rosy setiawati <rosy-s@fk.unair.ac.id>

# Manuscript submitted to Dove Medical Press - Response Required

1 message

**Sonam Patel** <kajalpatel@dovepress.com> Tue, Apr 13, 2021 at 10:22 AM
Reply-To: Sonam Patel <kajalpatel@dovepress.com>
To: Dr Setiawati <rosy-s@fk.unair.ac.id>

Dear Dr Setiawati,

Thank you for your manuscript submission to International Journal of General Medicine. On behalf of the Editor, I would like to inform you that your submitted manuscript 'Modified Chest X-ray Scoring Systems in Evaluating Severity of COVID-19 Patient in General Hospital Dr. Soetomo Surabaya, Indonesia' (310577) has been peer-reviewed and may be considered for publication after the necessary revisions are completed to the Editors satisfaction.

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Kind Regards,

Sonam Patel
On behalf of Dr Scott Fraser
Editorial Department
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rosy setiawati <rosy-s@fk.unair.ac.id>

# Dove Medical Press – Confirmation of Revision Period

1 message

**Lavina Thadani** <lavinathadani@dovepress.com> Tue, Apr 20, 2021 at 8:32 AM
Reply-To: Lavina Thadani <lavinathadani@dovepress.com>
To: Dr Setiawati <rosy-s@fk.unair.ac.id>

Dear Dr Setiawati

Titled: Modified Chest X-ray Scoring Systems in Evaluating Severity of COVID-19 Patient in General Hospital Dr. Soetomo Surabaya, Indonesia
Submission ID: 310577

Thank you for confirming your intention to submit a revised manuscript for International Journal of General Medicine. I have noted a due date of __date_4a_deadline__ in our system. If you require further time, please let us know as soon as possible. We look forward to receiving your revised manuscript.

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Kind regards

Lavina Thadani
lavinathadani@dovepress.com
Dove Medical Press
[ID 310577]

rosy setiawati <rosy-s@fk.unair.ac.id>

# Dove Medical Press: Submission accepted for publication

1 message

**Mrs Vivienne Gee** <viviennegee@dovepress.com> Fri, May 7, 2021 at 6:08 AM
Reply-To: Mrs Vivienne Gee <viviennegee@dovepress.com>
To: Dr Setiawati <rosy-s@fk.unair.ac.id>

Dear Dr Setiawati,

I am pleased to inform you that the submission, "Modified Chest X-ray Scoring Systems in Evaluating Severity of COVID-19 Patient in General Hospital Dr. Soetomo Surabaya, Indonesia", has been accepted for publication in "International Journal of General Medicine". The article publishing charge is now payable before the paper can be progressed any further and an invoice is accessible here: https://www.dovepress.com/invoice.php?i_key=3aUl6EEA94sbog88kO4zCWkl50862
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## Reviewer 1

| No | Evaluation | Comment |
|---|---|---|
| 1 | **Citate another manuscript**<br><br>- Wasilewski PG, Mruk B, Mazur S, Półtorak-Szymczak G, Sklinda K, Walecki J. COVID-19 severity scoring systems in radiological imaging – a review. Polish Journal of Radiology. 2020;85(1):361-368. doi:10.5114/pjr.2020.98009.<br>- Taylor E, Haven K, Reed P, et al. A chest radiograph scoring system in patients with severe acute respiratory infection: a validation study. BMC Med Imaging 2015; 15 : 61 | Thank you for the kind comment and suggestion, we have added the information related to our study received from the study mentioned (discussion, line 216, first paragraph). |
| 2 | **Report result semi quantitatively in a structured manner so the conclusion are clear** | We have modified our conclusion to be clearer. |

## Reviewer 2

| No | Evaluation | Comment |
|---|---|---|
| 1 | **Ethical Concern**<br>How the written consent taken from patient with septic shock, septicemia and clinically with moderate illness? Was it taken retrospectively for 200 patients? | All informed consent of unconscious or critically ill patients were taken from next of kin.<br>Yes, all informed consents were taken during admission.<br>We have added more information regarding information above in line 116 first paragraph in M&M |
| 2 | **Methods**<br>- Didn't correlate with clinical outcome (morbidity and mortality)<br>- How it will predict disease course and help early identification patient who will progress to severe disease and need advance medical care? | - We didn't correlate with the outcome, because our main purpose is to see severity of the chest x-ray when patient first come.<br>- unfortunately, we didn't include the parameter for |

| | | |
|---|---|---|
| | - Relationship between severity of score and mortality?<br>- Correlation of age with severity score?<br>- Chest x-ray which day of the illness was included in the study? Severity usually have multiple follow up xray until 7 to 10 days of illness | early prediction to disease progression.<br>- in our study we didn't measure the relationship between severity score and mortality, but thank you for the suggestion, we have included it in the suggestion for future study.<br>- We only use the initial xray during admission to measure the scoring. For future study we will use our scoring for the serial photos. |
| **3** | **Limitation**<br>- No need to mention control group to evaluate sensitivity and specificity<br>- Gold standard haven't been mentioned (RT-PCR) | Yes, we agree with this idea and we have deleted the statement. |
| **4** | **Conclusion**<br><br>Did we evaluate the all the serial x ray to assess the progression of disease on chest x-ray and correlated with clinically progression of disease, this is not clearly mentioned in methodology ? | Yes, we agree with this idea and have revised bellow statement.<br><br>We have added the statement in the methods in regards to timing when the chest xrays was taken and evaluated.<br>In this study we analyzed the initial chest xrays during admission to the hospital. |
| **5** | **Figure 2**<br>Replace figure with clear chest xray showing more air space shadowing/consolidation to make easier for readers understand the modified scoring | Yes, we have added another figure with lung abnormality for illustrating the application of our modified scoring. |

4

5 **Reviewer 3**

| No | Evaluation | Comment |
|---|---|---|
| 1 | **Grammar**<br>- Methods and Results (to past tenses)<br>- Conclusion (systems instead of system), (can help determine not determined), (shortage of resources instead of facilities)<br>- Many typos; a complete revision and editing of the English language is needed Punctuation needs an extensive revision; many commas are missing | Thank you for the correction, we have replaced the inappropriate language. |
| 2 | **Methods**<br>- Patient came to where? ED?<br>- Chest X-Rays<br>- How did the diagnosis of COVID19 confirmed<br>- The radiograph then will be described as negative or positive<br>- “Each region will be rated 0 to 2 based on lesion in the lungs" do you mean: according to the type of pulmonary abnormalities?<br>- "were calculated its normality with Kolmogorov Smirnov." this sentence needs to be rewritten<br>- In the M&M section I cannot find who performed the analysis of the X-RAY? how many readers with how many years of experience? in consensus? | - We have added the information of patient’s admission to specify where the patients came. We include all patients that came to our hospital either from ED or outpatient wards.<br>- We added confirmed covid-19 by definition of patient with positive PCR test and with positive covid chest xray abnormalities<br>- Yes, we did specify the lesion or pulmonary abnormalities in the next sentence (line 145-147)<br>- We had mentioned the definition of the observer in second paragraph of the methods in the line 116.<br>- We revised the statement with “Kolmogorov |

