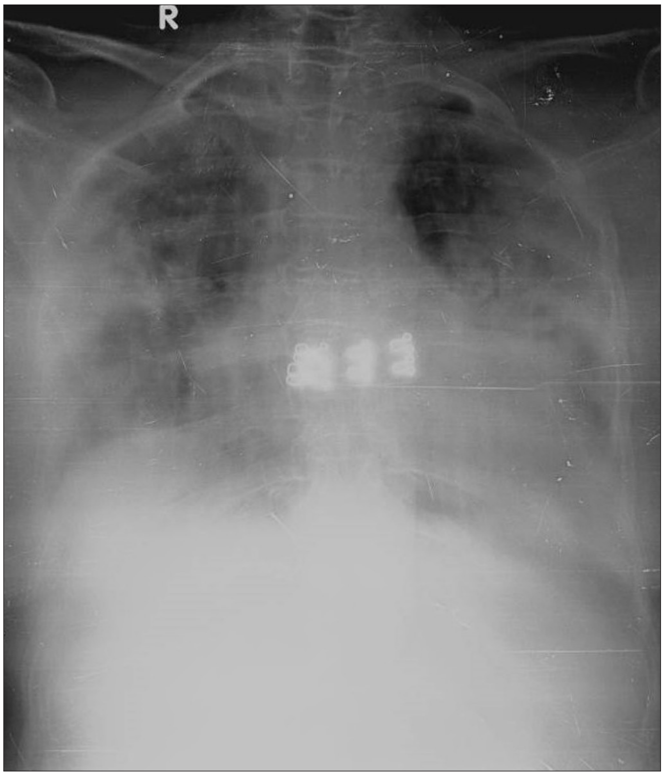

Fig. 5. Chest radiograph showing opacity involving more than 33% but less than 66% area of the right upper lung zone, less than 33% area of the left upper lung zone and more than two-thirds (67%) area of the bilateral middle and lower lung zones with obscuration of bilateral costophrenic angles, representing chest radiograph severity score of 17. This patient required ventilatory support.

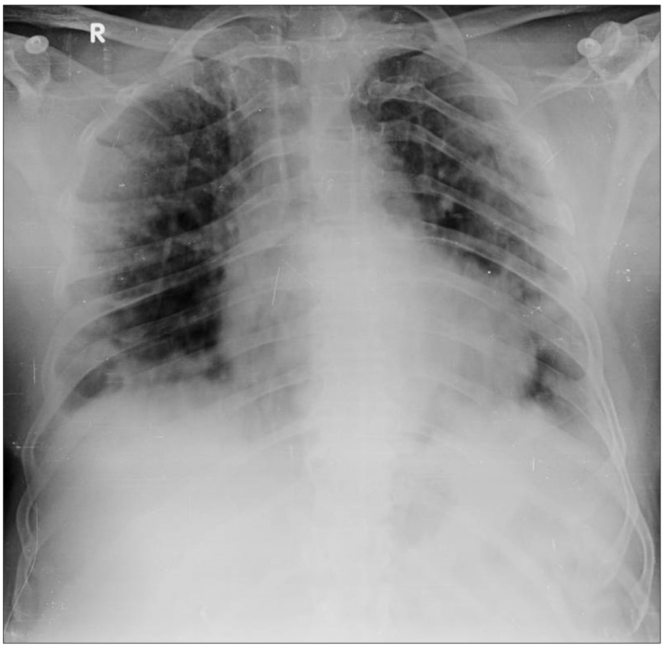

Fig. 6. Chest radiograph showing opacity involving less than 33% area of the bilateral upper and middle lung zones, more than 33% but less than 66% area of the right lower lung zone and more than two-thirds (67%) area of left lower lung zone with obscuration of bilateral costophrenic angles, representing chest radiograph severity score of 11. This patient required ventilatory support.

Table 1. Baseline characteristics among the study subjects

Variables	*N*=135	%
Male	81	60
Female	54	40
Age in years, mean (SD)	54.35 (14.49)	
Oxygen support	37	27.4
Ventilator support	98	72.6
Chest score, mean (SD)	10.28 (4.01)	
<8	31	23
>8	104	77
SPO_2, mean (SD)	86.99 (4.98)	
PaO_2, mean (SD)	79.88 (6.84)	

SD = standard deviation

Fig. 8 shows a ROC curve analysis of CXR severity score with an area under the curve of 0.973 with a cut-off value >8 having a sensitivity of 85.7%, specificity of 92.5% and accuracy of 89.5%.

