A Novel Severity Scoring Derived from Chest Radiographic Findings in COVID 19 Patients Admitted to a COVID Care University Hospital in India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Coronavirus (COVID 19) disease predominantly affects the Respiratory system and cause by the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-COV2). It enters into the host cells via angiotensin-converting enzyme-2 (ACE-2), a part of the renin-angiotensin system (RAS) found in the epithelium of the nasal, lungs.
Aim: Chest Radiographic findings in COVID-19 patients detected for COVID care. Applying the novel chest radiographic scoring in disease-spread patients is admitted to the COVID care center and its correlation with blood oxygen saturation (SpO2) and clinical severity.
Objective: 1) To apply the novel chest radiographic scoring in patients of COVID 19 infection are admitted to our Covid Care Centre and
2) To apply its correlation with blood oxygen saturation (SpO2) and clinical severity.

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Results: 1) We found a moderate negative correlation between the chest radiographic score and SpO2. 2) Weak positive correlation between Clinical grading and CxR score.
Conclusion: Chest radiographic score taking into account the nature of opacities and extent is useful in classifying the patients into mild-moderate, severe, and critical grades. Take-home Message: A chest radiograph can be used as a baseline radiological investigation in COVID 19 patients as it can help to triage them according to the severity and treat them accordingly.

1. INTRODUCTION

Coronavirus Disease (COVID19) is a primarily significant disease in the respiratory system, caused by the Corona virus 2 (SARS-COV2) Severe Acute Respiratory Syndrome [1]. The World Health Organization (WHO) declared a Public Health Emergency of international concern on 30 Jan 2020 and a pandemic on 11 March 2020, since it is highly infectious and disease-spreading in several nations. With a 79.6% sequence similarity to SARS COV and Corona Virus, the virus is penetrating the cells through Angiotensin-Converting Enzyme (ACE 2) receptors [2]. The virus has a resemblance to SARS and COV. As the input site for SARS COV2 in the cell, ACE2 and Trans membrane Serine Protease (TMPRSS2) plays a major role in the disease of the corona virus (COVID 19) [3].

The infected patients have varied presentations as cough, fever, sore throat, nasal congestion, headache in mild cases, malaise, and breathlessness with reduced SpO2 in moderate cases, features of pneumonia, and respiratory distress in severe and features of acute respiratory distress in critical cases in addition to the above.

Serological diagnosis with real-time reverse transcriptase-polymerase chain reaction (RT-PCR) the nasopharyngeal swab is definedin diagnosing the SARS-COV2 infection. Chest Computed Tomography (CT), Radiography, and Ultrasonography (USG) are commonly used radiological investigations for chest diseases. Each has its advantages and disadvantages. However, CT is a better modality for imaging of the lungs, limitations due to availability and infection concerns. The chest X-ray or CT is the most common and preferred method for analyzing, especially for symptomatic patients. With the availability of portable Digital Radiographic (DR) equipments, the quality of chest radiograph is no more concern even for ICU patients for diagnosis, prognostic and response evaluation of COVID 19 involving the lungs. As chest radiographs are being widely used as a baseline investigation along with other serological markers to help triage mildly symptomatic patients from moderate to severely symptomatic ones, we retrospectively analyzed the Chest Radiographs of the patients admitted to our covid care hospital and tried to analyze and develop scoring system taking into consideration the nature and extent of opacities [4].

2. MATERIALS AND METHODS

We retrospectively analyzed the 1st (baseline) of chest radiographs for 300 patients acquired at our tertiary COVID Care Hospital with the above aim. Portable chest radiographs were obtained for moderate, severe, and critical patients (n= 26) using a 400 mA Shimadzu Mobile Dart Evolution portable Digital Radiography (DR) system in Anteroposterior (AP) projection. Chest radiographs of mildly symptomatic or asymptomatic patients were obtained in posteroanterior projection (n=274) using a static 400mA BPL H-RAD 32 radiography system with FUJI film Computed Radiography (CR) system.