| | | |
|---|---|---|
| | | Smirnov were used to assess normality of the distribution.“ |
| **3** | **Result**<br>- Must be in past tense | Thank you for the correction, we have revised the inappropriate language. |
| **4** | **Statistical analysis**<br>- A statistical analysis to assess the correlation of the different radiological scores with the patients outcome is needed | Yes, we assessed the correlation of the different radiological score regarding with the clinical feature, but we didn’t measure it with the outcome. Thank you for the suggestion we will include it in future studies suggestion. |
| **5** | **Introduction**<br>- considering... there are many asymptomatic cases (replace the correspondent part)<br>- Explain the abbreviation CFR<br>- "in patients with COVID-19 pneumonia in Italy10, Tongji Hospital, Wuhan; Azienda Socio Sanitaria Territoriale, Spedali Civili of Brescia, Italy" this part of the sentence is unclear. Was this score tested in Italy and China??? Dott Wong et al (reference 11) did not apply the RALE score in their analysis, but a score based on the % of the affected lung, with a global score from 0 to 8. The same score proposed by Wong was used in other studies (e.g: Cellina M, Panzeri M, Oliva G. Chest Radiography Features Help to Predict a Favorable Outcome in Patients with Coronavirus Disease 2019. Radiology. 2020 Oct;297(1):E238. doi: 10.1148/radiol.2020202326; Orsi MA, Oliva G, Toluian T, Valenti Pittino C, Panzeri M, Cellina M. Feasibility, Reproducibility, and Clinical Validity of a Quantitative Chest X-Ray Assessment for COVID-19. Am J Trop Med Hyg. 2020 Aug;103(2):822-827. doi: 10.4269/ajtmh.20-0535. ):. Describe the | - Yes, we have added it in the abbreviation<br>- Yes, Brixia score was widely used in Italy, also in reference 10, they included it in the study.<br>- We founded in the M&M section of the literature that Wong et al did mentioned the radiograph scoring he used in the methods, and it is indeed RALE Score introduced by Warren et al., but even so we have added the statement that the methods were presented by Wong et al. (Line 93-100)<br>- We agree that general practitioners will be in difficulties dealing |

| | | |
|---|---|---|
| | score proposed by Wong et al as a possible alternative to the RALE and Brixia scores, adding the suggested references and verify if other published studies analysed the usefulness of this score<br>- I do not think that radiological scores based on the interpretation of chest X-Rays could be performed by general practitioners, especially when dealing with interstitial pneumonia | with interstitial pneumonia, but in this study, we want to simplify general abnormalities due to lack of specialist in rural area and increasing number of covid cases. Hopefully, general practitioner may involve in covid management. |
| **6** | **Discussion**<br>what do you men by "good spatial granularity "? | We have revised this statement.<br>Good spatial granularity means that they evaluate the lesion in detailed from area distribution as well as the presentation of interstitial to alveolar infiltration. |

6

7

8

# Modified Chest X-ray Scoring Systems in Evaluating Severity of COVID-19 Patient in General Hospital Dr. Soetomo Surabaya, Indonesia

Rosy Setiawati[1], Anita Widyoningroem[1], Triwulan Handarini[1], Fierly Hayati[1], Agnes Triana Basja[1], Atrikha Rahma Dyana Surya Putri[1], Merlin Guntur Jaya[2], Jessica Andriani[2], Melina Rosita Tanadi[2], Imran Harsam Kamal[2]

[1] Department of Radiology, Faculty of Medicine, Universitas Airlangga - General Hospital Dr. Soetomo, Surabaya, Indonesia; [2] Faculty of Medicine Universitas Airlangga, Surabaya, Indonesia

Correspondence: Rosy Setiawati. Tel [+62 878 5330 0019]. Fax [-]

Email: rosy-s@fk.unair.ac.id

**Abstract:**

**Introduction :** The management of COVID-19 patients requires efficiency and accuracy in methods of detection, identification, monitoring, and treatment feasible in every hospital. Aside from clinical presentations and laboratory markers, chest x-ray imaging could also detect pneumonia caused by COVID-19. It is also a fast, simple, cheap, and safe modality used for the management of COVID-19 patients. Established scoring systems of COVID-19 chest x-ray imaging include Radiographic Assessment of Lung Edema (RALE) and Brixia classification. Modified scoring system is adopted from BRIXIA and RALE scoring system, and has been made to adjust the scoring system needs in Dr. Soetomo General Hospital, Indonesia. This study aims to determine the value of scoring systems through chest x-ray imaging in evaluating the severity of COVID-19.

**Methods:** Data was collected from May to June of 2020 who underwent chest x-ray evaluation. Each image is then scored using three types of classifications; modified score, Warren score, and Brixia score. The scores are then analyzed and compared with the clinical conditions and laboratory markers to determine its value in evaluating the severity of COVID-19 infection in patients.

**Results:** 115 patients were males (51.1%) and 110 were females (48.9%). All three scoring systems are significantly correlated with the clinical severity of the disease, with the strengths of correlation in order from the strongest to weakest as Brixia ($p<0.01$, correlation coefficient 0.232), Warren ($p<0.01$, correlation coefficient 0.209), and General Hospital Dr. Soetomo ($p<0.01$, correlation coefficient 0.194). All three scoring systems correlate significantly with each other. General Hospital Dr. Soetomo correlates more towards Brixia ($p<0.01$, correlation coefficient 0.865) than Warren ($p<0.01$, correlation coefficient 0.855). Brixia to Warren correlates with a coefficient of 0.857 ($p<0.01$).

**Conclusion:** The modified scoring system can help determined the severity of the disease progression in COVID-19 patients especially in areas with shortages of facility and specialists.

**Keywords:** Brixia Score ,Chest radiographs, COVID-19, modified score, RALE Score

# Introduction

COVID-19 appeared in Wuhan, China on the late December 19 with fever, cough, and myalgia as the most common symptoms.[1] The disease manifests in varying degrees from mild to severe and may progress to acute respiratory distress syndrome (ARDS).[2] Current case fatality rate of COVID-19 varies between countries, although the exact number of mortality rate remains unknown, due to the number of asymptomatic cases.[3] Within only a few months, the pathogen had spread all over the world and contributed to a 3-5% of mortality.[4] By the end of March 2020, the Case Fatality Rate (CFR) of COVID-19 in Indonesia was 8,9 %. This is higher than mean CFR all over the world.[5] Radiological examination is reported to play an important role in the diagnosis of COVID-19. A systematic review of case series with a total of 919 patients in China and Korea suggested that chest X-ray (CXR) may not be reliable for diagnosing COVID-19 in its early stage. Only in its intermediate and severe stages is when COVID-19's feature of the lungs is seen on CXR. The British Society of Thoracic Imaging (BSTI) suggested chest radiography to all seriously ill patients (oxygen saturation <94%, National early warning score (NEWS) >3) and if 'clinically required'.[6] On the other hand, chest computed tomography (CT) could provide a more accurate identification of severe lung diseases in COVID-19 with a sensitivity of 83,3% and a specificity of 94%.[7] Although chest-CT is more sensitive and specific than CXR, interpreting CXRs had always been a routine practice for clinicians to rule out other causes of respiratory disease.[8] The lack of CT-scans and radiologists, especially in developing countries such as Indonesia, makes CXR a great substitute to diagnose and determine the severity and progression of lung abnormalities in COVID-19 patients.[9]

