Research Article

Chest X-Ray Scoring System in COVID-19 Pneumonia: An Added Value in the Evaluation of the Disease Severity

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Abstract

Objectives: To analyze the added value of a new CXR scoring system in the evaluation of the COVID-19 pneumonia severity.

Methods: This retrospective study included, from March to April 2020, 169 (132M/37F) hospitalized COVID-19 patients, mean age 65.6±10.8 years; 57 had low-pressure ventilation (Group A), 50 positive-pressure ventilation (Group B) and 62 invasive ventilation (Group C). Two radiologists in consensus evaluated the CXRs using an 18-points scoring system. CXR scores were compared in each Group and among the three Groups. Then in each Group CXR scores were correlated with Pa02/Fi02 and, in Group C, with Simplified Acute Physiology Score (SAPS). Non-parametric tests were used.

Results: In Group A the median score at admission was 8 [Interquartile range (IR) 7-9] and the median of the highest scores was 9 [IR 8-10](p=0.0738). Median scores at admission and before the start of the ventilation (pre-ventilation) are resulted, in Group B, 10 [IR 8-10] and 11 [IR 10-14](p<0.0001) and, in Group C, 10 [IR 8-11] and 12 [IR 11-13](p<0.0001). In Group A the CXR scores at admission were lower than in Group C (p=0.0257), and the highest scores were lower than the pre-ventilation ones of Groups B (p=0.0018) and C (p=0.0001). The CXR scores correlated negatively with Pa02/Fi02 and positively with SAPS.

Conclusion: CXR scoring system could be an added value in the evaluation of COVID-19 pneumonia severity. With low-pressure ventilation, the CXR scores were lower than with positive-pressure and invasive ventilation. Furthermore, CXR scores showed negative correlation with Pa02/Fi02 and positive with SAPS.

Implications for practice: This new CXR scoring system could be a useful diagnostic tool to quantify the COVID-19 pneumonia severity and to guide to choice of the correct ventilation support.

Keywords: CXR, Chest X-ray, Coronavirus Disease, Scoring System

S evere acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is responsible for the new world-wide respiratory pandemic, called coronavirus disease 2019 (COVID-19).[1, 2]

Since the beginning, Radiological Departments played a crucial role in the diagnosis and in the assessment of the disease evolution.[3]

Computed tomography (CT) is the most accurate imaging modality to detect the lung abnormalities, especially in the early stage, and to assess the disease progression with serial chest CT exams at different times (from three to seven days).[4, 5]

These considerations are also reported in a consensus statement of the Fleischner Society, in which was explored the application of CT in the detection, evaluation and risk stratification of the patients with COVID-19.[6]

However, during COVID-19 pandemic, in the hospitals with a high number of patients admitted, the routine use of CT is difficult to sustain, due to the need to move many bed-ridden patients raising the risk of cross-infection and due to the necessity of frequent CT scanner disinfections with a huge increasing in time and in work for the whole Radiology Department. Moreover, serial chest CT exams cause an excessive cumulative radiation dose, with particular concern in young patients.[7, 8]

Finally, especially in hospital with reduced economic and medical resources, the use of dedicated CT scanner may disrupt radiological service availability.[9, 10]

Consequently, the American College of Radiology and the Society of Thoracic Radiology suggested considering portable chest X-ray (CXR) as an alternatives to CT for large-scale diagnosis and disease evolution control.[9, 11]

Although it is known that CXR has low sensitivity for diagnosis of COVID-19, its usefulness in the evaluation of the disease severity and in the follow-up of the evolution remains unclear.[12]

To improve the risk stratification, as already happened for the CT,[13] in our Radiology Department was introduced a new CXR scoring system to better quantify the lung disease severity and to aid in defining an appropriated level of care for patients. This new CXR scoring system (named Brixia Score), already used in previous works and based on an 18-point severity scale, ranks the pulmonary involvement according to the types and the extension of COVID-19 lung abnormalities.[14, 15]

Therefore, the purpose of this study is to analyze the added value of this CXR scoring system in the evaluation of the disease severity in COVID-19.

Methods

Study Population

The Institutional Review Board approved the study protocol. The Ethics Committee deemed is not necessary the informed patient consent.