The radiographs which did not fit the laid down criteria of an acceptable radiograph were excluded. The acceptable criteria for inclusion of a chest PA or AP radiograph were adequate-

- Symmetrical reproduction of the thorax
- Sharp medial borders of the scapula
- Appropriate exposure
- Image annotations not obscuring the lung fields
- Appropriate collimation
- Visualization of both apices, rib cage, costophrenic angles

It is required to triage moderate to severe symptomatic patients, and patients with moderate symptoms of co-morbidity due to high infectiousness, morbidity, and death. This is required to prevent problems and early

treatment. Chest X-ray is a handy and reproductive tool for diagnosing the degree of lung participation and triaging the grade of the patient.

Pulmonary implication in any disease processed results in lung opacities with defined nomenclatures, including densities and heat in the ground-glass pulmonary, reticular, and alveolar and consolidation.

Lower zones (C and F on the right and left, respectively): caudal to the right inferior pulmonary vein's margin corresponding to the lung bases. These were also divided into medial and lateral compartments CM, CL, FL, and FM.

Each compartment of the lung on the chest radiographs was scored as:

Score 0: no lung parenchymal abnormalities.
Score 1: reticular opacities.

Score 2: reticular and alveolar opacities with reticular predominance.
Score 3: reticular and alveolar opacities with alveolar predominance.
Score 4: consolidation with density obscuring the rib margins in the background.
Score 5: increase in the density of the consolidation equal to the mediastinum.

If a compartment contained more than one pattern of opacities, the predominant pattern was taken into consideration. If all the patterns were equal, the pattern with the highest score was attributed to that compartment.

Chest radiographics scoring ranging from 0 (normalradiograph) to maximum 60 (5 x 12). Other CXR findings (cardiomegaly, pulmonary vessel enlargement, etc.), not included in the scoring system, were recorded. A representative scoring of one patient is shown in Fig. 2.
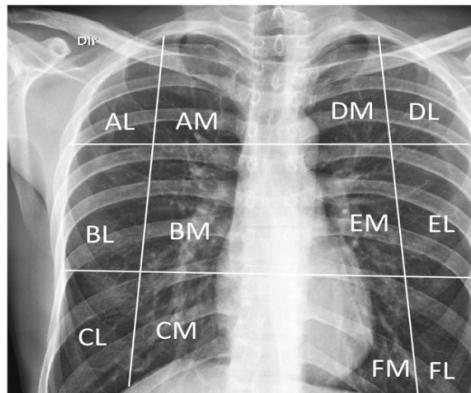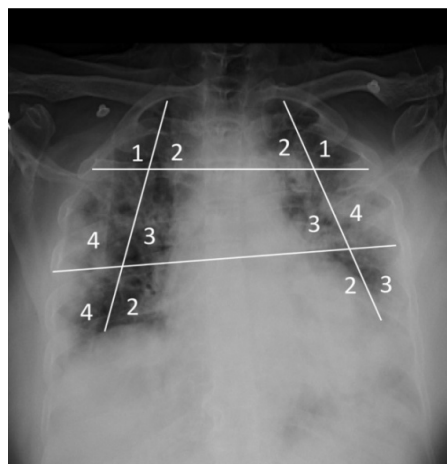

Fig. 1. Normal chest radiograph with lines demarking the division of 12 compartments

Fig. 2. Representative example of novel scoring of the chest radiographic opacities

Clinically the symptomatic patients were graded as mild, moderate, severe, and critical. The clinical grading was done as per the guidelines laid down by the Ministry of Health and Family Welfare, the Directorate General of Health Services, of EMR division, Govt. of India [5]. Scores of 1, 2, 3, and 4 were attributed to mild, moderate, severe, and critical patients respectively. The asymptomatic patients have attributed a score of 0 (zero).