The currently established CXR scorings system are Brixia and Radiographic Assessment of Lung Edema (RALE) scoring systems. Brixia scoring system has been used widely as a tool to monitor the severity and progression of COVID-19 pneumonia in Tongji Hospital, Wuhan and Azienda Socio Sanitaria Territoriale, Spedali Civili of Brescia, Italy.[10] RALE scoring system, presented by Wong et al., has been used in Queen Mary Hospital, Hong Kong; Pamela Youde Nethersole Eastern Hospital, Hong Kong; The University of Hong Kong; Shenzhen Hospital,

Shenzhen; and University Hospital Careggi.[11–13] One of the important difference between the two scoring is that RALE can be done by a general practitioner due to its simplicity, while Brixia is designed to be used by a trained radiologist. The RALE scoring system only divides the lung into two regions; making it not specific for smaller lesion.[14]

Seeing the current conditions regarding the lack of distribution of trained radiographers and radiologists in Indonesia, we proposed a CXR scoring system for evaluating the severity of COVID-19 patients in Dr. Soetomo General Hospital, Surabaya, Indonesia. A modified scoring system is adopted from Brixia and RALE scoring systems, and has been made to adjust to the needs and resources in Dr. Soetomo Academic General Hospital, Indonesia. This scoring system is aimed to be applicable for mild pneumonia cases and provide a faster and more accurate analysis. This study aims to determine the value of scoring systems through CXR imaging in evaluating the severity of COVID-19.

# Material and methods

This is a retrospective study of patients with RT-PCR-confirmed COVID-19 in Dr. Soetomo Academic General Hospital. This study was conducted in accordance with the Declaration of Helsinki. This study was approved by the Medical Research Ethic Committee of Dr. Soetomo Academic General Hospital, Surabaya. All participants included had given their written informed consent to participate in this study during admission. In cases of decrease of consciousness and severe illness written informed consent were represented by next of kin.

We included 225 patients that came to the emergency ward and outpatient clinic from May – June 2020. Every patient with symptoms and had RT-PCR-confirmed COVID-19 and positive CXR abnormalities was included. In this study, we analyzed the initial CXR of when the patient was first admitted. The CXRs were analyzed by 2 radiologists with an experience of more than 10 years.

Chest radiographs were acquired following the usual protocols and performed with posteroanterior or anteroposterior projection. The radiographs were then interpreted as normal or abnormal. The abnormalities are described by the distribution (upper zone predominant, middle

zone predominant, or lower zone predominant), side (right or left lung), and peripheral or perihilar dominance. Other features, such as pleural effusions and nodules, will also be mentioned.

The severity based on the imaging was calculated using Brixia, RALE, and the Dr. Soetomo Academic General Hospital scoring system (Modified Chest X-ray Scoring System).

Brixia scoring system divided the lungs into six regions. There were 2 lines dividing the lungs into six region; first line was drawn at the level of the inferior wall of the aortic arch and the second line at the level of the right inferior pulmonary vein. Radiologist rate each region from 0-3 based on the severity of the lesion. Score 0 for no lung abnormalities, 1 for interstitial infiltrates, 2 for interstitial and alveolar infiltrates (interstitial dominant), and 3 for interstitial and alveolar infiltrates (alveolar dominant). The score ranges from 0 to 18. Other findings, such as pleural effusion, pulmonary vessel enlargements were not included in Brixia scoring system.[10]

The RALE scoring system divided the lungs into 2 regions; left and right lung. Each lung are scored 0 to 4 each; score 0 for no involvement, 1 for less than 25% involvement, 2 for 25%-50% involvement, 3 for 50-75% involvement, and score 4 for more than 75% involvement. The maximum score for RALE scoring is 8.[14]

The Modified Chest X-ray Scoring System calculated the score or severity from the posteroanterior and anterior projection of CXR by dividing the lungs into 6 regions. Two lines divided the lung horizontally, resulting in each lung into having 3 regions, as shown in (Figure 1). Each region were rated 0 to 2 based on the lesions; score 0 if there is no involvement, 1 if infiltrates or consolidations are less than 50%, and 2 if infiltrates or consolidations are more than 50%. The maximum score for the Modified Chest X-ray scoring system is 12. The final scores were then classified further into mild (score 1-4), moderate (score 5-8) and severe (score 9-12). The example of the application of this scoring system is shown in (Figure 2).

The data was analyzed with IBM SPSS version 25 software. Kolmogorov Smirnov were used to assess normality of the distribution of each scoring system. Spearman correlation test was used for correlating Modified Chest X-Ray scoring system with RALE and Brixia scoring system. P value of $<0.01$ was considered statistically significant.

# Results

## Patient Characteristics

The characteristics of patients were summarized in (Table 1). This study included 115 men (51.1%) and 110 women (48.9%), with a mean age of 53 (21–81) years. Most presented with mild pneumonia (29.8%), and no comorbidities (51.1%).

## Chest Radiography Features

Out of 225 patients, 210 patients had abnormal chest radiograph findings as shown in (Table 2). The distribution of lesion were mostly upper, middle and lower zone predominance (103 of 225; 45.6%). A total of 179 out of 225 (79.2%) presented with lesions on bilateral lungs, and 121 out of 225 (53.5%) were peripheral dominant. Other features on CXR included pleural effusion in 28 patients (12.4%) and pulmonary nodules in 33 patients (14.6%).

## Chest Radiography Scoring and Clinical Feature

Based on the RALE scores, most patients of all clinical characteristics scored 5 (17.3%). Asymptomatic patients and those with mild pneumonia mostly scored 2 (11 patients, 4.9%, and 17 patients, 7.6%). Patients with severe pneumonia mostly scored in 5 (9 patients, 4%), while those with ARDS mostly scored 4 and 5 (4 patients, 1.8%). Septic patients mostly scored 7 (7 patients, 3.1%), while patients with septic shock mostly scored 5 (7 patient, 3.1%).

On the other hand, the Brixia scores ranged from 0–18. Most patients scored 6 (22 patients, 9.8%). Asymptomatic patients scored 6 (11 patient, 4.9%), while most of the patient with mild pneumonia scored 5 (8 patients, 3.6%); those with severe pneumonia scored 7 (7 patients, 3.1%); those with ARDS patients scored 6; 15, and 18 (2 patients, 0.9%); septic patients scored 6 (5 patients, 2.2%); and septic shock patients scored 14 (6 patients, 2.7%).

The Modified Chest X-ray score ranged from 0-12. Most patients scored in 6 (30 patients, 13.3%), while there were no patients who scored 13-17. Asymptomatic patients mostly scored in 6 (11 patients, 4.9%); patients with mild pneumonia mostly scored in 9 (11 patients, 4.9%);

patients with severe pneumonia mostly scored in 6 (10 patients, 4.4%). ARDS patients scored in 7 (4 patients, 1.8%); septic patients mostly scored in 5 (6 patients, 2.7%); while patients with septic shock mostly scored in 10 (7 patients, 3.1%).

Based on (Table 3), most patients were classified as severe based on the CXR score classification (92 patients, 40.89%). Most patients with mild CXR score classification also presented with mild clinical presentation (19 patients, 44.19%). Those classified as moderate were mostly asymptomatic and had a clinical feature of mild pneumonia (23 patients, 25.5%), while those classified as severe in CXR classification mostly had mild pneumonia as a clinical feature (25 patients, 27.17%)

**Correlation of Chest Radiography Scoring Categorized and Clinical feature**

The correlation coefficient of the CXR was 0.164 ($p<0.01$).