In this retrospective study we enrolled, from March 01 to April 05, 2020, consecutive patients at our hospital with COVID-19 infection confirmed by real-time reverse transcription polymerase chain reaction with oropharyngeal swab. The enrolled patients, based on the type of respiratory support, were divided into three groups: with low-pressure ventilation (Group A), with positive-pressure ventilation (Group B) and with invasive ventilation (Group C). The inclusion criteria in Group A were the presence of CXR at admission and during hospitalization, in Groups B and

C the presence of CXR at admission and before the start of the ventilation (pre-ventilation). Exclusion criteria were inaccessible clinical data and CXR unavailable.

The final study population was composed by 169 patients, of which 57 in Group A, 50 in Group B and 62 in Group C. Patient's selection is illustrated in Figure 1.

Clinical Features

For each patient age, gender and PaO2/FiO2 were annotated. Finally, pre-ventilation Simplified Acute Physiology Score (SAPS) in Group C was collected.

Distribution gender and mean age were compared among the three Groups.

CXR Evaluation and Comparison

Two radiologists assessed in consensus the CXRs using an 18-points score system. In each CXR both lungs were divided into three equal parts: upper, middle and lower, for a total of six zones. Then a score (from 0 to 3) was assigned to each zone based on the lung abnormalities detected on frontal view as follow:

0 – no abnormalities;

1 – interstitial infiltrates;

2 – interstitial and alveolar infiltrates (interstitial predominance);

3 – interstitial and alveolar infiltrates (alveolar predominance).

The scores of the six lung zones were then added to obtain an overall CXR score ranging from 0 to 18. To minimize bias, two radiologists were blinded to patient histories.

In Group A the CXR scores at admission and the highest CXR scores during hospitalization were collected. In Groups B and C the CXR scores at admission and pre-ventilation were collected. In each Group the CXR scores at different times were compared.

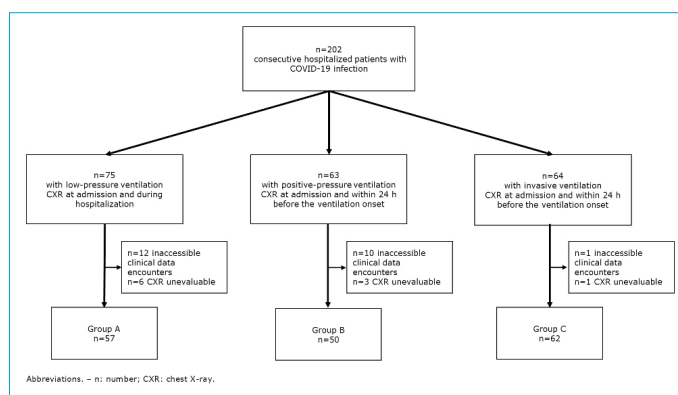Then, among the three Groups, the CXR scores at admis-

Figure 1. Patient's selection.

sion and the highest CXR scores of Group A with the pre-ventilation CXR scores of Groups B and C were compared.

CXR Score Correlation

In group A the highest CXR scores were correlated with the PaO2/FiO2 of the same day. In Groups B and C, the pre-ventilation CXR scores were correlated with the pre-ventilation PaO2/FiO2. Finally, in Group C, the pre-ventilation CXR scores were correlated with the pre-ventilation SAPS.

Statistical Analysis

A dedicated statistical software was used (MedCalc v19.1.6, MedCalc Software, Ostend, Belgium). Continuous variables were reported as mean±standard deviation and categorical variables as counts and percentages or as median and interquartile range. Mean age and gender distribution were compared between each group using, respectively, Friedman test and chi-square test. The CXR scores at different times were compared, in each group, using Wilcoxon test. The highest CXR scores of Group A and the pre-ventilation CXR scores of Groups B and C were compared using Friedman test for paired samples. CXR scores were correlated with Pa02/Fi02 and SAPS using Spearman's correlation. $p<0.05$ was defined as statistically significant.

Results

Study Population

Out of the 169 included patients, 132 (78.1%) were males and 37 (21.9%) females, mean age 65.6±10.8 [95% IC: 63.6-67.7] years. Patients' clinical features are illustrated in Table 1.