Discussion

The COVID-19 pandemic placed unforeseen burdens on healthcare and highlighted the role of CXR in management, admission and predicting outcomes, especially with limited resources.[3,4] In our study, we evaluated the role of initial CXR in COVID-19 disease in emergency settings. The CXR severity score on the initial chest radiograph can be used as a predictor for ventilatory support.[3] Other criteria such as old age, obesity, diabetes and hypertension-like comorbidities are important factors in predicting ventilatory support.[3]

Table 2. Comparison of SPO_2 and PaO_2 with total CXR severity score

Total score	Statistical characteristic	SPO_2	PaO_2
<8	Mean	91.35	88.33
	SD	1.082	1.826
>8	Mean	85.69	78.88
	SD	4.950	6.515
t-test	-	39.79	28.45
p-value	-	<0.01*	<0.01*

CXR = chest X-ray.
*Statistically significant.

Table 3. Comparison of support according to mean total chest radiograph severity score

Support	Mean (SD)	*t*-test	*p*-value
Oxygen support	5.62 (1.605)	140.12	<0.01*
Ventilator support	12.04 (3.142)		

*Statistically significant.

In the present study, most of the subjects were male (60%) and their mean age was 54 ± 14 years. Most of the patients with high CXR severity scores were >50 years of age. In a study by Hanley *et al*.,[7] out of 325 hospitalised and COVID-19-positive patients, 63% were male, with 65 years as the mean age of the study group. In another study by Toussie *et al*.,[3] out of 338 COVID-19-positive patients, 62% were male, with a median age of 39 years.

Hanley *et al*.[7] in their study, also stated that out of 325 patients, non-invasive ventilation was required in 9%, intubation and ICU admission were required in 14% during admission, and 69% were discharged without intubation.

In our study, patients with higher SPO_2 (91.35 ± 1.082) and PaO_2 (88.33 ± 1.826) levels had lower CXR severity scores, i.e. <8 and vice versa. This difference was statistically significant (p<0.01).

We believe that our study is unique as no other study in recent medical literature has compared CXR severity score with SPO_2 or PaO_2. However, in a study by Baratella *et al*.,[8] degree of hypoxia was assessed using the PaO_2/FiO_2 ratio. Lower baseline PaO_2/FiO_2 values were reported in critically ill patients than in non-severely ill patients. In addition, patients with significantly lower PaO_2/FiO_2 ratios succumbed. Balbi *et al*.[4] in their study, stated that older patients with a higher number of comorbidities had lower SpO_2 and PaO_2/FiO_2 values along with severe CXR findings at the time of admission than in patients who survived (p <0.001).

In our study, CXR severity score in patients needing oxygen support was lower (5.62) v. those needing ventilatory support (12.04). This difference was statistically significant (p<0.01). Hanley *et al*.[7] in their study, reported a median score of 11.5 for pre-intubation CXR in an ICU group with a median score of 9 at the time of admission. Toussie *et al*.[3] reported that a CXR severity score ≥3 independently predicted intubation with a p-value of 0.002.

In our study, among the subjects having a CXR severity score <8, 31 subjects required oxygen support and no subject required ventilator support. Among patient with a CXR severity score >8, 98 of 104 cases required ventilator support while only 6 required oxygen support. This difference was statistically significant (p<0.01). Hanley *et al*.[7] reported

Table 4. Comparison of support according to total chest radiograph severity score

Support	Number of patients and percentage	Total score <8	Total score >8	Chi-square	*p*-value
Oxygen support	*n*	31	6	106.58	<0.01*
	%	100.0%	5.8%		
Ventilator support	*n*	0	98		
	%	0.0%	94.2%		
Total	*N*	31	104		
	%	100.0%	100.0%		

* Statistically significant.