**Chest Radiography Scoring Correlation with Each Other**

The correlation coefficient between the Modified chest X-Ray score and Brixia score was 0.865 ($p<0.01$), and the correlation coefficient of the Modified chest X-Ray score and RALE score was 0.855 ($p<0.01$) (Table 4). On the other hand, the correlation coefficient of Brixia and RALE score was slightly lower, which was 0.802 ($p<0.01$). This indicated that the Modified Chest X-ray Scoring System had a higher correlation coefficient relative to both established Brixia and RALE scoring system.

# Discussion

In this pandemic, an accurate radiological approach is necessary for a more rapid classification of COVID-19 patients. CXR may not be as sensitive as CT, but it still plays a major role in developing countries that lack more sophisticated modalities. Moreover, CXR can be brought to the patient's bedside, minimizing the risk of cross-infections.[15] Although CXR has a low sensitivity for early-stage disease of COVID-19, it can be used for monitoring the advancement and preceding stages of COVID-19 especially in critical care. [16]

Signorino *et al*. stated that Brixia score system to be a good scoring system, that provided detailed presentation and distribution of the lung (6 regions) and a sensibility (4 levels).[17]

Borghesi *et al*. also stated that Brixia scoring is a very useful method for ranking the stratification risk of patients with COVID-19 infection based on the severity of cases.[10] However, Brixia scoring requires a trained radiologist to interpret a CXR, due to its more complex indicators and nature for diagnosing COVID-19 pneumonia. This could be an obstacle for primary healthcare physicians who require an accurate and simple technique for early diagnosis of COVID-19 pneumonia, but lack the knowledge and experience to do so. Meanwhile, RALE scoring can predict supplemental oxygen requirement and the needs of ICU admission for mechanical ventilation.[15,18] Compared to Brixia, RALE scoring lacks a detailed and more complex indicators in scoring chest x-rays to diagnose COVID-19 pneumonia. We introduced the use of the Modified Chest X-ray Scoring System of Dr. Soetomo Academic General Hospital and compared it with the established Brixia and RALE scoring systems.

In this study, we found that most of the patients with severe clinical presentation (severe pneumonia, ARDS, sepsis, and septic shock) had 5 or more score with RALE scoring system. Meanwhile, patients with severe clinical presentation had 6 or more score with the Brixia scoring. The Modified Chest X-Ray scoring system showed 5 or more score for patients with severe clinical presentation.

All three scoring systems correlated significantly to each other. Modified Chest X-ray Scoring System of General Hospital Dr. Soetomo correlates more towards Brixia ($p<0.01$, correlation coefficient 0.865) than RALE ($p<0.01$, correlation coefficient 0.855). This result indicates the reliability of Modified Chest X-ray Scoring System in diagnosing COVID-19 pneumonia, and can help in the determination of management of COVID-19 patients early on. However, it should also be noted that COVID-19 patients don't always present with pneumonia.

Modified Chest X-ray Scoring System helps medical professionals in diagnosing COVID-19 pneumonia through a simple and fast method. Further study regarding its efficacy on a larger scale and possibly more heterogenous cases and should be performed in the hopes of its implementation on multiple healthcare center with X-ray devices and without CT scans. Also, study of correlation of the scoring and the outcome of care with serial radiographs will add great

value to predict patient condition, monitoring progression, later stages of COVID-19, and better management of the disease.

The main limitation of this study is the lack of comparison between the scoring systems and patient's clinical condition because some clinical data were only available in a small percentage of subjects. Another limitation of this study is the lack of comparison between chest x-ray score and patient comorbidities (i.e., hypertension, diabetes, cardiovascular disease, and oncologic history) or final outcome.

# Conclusion

Chest radiography can be considered as a tool to diagnose or measure severity of COVID-19 with certain approach through scoring systems such as Brixia Score, RALE Score, and the Modified Chest X-Ray score, although it may still be less sensitive than CT-Scan. The modified scoring system can help determine COVID-19 patient's severity, especially in areas with shortages of resources and specialists.

# Acknowledgments

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# Disclosure

The authors report no conflicts of interest in this work.

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**Table 1: Sample Characteristic at Presentation**

| **Parameter** | **No. of Patients** ***(n = 225)*** |
|---|---|
| **Patient Characteristic** | |
| **Male** | 115 (51.1%) |
| **Female** | 110 (48.9%) |
| **Age (year)** | 53 ± 13 |
| **Comorbidities** | |
| **No comorbid** | 115 (51.1%) |
| **Hypertension** | 10 (4.4%) |
| **Obesity** | 4 (1.8%) |
| **Diabetes** | 17 (7.6%) |
| **Heart abnormalities** | 5 (5%) |

| | |
|---|---|
| **Other lung abnormalities** | 6 (2.7%) |
| **Renal abnormalities** | 4 (1.8%) |
| **Hepatitis** | 9 (4.0%) |
| **Combine comorbid** | 40 (6.7%) |
| **Others** | 15 (6.5%) |

279

280 **Table 2: Radiographic findings on Chest Radiographs**

| **Radiographic Characteristic** | **No. of Findings (*n = 225)*** |
|---|---|
| **Normal chest radiograph** | 15 (6.6%) |
| **Distribution of lesion** | |
| **Upper Zone predominant** | 1 (0.4%) |
| **Middle Zone predominant** | 4 (1.8%) |
| **Lower Zone predominant** | 33 (14.6%) |
| **Upper and Middle zone predominant** | 3 (1.3%) |
| **Upper and Lower zone predominant** | 1 (0.4%) |
| **Middle and Lower zone predominant** | 65 (28.8%) |
| **Upper, Middle, and Lower zone predominant** | 103 (45.6%) |
| **Right Lung** | 14 (6.2%) |
| **Left Lung** | 17 (7.5%) |
| **Bilateral Lung** | 179 (79.2%) |
| **Peripheral predominant** | 121 (53.5%) |
| **Perihilar predominant** | 5 (2.2%) |

| | |
|---|---|
| **Peripheral and perihilar predominant** | 84 (37.2%) |
| **Lung Abormality Features on chest x-ray** | |
| **Reticular-nodular opacities** | 33 (11.6%) |
| **Patchy opacities** | 35 (12.4%) |
| **Consolidation** | 187(66.1%) |
| **Pleural effusion** | 28 (9.8 %) |

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283 **Table 3: Modified Chest X-ray Scores and Clinical Feature Classification**

| | **Asymptomatic** | **Mild pneumonia** | **Severe Pneumonia** | **ARDS** | **Sepsis** | **Septic shock** | **Total** |
|---|---|---|---|---|---|---|---|
| **Mild** | 8 | 19 | 5 | 3 | 4 | 4 | 43 |
| **Moderate** | 23 | 23 | 14 | 7 | 14 | 9 | 90 |
| **Severe** | 11 | 25 | 19 | 5 | 15 | 17 | 92 |