Mild (Score 1):Uncomplicated upper respiratory tract is infected with mild symptoms like dry cough, fever, soreness of throat, malaise, headache,nasal congestion with no evidence of breathlessness or hypoxia [6] (normal bloodoxygen saturation measured with Pulse oximeter).

Moderate (Score2): Symptoms of breathlessness, fever, cough with SpO2 <94% (range 90-94%) on room air, the respiratory rate more than or equal to 24/minute.

Severe (Score3): Clinical signs of lung infection (Pneumonia)with one of the following: respiratory rate >30 breaths per minute, severe respiratory distress, SpO2<90% on room air.

Critical (Score4) Fever and breathlessness accompanied by new or worsening of symptoms indicating ARDS. Objective criteria for ARDS: P/F ratio of less than 200. PaO2/FiO2 ratio (P/F ratio) is the ratio of partial arterial oxygen pressure (PaO2 in mmHg) to fractional inspired oxygen level (FiO2) is expressed as a fraction.

The association between the two variables viz. chest radiographic score and SpO2 were calculated using the Pearson correlation coefficient. Kolmogorov-Smirnov test [7] of normality was applied to the chest radiographic scores of asymptomatic, mild, moderate, and severely affected patients. The statistical calculation is done online with Pearson's correlation coefficient and Kolmogorov-Smirnov normality test on social science calculator website [8].

3. RESULTS

Of the total 1012 patients admitted to our hospital during the period from 8th April 2020 to 30 /06 / 2020, we could collect the required clinical data, baseline radiographic score, and SpO2 of 300

patients for an analysis whose chest radiographs were satisfying the inclusion criteria. As shown in Fig. 3, among the 300 patients analyzed, 175 (58.33%) were asymptomatic at presentation and were attributed clinical score 0 (zero), 99 (33%) were mildly symptomatic and attributed clinical score 1, 12 (4%) patients were moderately symptomatic. They attributed clinical score 2, 13 (4.33%) patients were severely symptomatic and attributed clinical score 3. Only 1 (0.33%) was critical at presentation and was attributed a score of 4. This only patient who was critical on presentation was hypotensive with a systolic/diastolic blood pressure of 90 /60 mm Hg, raised CRP of 89.67, LDH of 450, ANC/ALC ratio 12.78, and PF ratio of 188.

Fig. 3 shows the graphical representation of the clinical condition of the patients at presentation. Of the 300 patients males (n= 165, 55%) marginally outnumbered females (n=135, 45%) shown in Fig. 4. The average age of 300 patients analyzed was 43.08 years with a standard deviation (SD) of 19.11. More than half of the 300 patients, i.e., 53.15%, were above the age of 40, with 12.74% being below the age of 20. The graphical representation of the age distribution is a plot in Fig. 5.

The baseline chest radiographs [7] of 300 COVID 19 patients which satisfied the inclusion criteria and acquired within 24 hours of admission in our hospital were analyzed, and the correlation between variables was analyzed (CxR novel scoring and SpO2, CxR scoring, and clinical grading) using Pearson's correlation coefficient.

274 asymptomatic and mildly symptomatic patients underwent a PA chest radiograph on a static 400mA BPL H-RAD 32 radiography system with FUJI film computed radiography (CR). Total 26 patients (12 moderate, 13 severe, and one critical patient) admitted in the High Dependency Unit (HDU), as well as the Intensive Care Unit (IC), underwent AP radiographs with a 400 mA portable Shimadzu Mobile Dart Evolution.