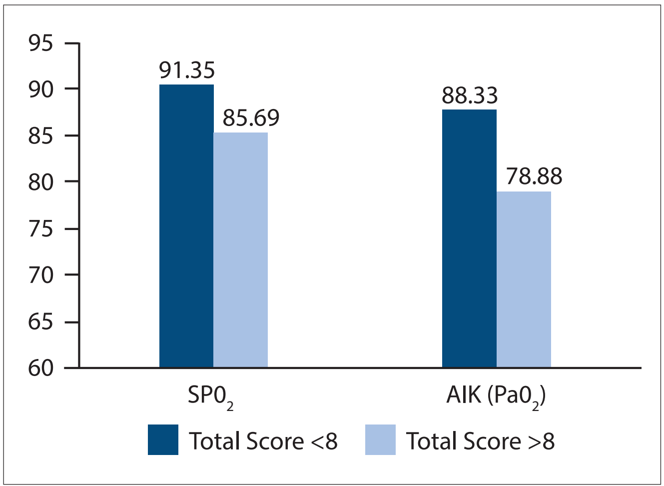

Fig. 7. Graphical representation of comparison of SPO_2 *and* PaO_2 *with total CXR severity score.*

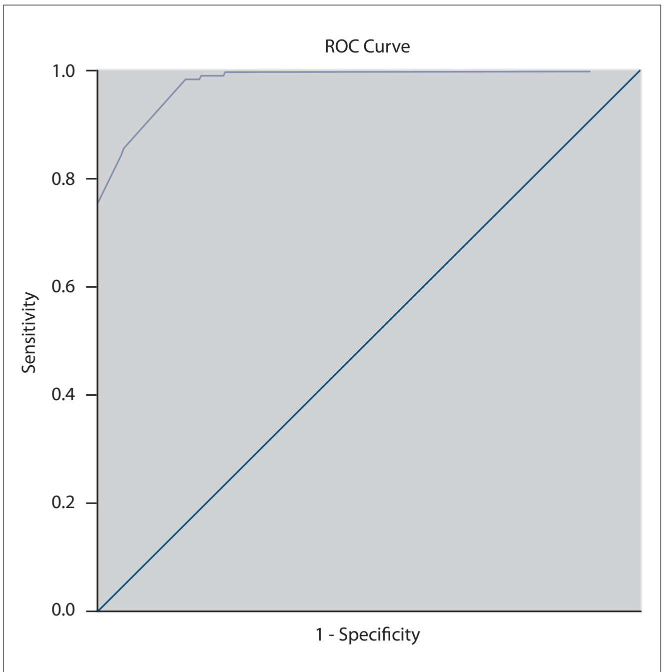

Fig. 8. The ROC curve.

that patients who had a baseline CXR score of 9 - 11.5 were admitted to ICU and intubated, with a *p*-value <0.01. They also stated that a similar score was also seen in deceased patients during their hospitalisation, with a *p*-value <0.001. Toussie *et al.*[3] studied the severity of opacification on the initial CXR and reported that the need for hospitalisation or for ventilatory support could be assessed by severity of opacification. If at least two lung zones were affected, the patient should be hospitalised and, if opacities were present in ≥3 lung zones, the patient would require ventilatory support.

In our study, ROC curve analysis of the CXR severity score with an area under the curve of 0.973 with a cut-off value >8 revealed a sensitivity of 85.7%, specificity of 92.5% and accuracy of 89.5%.

Study limitations

- Firstly, owing to the study's retrospective nature, observer bias cannot be avoided. As chest radiographs were done in the emergency department, reports could have influenced the decision of physicians to admit, resulting in overestimating the relationship between admission and chest radiograph severity. However, the degree of influence is unclear, and a previous study[9] has reported that physicians in the emergency department do not take chest radiographs as the basis of decision-making for admitting community-acquired pneumonia patients.
- Secondly, because patients were bed-ridden, most of the CXRs included in the study were portable, taken in the antero-posterior projection, leading to suboptimal evaluation of the lungs.
- As there was an imbalance between the need for ventilatory support and resources, not all the patients who needed ventilation had their requirements fulfilled.
- Readers of the study were not blinded to the severity of outcome.
- Comorbidities might have affected the CXR findings.

Conclusion

Based on the results of our study, we conclude that the chest radiograph severity score noted on initial radiography at the time of admission to the emergency department can be used to evaluate the need for oxygen/ventilator support in COVID-19 patients. Patients with a chest radiograph severity score >8 pose a high chance of requiring ventilatory support; hence, aggressive management with close monitoring is needed to reduce overall mortality and morbidity in such patients.

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Conflicts of interest. None.

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