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285

286 **Table 4: Analysis result Spearman's Correlation of Modified Chest x-ray, Brixia and**
287 **RALE scores**

| | **Brixia Score** | **RALE Score** |
|---|---|---|
| **Modified Chest-xray Score** | r = 0.865 | r = 0.855 |
| | p < 0.001 | p < 0.001 |
| | n = 225 | n = 225 |
| **RALE Score** | r =0.802 | |
| | p < 0.001 | |

n = 225

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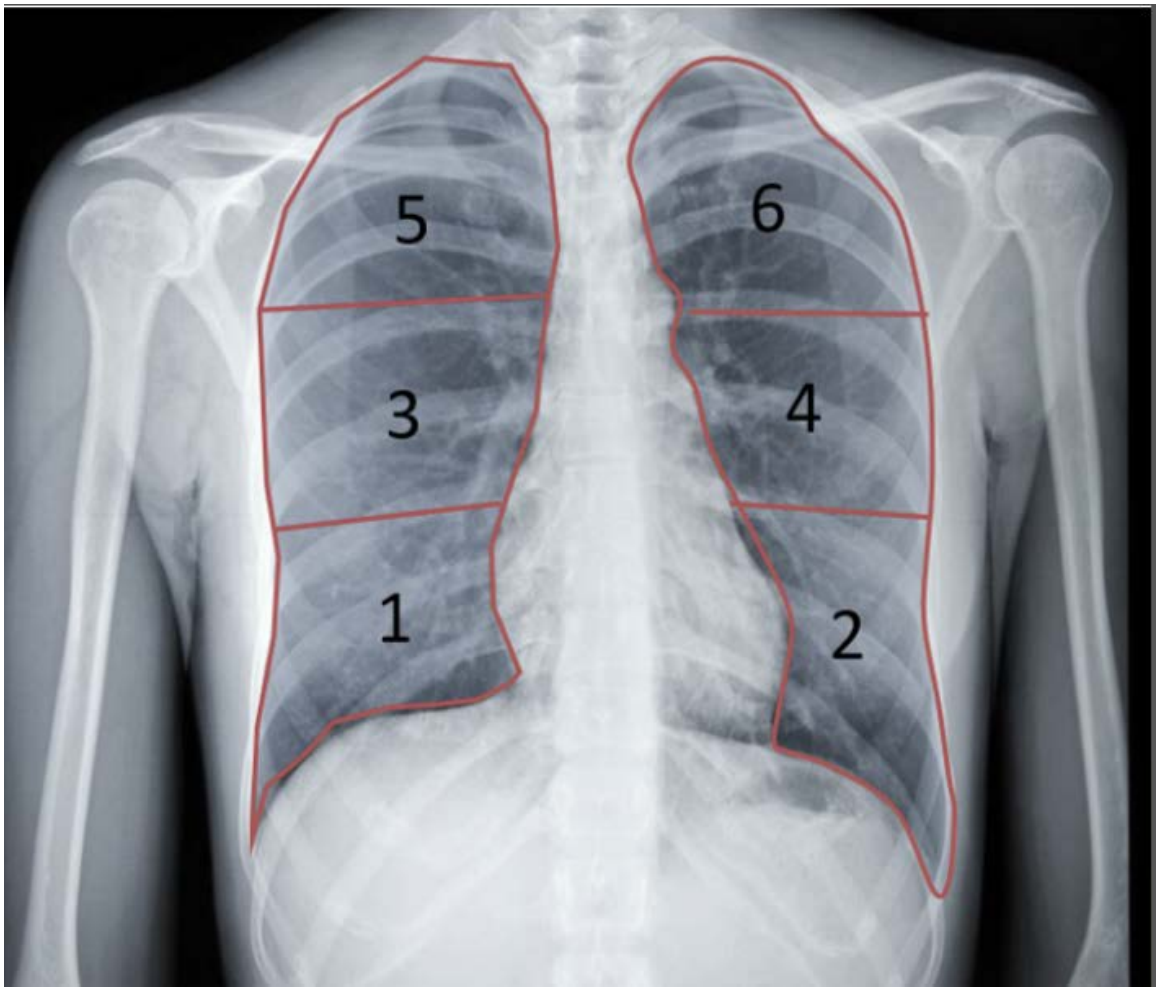


Figure 1. Lung field division using modified chest x-ray scoring system on chest posteroanterior (PA) projection, The lung field is divided into six zones lower zone (1 or 2) is under the inferior wall of the lower right pulmonary vein (lung base), middle zones (3 or 4) is below the inferior wall of the aortic arch and above the inferior wall of the lower right pulmonary vein (i.e., hilar structures), and upper zone (5 or 6) is above the inferior wall of the aortic arch

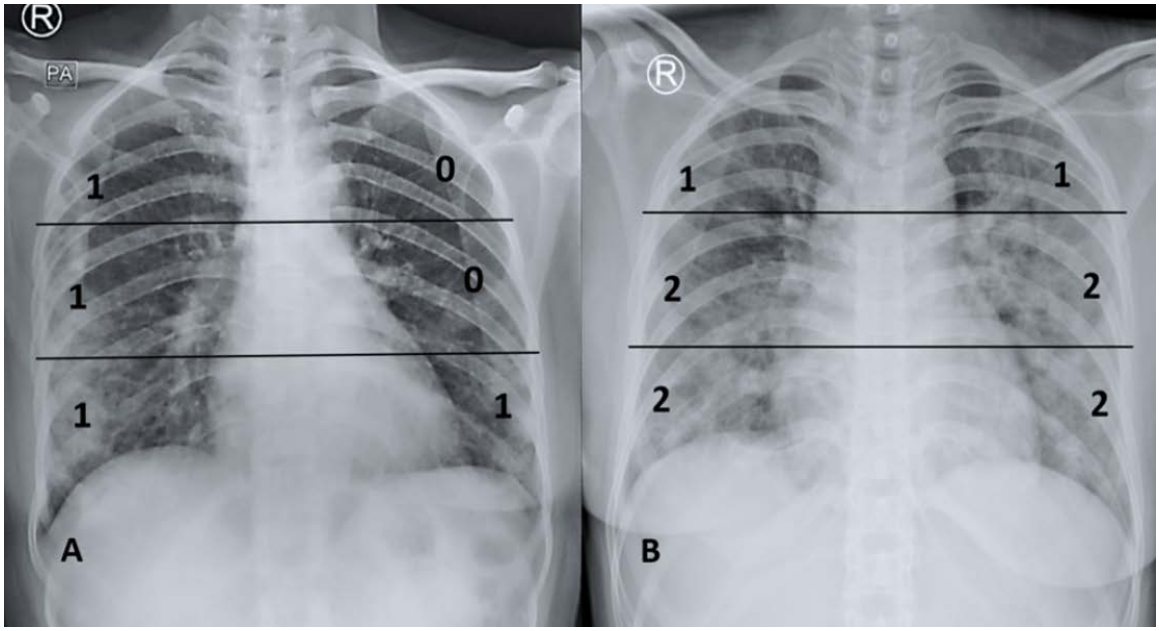


Figure 2. Two Case Ilustrations of applying Modified Chest X-ray Scoring System on AP projection. (A). The total calculated score of the 6 chest divisions is 4, classified as mild severity score. (B) The total calculated score of the 6 chest divisions is 9, classified as severe severity score

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ORIGINAL RESEARCH

# Modified Chest X-Ray Scoring System in Evaluating Severity of COVID-19 Patient in Dr. Soetomo General Hospital Surabaya, Indonesia

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**Introduction:** The management of COVID-19 patients requires efficiency and accuracy in methods of detection, identification, monitoring, and treatment feasible in every hospital. Aside from clinical presentations and laboratory markers, chest x-ray imaging could also detect pneumonia caused by COVID-19. It is also a fast, simple, cheap, and safe modality used for the management of COVID-19 patients. Established scoring systems of COVID-19 chest x-ray imaging include Radiographic Assessment of Lung Edema (RALE) and Brixia classification. A modified scoring system has been adopted from BRIXIA and RALE scoring systems and has been made to adjust the scoring system needs at Dr. Soetomo General Hospital, Indonesia. This study aims to determine the value of scoring systems through chest x-ray imaging in evaluating the severity of COVID-19.