It is impossible to mobilize patients in HUU and ICU and make them erect and give a position for PA radiographs; hence, AP supine radiographs were obtained. The basic difference in PA and AP projection radiographs is magnifying the mediastinal structures and crowding of the ribs and vascular structures due to poor inspiration due to the patients' condition.
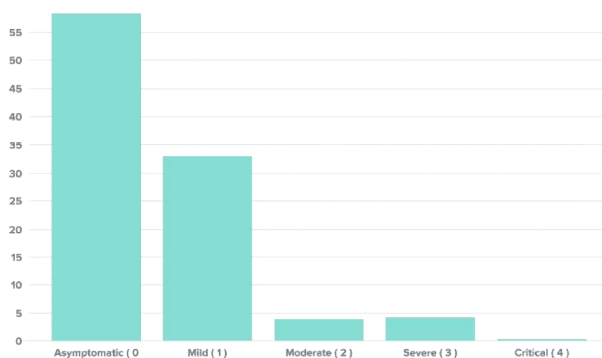
Clinical Severity (Score)

Fig. 3. Distribution of the clinical severity scores of the patients
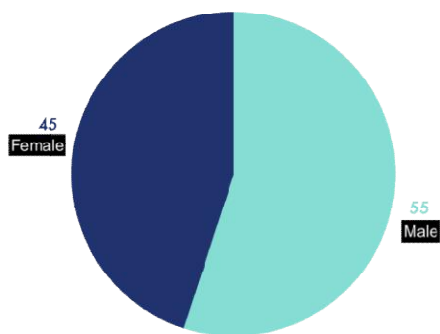
Sex Distribution

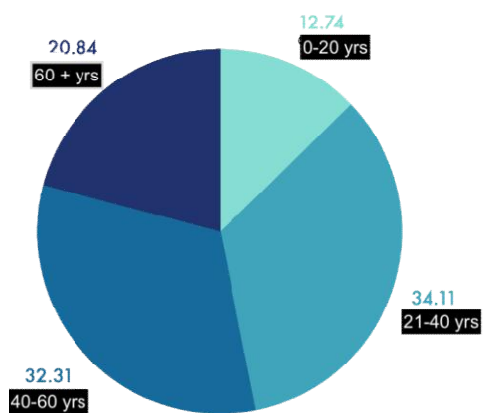**Fig. 4. Sex distribution of the patients**

Age Distribution

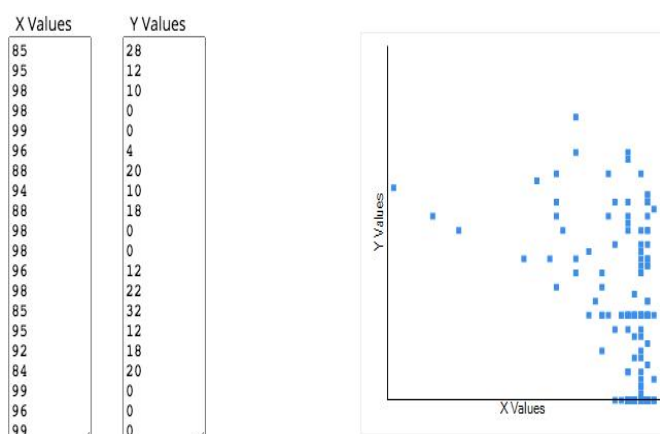**Fig. 5. Age distribution of the patients**

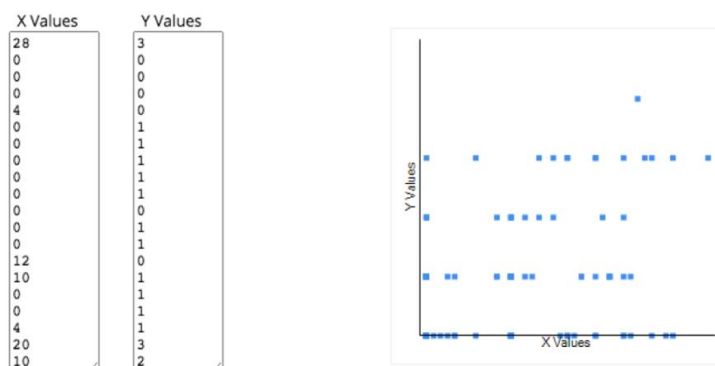**Fig. 6. Distribution of SpO2 and the CxR score along the X and Y-axis**

Fig. 7. Distribution of CxR score and Clinical severity score plot on X and Y-axis

The findings revealed a moderate negative correlation between the radiographic chest score and SpO2, with Pearson's Correlation coefficient of -0.5075 with a P-value < 0.00001. The distribution of SpO2 and the CxR score is shown in Fig. 6 along the X and Y-axis, respectively. A weak positive correlation was found between clinical grading and CxR score with Pearson's correlation coefficient of 0.4656. P-valueis less than0.00001. The distribution of the CxR score and Clinical severity score is shown in Fig. 7 along the X and Y axis, respectively, to calculate Pearson's correlation coefficient.