**Methods:** Data were collected from May to June of 2020 who underwent chest x-ray evaluation. Each image is then scored using three types of classifications: modified score, RALE score, and Brixia score. The scores are then analyzed and compared with the clinical conditions and laboratory markers to determine their value in evaluating the severity of COVID-19 infection in patients.

**Results:** A total of 115 patients were males (51.1%) and 110 were females (48.9%). All three scoring systems are significantly correlated with the clinical severity of the disease, with the strengths of correlation in order from the strongest to weakest as Brixia score ($p<0.01$, correlation coefficient 0.232), RALE score ($p<0.01$, correlation coefficient 0.209), and Dr. Soetomo General Hospital score ($p<0.01$, correlation coefficient 0.194). All three scoring systems correlate significantly with each other. Dr. Soetomo General Hospital score correlates more towards Brixia score ($p<0.01$, correlation coefficient 0.865) than RALE score ($p<0.01$, correlation coefficient 0.855). Brixia to RALE score correlates with a coefficient of 0.857 ($p<0.01$).

**Conclusion:** The modified scoring system can help determine the severity of the disease progression in COVID-19 patients especially in areas with shortages of facilities and specialists.

**Keywords:** Brixia score, chest radiographs, COVID-19, modified score, RALE score

## Introduction

COVID-19 appeared in Wuhan, China on the late December 19 with fever, cough, and myalgia as the most common symptoms.[1] The disease manifests in varying degrees from mild to severe and may progress to acute respiratory distress syndrome (ARDS).[2] In current cases, the fatality rate of COVID-19 varies between countries, although the exact number of mortality rate remains unknown, due to the

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number of asymptomatic cases.[3] Within only a few months, the pathogen had spread all over the world and contributed to a 3–5% of mortality.[4] By the end of March 2020, the Case Fatality Rate (CFR) of COVID-19 in Indonesia was 8.9%. This is higher than the mean CFR all over the world.[5] Radiological examination is reported to play an important role in the diagnosis of COVID-19. A systematic review of case series with a total of 919 patients in China and Korea suggested that chest X-ray (CXR) may not be reliable for diagnosing COVID-19 in its early stage. Only in its intermediate and severe stages is when COVID-19's feature of the lungs is seen on CXR. The British Society of Thoracic Imaging (BSTI) suggested chest radiography to all seriously ill patients (oxygen saturation <94%, National early warning score (NEWS) >3) and if "clinically required".[6] On the other hand, chest computed tomography (CT) could provide a more accurate identification of severe lung diseases in COVID-19 with a sensitivity of 83.3% and a specificity of 94%.[7] Although chest-CT is more sensitive and specific than CXR, interpreting CXRs had always been a routine practice for clinicians to rule out other causes of respiratory disease.[8] The lack of CT-scans and radiologists, especially in developing countries such as Indonesia, makes CXR a great substitute to diagnose and determine the severity and progression of lung abnormalities in COVID-19 patients.[9]

The currently established CXR scoring systems are Brixia and Radiographic Assessment of Lung Edema (RALE) scoring systems. Brixia scoring system has been widely used as a tool to monitor the severity and progression of COVID-19 pneumonia in Tongji Hospital, Wuhan and Azienda Socio Sanitaria Territoriale, Spedali Civili of Brescia, Italy.[10] RALE scoring system, presented by Wong et al, has been used in Queen Mary Hospital, Hong Kong; Pamela Youde Nethersole Eastern Hospital, Hong Kong; The University of Hong Kong; Shenzhen Hospital, Shenzhen; and University Hospital Careggi.[11–13] One of the important differences between the two scorings is that RALE can be done by a general practitioner due to its simplicity, while Brixia is designed to be used by a trained radiologist. The RALE scoring system only divides the lung into two regions, making it not specific to smaller lesions.[14]

Seeing the current conditions regarding the lack of distribution of trained radiographers and radiologists in Indonesia, we proposed a CXR scoring system for evaluating the severity of COVID-19 patients in Dr. Soetomo General Hospital, Surabaya, Indonesia. A modified scoring system has been adopted from Brixia and RALE scoring systems, and has been made to adjust to the needs and resources of Dr. Soetomo General Hospital Surabaya, Indonesia. This scoring system is aimed to be applicable to mild pneumonia cases and provide a faster and more accurate analysis. This study aims to determine the value of scoring systems through CXR imaging in evaluating the severity of COVID-19.

## Materials and Methods

This is a retrospective study of patients with RT-PCR-confirmed COVID-19 in Dr. Soetomo General Hospital. This study was conducted in accordance with the Declaration of Helsinki. This study was approved by the Medical Research Ethics Committee of Dr. Soetomo General Hospital, Surabaya. All participants included had given their written informed consent to participate in this study during admission. In cases of decreased consciousness and severe illness, written informed consent was represented by next of kin.

We included 225 patients who came to the emergency ward and outpatient clinic from May – June 2020. Patients with symptoms and who had RT-PCR-confirmed COVID-19 and positive CXR abnormalities were included. In this study, we analyzed the initial CXR of when the patient was first admitted. The CXRs were analyzed by 2 radiologists with an experience of more than 10 years.

Chest radiographs were acquired following the usual protocols and performed with posteroanterior or anteroposterior projection. The radiographs were then interpreted as normal or abnormal. The abnormalities are described by the distribution (upper zone predominant, middle zone predominant, or lower zone predominant), side (right or left lung), and peripheral or perihilar dominance. Other features, such as pleural effusions and nodules, will also be mentioned.

The severity based on the imaging was calculated using Brixia, RALE, and the Dr. Soetomo General Hospital scoring system (Modified Chest X-ray Scoring System).

Brixia scoring system divided the lungs into six regions. There were 2 lines dividing the lungs into six regions; the first line was drawn at the level of the inferior wall of the aortic arch and the second line at the level of the right inferior pulmonary vein. Radiologists rate each region from 0 to 3 based on the severity of the lesion. Score 0 for no lung abnormalities, 1 for interstitial infiltrates, 2 for interstitial and alveolar infiltrates (interstitial dominant), and 3 for interstitial and alveolar infiltrates (alveolar

dominant). The score ranges from 0 to 18. Other findings, such as pleural effusion and pulmonary vessel enlargements, were not included in Brixia scoring system.[10]

The RALE scoring system divided the lungs into 2 regions, left and right lung. Each lung is scored from 0 to 4 each; score 0 for no involvement, 1 for less than 25% involvement, 2 for 25%-50% involvement, 3 for 50–75% involvement, and score 4 for more than 75% involvement. The maximum score for RALE scoring is 8.[14]

The Modified Chest X-ray Scoring System calculated the score or severity from the posteroanterior and anterior projection of CXR by dividing the lungs into 6 regions. Two lines divided the lung horizontally, resulting in each lung into having 3 regions, as shown in (Figure 1). Each region was rated 0 to 2 based on the lesions; score 0 if there is no involvement, 1 if infiltrates or consolidations are less than 50%, and 2 if infiltrates or consolidations are more than 50%. The maximum score for the Modified Chest X-ray scoring system is 12. The final scores were then classified further into mild (score 1–4), moderate (score 5–8) and severe (score 9–12). The example of the application of this scoring system is shown in (Figure 2).

The data were analyzed with IBM SPSS version 25 software. Kolmogorov–Smirnov test was used to assess the normality of the distribution of each scoring system. Spearman correlation test was used to correlate Modified Chest X-Ray scoring system with RALE and Brixia scoring system. P value of <0.01 was considered statistically significant.

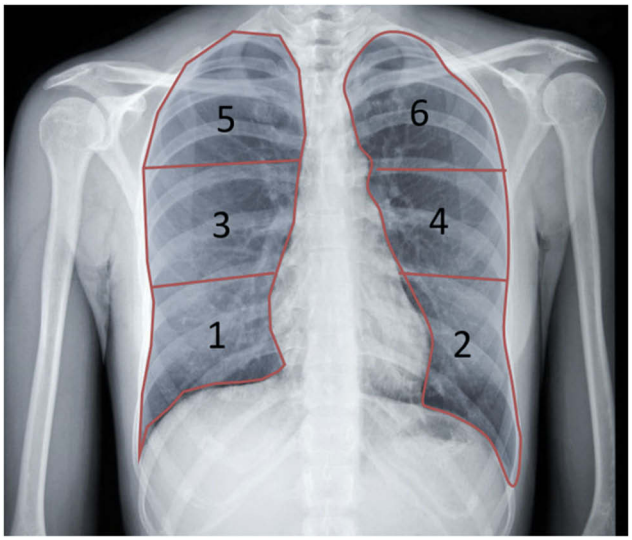


**Figure 1.** Lung field division using Modified Chest X-ray Scoring System on chest posteroanterior (PA) projection, The lung field is divided into six zones lower zone (1 or 2) is under the inferior wall of the lower right pulmonary vein (lung base), middle zones (3 or 4) is below the inferior wall of the aortic arch and above the inferior wall of the lower right pulmonary vein (ie, hilar structures), and upper zone (5 or 6) is above the inferior wall of the aortic arch.

# Results

## Patient Characteristics

The characteristics of patients were summarized in (Table 1). This study included 115 men (51.1%) and 110 women (48.9%), with a mean age of 53 (21–81) years. Most presented with mild pneumonia (29.8%), and no comorbidities (51.1%).

## Chest Radiography Features

Out of 225 patients, 210 patients had abnormal chest radiograph findings as shown in (Table 2). The distribution of lesions was mostly upper, middle and lower zone predominance (103 of 225; 45.6%). A total of 179 out of 225 (79.2%) presented with lesions on bilateral lungs, and 121 out of 225 (53.5%) were peripheral dominant. Other features of CXR included pleural effusion in 28 patients (12.4%) and pulmonary nodules in 33 patients (14.6%).

## Chest Radiography Scoring and Clinical Feature

Based on the RALE scores, most patients of all clinical characteristics scored 5 (17.3%). Asymptomatic patients and those with mild pneumonia mostly scored 2 (11 patients, 4.9%, and 17 patients, 7.6%). Patients with severe pneumonia mostly scored in 5 (9 patients, 4%), while those with ARDS mostly scored 4 and 5 (4 patients, 1.8%). Septic patients mostly scored 7 (7 patients, 3.1%), while patients with septic shock mostly scored 5 (7 patients, 3.1%).

On the other hand, the Brixia scores ranged from 0 to 18. Most patients scored 6 (22 patients, 9.8%). Asymptomatic patients scored 6 (11 patients, 4.9%), while most of the patients with mild pneumonia scored 5 (8 patients, 3.6%); those with severe pneumonia scored 7 (7 patients, 3.1%); those with ARDS patients scored 6; 15, and 18 (2 patients, 0.9%); septic patients scored 6 (5 patients, 2.2%); and septic shock patients scored 14 (6 patients, 2.7%).

The Modified Chest X-ray score ranged from 0 to 12. Most patients scored in 6 (30 patients, 13.3%), while there were no patients who scored 13–17. Asymptomatic patients mostly scored in 6 (11 patients, 4.9%); patients with mild pneumonia mostly scored in 9 (11 patients, 4.9%); patients with severe pneumonia mostly scored in

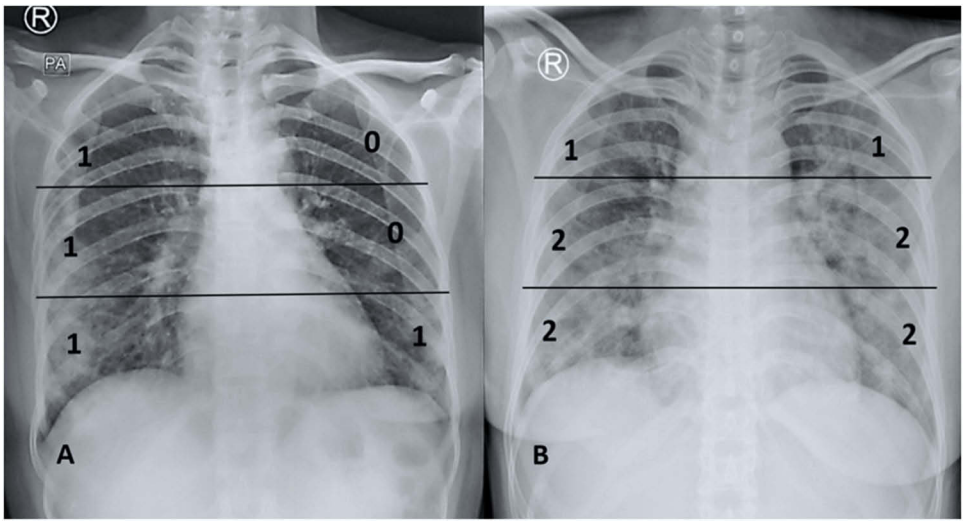


**Figure 2.** Two case illustrations of applying Modified Chest X-ray Scoring System on AP projection. (**A**). The total calculated score of the 6 chest divisions is 4, classified as mild severity score. (**B**) The total calculated score of the 6 chest divisions is 9, classified as severe severity score.

6 (10 patients, 4.4%). ARDS patients scored in 7 (4 patients, 1.8%); septic patients mostly scored in 5 (6 patients, 2.7%); while patients with septic shock mostly scored in 10 (7 patients, 3.1%).