The baseline radiographs of 300 patients were analyzed; among that, 175 patients were asymptomatic, 99 were mildly symptomatic, 12 were moderately symptomatic, 13 were severely symptomatic, and one patient was critical.

We applied the Kolmogorov-Smirnov test of normality for each of the data sets of X-ray scores. The asymptomatic and mildly symptomatic cases were not normally distributed, and hence the median and Interquartile Range (IQR) was calculated for their central tendency. The moderate and severe cases were normally distributed and hence the mean and standard deviation for their central tendency.

The median and IQR of chest radiographic [4] score of asymptomatic patients were 0 with a maximum score of 35 and a minimum score of 0. The median and IQR of the mildly symptomatic patients' chest radiographic scores were 0 and 10, respectively, with a maximum score of 29 and a minimum score of 0. The arithmetic mean and standard deviation of the chest radiographic scores of moderately symptomatic patients were 12.25 and 9.12, respectively, with a maximum score of 28 and a minimum score of 0. The arithmetic mean and standard deviation of the radiographic chest score of severely symptomatic patients were 22.69 and 11.10, respectively, with a maximum score of 40 and a minimum score of 0. The only critical patient at

presentation whose required parameters and data were available had a chest X-ray [9] score of 30.

4. DISCUSSION

Its early diagnosis is necessary for triaging of moderate to severely symptomatic patients and mildly symptomatic patients with comorbidities because of its high infectivity, morbidity, and mortality. This is necessary for early treatment and preventing complications. Chest X-ray provides a convenient and reproducible method to diagnose the severity of lung involvement and triage the patient's grade.

Lung involvement in any pathological process gives lung opacities whose nomenclatures are standardized, including ground-glass densities/haziness, reticular opacities, alveolar opacities, and consolidations.

The haziness is seen as an ill-defined increase in parenchymal density due to early interstitial or alveolar involvement of a pathological process. The bronchovesicular markings are seen through it. The reticular pattern on a radiograph is due to any pathological process in or around the lung interstitial, which may be due to blood, water, tumor cells, fibrosis, or a combination of these depending upon the pathology. The reticular pattern of infection is due to the accumulation of interstitium inflammatory fluid infection. The filling of airspaces by blood, water, and tumor cells causes the alveolar opacities on radiographs. The alveolar opacities in infective pneumonia are commonly due to fluid or pus. Consolidation is when the alveolar opacities become confluent. It may be sub-segmental, segmental, or lobar, depending on the extent [6].

Ventilation / perfusion (V/Q) maladjustment is the common cause of hypoxia. Infection consolidation operates as a pulmonary vasoconstruction collapse of the lung and shunting of blood into the more ventilated regions. Infection and inflammation of pneumonia in COVID 19 lead, due to pulmonary arterial vasoconstriction, to a decrease in the ventilation and blood shift of the diseased lung. Sepsis is frequently related to coagulopathy and is susceptible to serious COVID19 outcome [10]. The probability of acute pulmonary artery disorder is increasing in COVID 19 patients and thus the ratio of V/Q and hypoxia is disrupted [11].

Reticular opacities, which are one of the earliest features of COVID pneumonia, and haziness in the lungs, cause the least impediment to the alveolar exchange, followed by alveolar opacities and consolidations. The consolidation density also indicates the severity of impediment to the alveolar exchange of oxygen[12].