Based on (Table 3), most patients were classified as severe based on the CXR score classification (92 patients, 40.89%). Most patients with mild CXR score classification also presented with mild clinical presentation (19 patients, 44.19%). Those classified as moderate were mostly asymptomatic and had a clinical feature of mild pneumonia (23 patients, 25.5%), while those classified as severe in CXR classification mostly had mild pneumonia as a clinical feature (25 patients, 27.17%)

## Correlation of Chest Radiography Scoring Categorized and Clinical Feature

The correlation coefficient of the CXR was 0.164 ($p<0.01$).

**Table 1.** Sample Characteristic at Presentation

| Parameter | No. of Patients (n = 225) |
|---|---|
| Patient Characteristic | |
| Male | 115 (51.1%) |
| Female | 110 (48.9%) |
| Age (year) | 53 ± 13 |
| Comorbidities | |
| No comorbid | 115 (51.1%) |
| Hypertension | 10 (4.4%) |
| Obesity | 4 (1.8%) |
| Diabetes | 17 (7.6%) |
| Heart abnormalities | 5 (5%) |
| Other lung abnormalities | 6 (2.7%) |
| Renal abnormalities | 4 (1.8%) |
| Hepatitis | 9 (4.0%) |
| Combine comorbid | 40 (6.7%) |
| Others | 15 (6.5%) |

**Table 2.** Radiographic Findings on Chest Radiographs

| Radiographic Characteristic | No. of Findings (n = 225) |
|---|---|
| Normal chest radiograph | 15 (6.6%) |
| Distribution of lesion | |
| Upper Zone predominant | 1 (0.4%) |
| Middle Zone predominant | 4 (1.8%) |
| Lower Zone predominant | 33 (14.6%) |
| Upper and Middle zone predominant | 3 (1.3%) |
| Upper and Lower zone predominant | 1 (0.4%) |
| Middle and Lower zone predominant | 65 (28.8%) |
| Upper, Middle, and Lower zone predominant | 103 (45.6%) |
| Right Lung | 14 (6.2%) |
| Left Lung | 17 (7.5%) |
| Bilateral Lung | 179 (79.2%) |
| Peripheral predominant | 121 (53.5%) |
| Perihilar predominant | 5 (2.2%) |
| Peripheral and perihilar predominant | 84 (37.2%) |
| Lung Abormality Features on chest x-ray | |
| Reticular-nodular opacities | 33 (11.6%) |
| Patchy opacities | 35 (12.4%) |
| Consolidation | 187(66.1%) |
| Pleural effusion | 28 (9.8%) |

**Table 3.** Modified Chest X-Ray Scores and Clinical Feature Classification

| | Asymptomatic | Mild Pneumonia | Severe Pneumonia | ARDS | Sepsis | Septic Shock | Total |
|---|---|---|---|---|---|---|---|
| Mild | 8 | 19 | 5 | 3 | 4 | 4 | 43 |
| Moderate | 23 | 23 | 14 | 7 | 14 | 9 | 90 |
| Severe | 11 | 25 | 19 | 5 | 15 | 17 | 92 |

**Table 4.** Analysis Result Spearman Correlation of Modified Chest X-Ray, Brixia and RALE Scores

| | Brixia Score | RALE Score |
|---|---|---|
| Modified Chest-xray Score | r = 0.865<br>p < 0.001<br>n = 225 | r = 0.855<br>p < 0.001<br>n = 225 |
| RALE Score | r =0.802<br>p < 0.001<br>n = 225 | |

### Chest Radiography Scoring Correlation with Each Other

The correlation coefficient between the Modified chest X-Ray score and Brixia score was 0.865 ($p<0.01$), and the correlation coefficient of the Modified chest X-Ray score and RALE score was 0.855 ($p<0.01$) (Table 4). On the other hand, the correlation coefficient of Brixia and RALE score was slightly lower, which was 0.802 ($p<0.01$). This indicated that the Modified Chest X-ray Scoring System had a higher correlation coefficient relative to both established Brixia and RALE scoring systems.

## Discussion

In this pandemic, an accurate radiological approach is necessary for a more rapid classification of COVID-19 patients. CXR may not be as sensitive as CT, but it still plays a major role in developing countries that lack more sophisticated modalities. Moreover, CXR can be brought to the patient's bedside, minimizing the risk of cross-infections.[15] Although CXR has a low sensitivity to early-stage disease of COVID-19, it can be used for monitoring the advancement and preceding stages of COVID-19 especially in critical care.[16]

Signorino et al stated that Brixia score system to be a good scoring system that provided detailed presentation and distribution of the lung (6 regions) and a sensibility (4 levels).[17] Borghesi et al also stated that Brixia scoring is a very useful method for ranking the stratification risk of patients with COVID-19 infection based on the severity of cases.[10] However, Brixia scoring requires a trained radiologist to interpret a CXR, due to its more complex indicators and nature for diagnosing COVID-19 pneumonia. This could be an obstacle for primary healthcare physicians who require an accurate and simple technique for early diagnosis of COVID-19 pneumonia, but lack the knowledge and experience to do so. Meanwhile, RALE scoring can predict supplemental oxygen requirements and the need for ICU admission for mechanical ventilation.[15,18] Compared to Brixia, RALE scoring lacks a detailed and more complex indicator in scoring chest x-rays to diagnose COVID-19 pneumonia. We introduced the use of the Modified Chest X-ray Scoring System at Dr. Soetomo Academic General Hospital and compared it with the established Brixia and RALE scoring systems.

In this study, we found that most of the patients with severe clinical presentation (severe pneumonia, ARDS, sepsis, and septic shock) had 5 or more score with RALE scoring system. Meanwhile, patients with severe clinical presentation had 6 or more score with the Brixia scoring. The Modified Chest X-Ray scoring system showed 5 or more score for patients with severe clinical presentation.

All three scoring systems correlated significantly with one another. Modified Chest X-ray Scoring System of Dr. Soetomo General Hospital correlates more towards Brixia ($p<0.01$, correlation coefficient 0.865) than RALE ($p<0.01$, correlation coefficient 0.855). This result indicates the reliability of Modified Chest X-ray Scoring System in diagnosing COVID-19 pneumonia, and can help in the determination of management of COVID-19 patients early on. However, it should also be noted that COVID-19 patients do not always present with pneumonia.

Modified Chest X-ray Scoring System of Dr. Soetomo General Hospital helps medical professionals in diagnosing COVID-19 pneumonia through a simple and fast method. Further study regarding its efficacy on a larger scale and possibly more heterogeneous cases and should be performed in the hope of its implementation on multiple healthcare center with X-ray devices and without CT scans. Also, study of the correlation of the scoring and the

outcome of care with serial radiographs will add great value to predict patient condition, monitoring progression, later stages of COVID-19, and better management of the disease.

The main limitation of this study is the lack of comparison between the scoring systems and patient's clinical condition because some clinical data were only available in a small percentage of subjects. Another limitation of this study is the lack of comparison between chest x-ray score and patient comorbidities (ie, hypertension, diabetes, cardiovascular disease, and oncologic history) or final outcome.

## Conclusion

Chest radiography can be considered as a tool to diagnose or measure the severity of COVID-19 with certain approach through scoring systems such as Brixia Score, RALE Score, and the Modified Chest X-Ray score of Dr. Soetomo General Hospital, although it may still be less sensitive than CT-Scan. The modified scoring system can help determine COVID-19 patient's severity, especially in areas with shortages of resources and specialists.

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## Disclosure

The authors report no conflicts of interest in this work.

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