A moderate negative correlation between the radiographic score and SpO2 suggests that the severity of hypoxia and thus barrier to the alveolar exchange increases in severity from reticular to alveolar opacities. As the alveolar opacities become more dominant, confluent, and dense, the infective/inflammatory fluid accumulated in the alveoli hampers the alveolar exchange.

The fact that hypoxia is not just the consequence of reduced ventilation {the alveolar oxygen barrier (O2)–carbon dioxide (CO2)} but also owing to the microemboli that leads to a reduced contamination may lead to a lack of substantial negative correlation.

A basic radiograph might assist triage patients depending on the radiographic findings to correlate chest radiographic score and clinical grading of severity if weak. Chest x-rays even with stringent social distance standards might be acquired which become challenging with clinical evaluations including a close relationship between the patient and the health care professional.

In [13] used a similar experimental scoring system for objectively quantifying the lung abnormalities. They found it a very clear way to provide relevant information to the clinicians from this, our study differs in several aspects. We used 12 quadrants for scoring rather than six used. We also used the consolidation density as a criterion affecting the severity score from 4 to 5. This is supported by the fact that the difference in the density indicated a variable amount of fluid in the alveoli and hence a variable barrier for oxygen exchange. The denser the opacities is the higher the score. Also, in our study, we correlated the novel CxR scoring method with SpO2 and Clinical grading, which helped us establish objective criteria for grading patients as mild, moderate, and severe[14].

The median indicated the central tendency of the Chest radiographic score for Asymptomatic and mildly symptomatic patients measures as their medians were 0 (zero), indicating that most of

these patients were normal. The mean indicating the central tendency of the chest radiographic score for moderately symptomatic was 12.25, and that for severely symptomatic patients was 22.69. This shows that most moderate and severely symptomatic patients are likely to have lung involvement, and a chest radiograph [15] score would be useful in these patients. The lower average score for moderately severe patients clinically confirms our hypothesis that the ventilation barrier's severity increased from reticular opacities to consolidation. This further system is increased with an increment in the density of consolidation. Also, the moderate negative correlation between SpO2 and chest radiographic score could be due to pulmonary emboli, which has also played an important role in the outcome of COVID 19 patients, which is missed by radiographs.

Reduced SpO2 is used as one of the major criteria for triaging patients worldwide. Also, the clinical guidelines for classification used in our study are set by India's government and are extensively used. A moderate negative correlation between CxR scoring -SpO2 and a weak positive correlation between CxR scoring – clinical grading helps us validate the scoring proposed Novel Chest Radiographic scoring developed.

However, a few drawbacks of our study chest radiographs: 1) Technical factors as exposure factors and 2) Limitations of chest radiographs as hidden areas of the chest. 3) Observer bias.

5. CONCLUSION

Radiographic exposure factors could overestimate the findings in underexposed radiographs and underestimate in overexposed radiographs. This is overcome to a significant extent with the extensive use of portable digital and computed radiography systems in our study. Few areas of the chest that are difficult to analyze are known as hidden areas such as posterior costophrenic recess, retrocardiac, retro-hilar, and apical regions, could underestimate the chest radiographic findings. Also, the radiographs were analyzed by only one radiologist. A blinded study with a radiographic score by another equally experienced radiologist could have helped avoid selection bias. Hence, further validation of our findings is needed with more standardized radiographic techniques and including a blinded second observer's findings.

Also, correlation of radiographic findings with those on CT scan is worthwhile.

Chest radiography is a useful baseline investigation for SARS COV2 infection. Severity scoring taking into account the nature of opacities and extent is useful in classifying the patients into mild, moderate, severe, and critical grades for triaging and better managing the patients in the present COVID 19 pandemic.

DISCLAIMER

CONSENT

As per international standard or university standard, patient's written consent has been collected and preserved by the author(s).

ETHICAL APPROVAL

Taken from Symbiosis Medical College for Women, Symbiosis International (Deemed University), Pune, Maharashtra, India.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle4.com/review-history/69558