Table 1. Patients' clinical features

Features	All patients (n=169)
Age (y)	65.6 ± 10.8 [95% IC: 63.6-67.7]
Gender	
Male	132 (78.1%)
Female	37 (21.9%)
Height (cm)	170.6 ± 7.9 [95% IC: 168.6-172.7]
Weight (kg)	82.5 ± 14.0 [95% IC: 78.5-85.8]
Smoker	45 (26.6%)
Previous pathologies	
Pulmonary Hypertension	81 (47.9%)
Diabetes	40 (23.7%)
Pulmonary disease	29 (17.1%)
Renal disease	18 (10.6%)
Cardiovascular disease	30 (17.8%)
Oncologic disease	32 (18.9%)

Abbreviations. – n: number; IC: interval of confidence.

Clinical Features

Out of the 57 patients included in Group A, 47 were males and 10 females, mean age 64.7±11.5 [95% IC: 61.4-67.9] years. Out of 50 patients included in Group B, 38 were males and 12 females, mean age 64.9±10.8 [95% IC: 61.2-68.6] years. Out of the 62 patients included in Group C, 47 males and 15 females, mean age 66.6±9.9 [95% IC: 63.5-68.9]. No statistical difference was observed in mean age (p=0.6279) and in gender distribution (p=0.6212) among the three Groups.

CXR Evaluation and Comparison

A total of 338 CXR scored was selected.

In Group A, median CXR score at admission was 8 [IR 7-9] and the median of the highest CXR scores was 9 [IR 8-10], with no statistically significant difference (p=0.0738).

In Group B, median CXR score at admission was 10 [IR 8-10] and the median of the highest CXR scores was 10 [IR 10-14, range 0-16], with statistically significant difference (p<0.0001).

In Group C, median CXR score at admission was 10 [IR 8-11] and the median of the highest CXR scores was 12 [IR 11-13], with statistically significant difference (p<0.0001).

The CXR scores at admission in Group A were statistically lower than in Group C (p=0.0257), the highest CXR scores were lower than pre-ventilation scores of Group B (p=0.0018) and Group C (p=0.0001). CXR scores and their comparison are summarized in Table 2. Clinical cases of patients in each Groups are showed in Figures 2-4.

CXR Clinical Correlation

In group A, CXR scores had a significant negative correlation with PaO2/FiO2 (r=-0.297, p=0.0261).

In group B, CXR scores had a significant negative correlation with PaO2/FiO2 (r=-0.332, p=0.0224).

In group C, CXR scores had a significant negative correlation with PaO2/FiO2 (r=-0.267, p=0.0330), and they had a significant positive correlation with SAPS (r=0.308, p=0.0134).

Discussion

CT is considered the most effective method in the detection and evaluation of COVID-19 pneumonia,[16] but the increasing number of patients and the high challenge for cross-infection control make the routine use of CT difficult to sustain.[7] Therefore, the American College of Radiology and the Society of Thoracic Radiology suggested the use of portable CXR to avoid disruption of radiological service availability.[9,11,17] However, CXR usefulness in the evaluation of disease severity remains unknown.[12,18] An 18-point se-

Table 2. CXR scores and their comparison

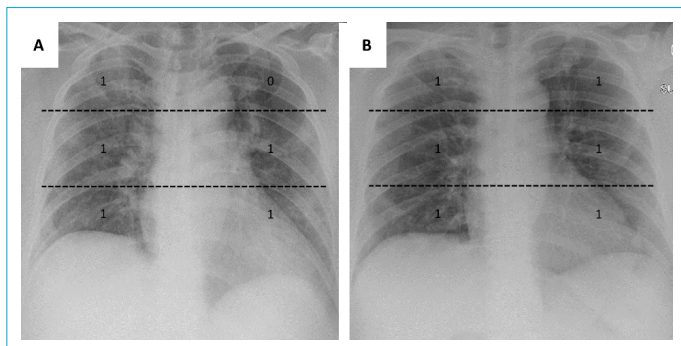| Group A	Group B	Group C	A vs B (p)	A vs C (p)	B vs C (p)
Admission 8 [IR 7-9]	Admission 10 [IR 8-10]	Admission 10 [IR 8-11]	0.1998	0.0257	0.2027
Highest 9 [IR 8-10] p=0.0738	Pre-ventilation 11 [IR 10-14] p<0.0001	Pre-ventilation 12 [IR 11-13] p<0.0001	0.0018	0.0001	0.8955

Figure 2. 61 year-old-female with low-pressure ventilation.
CXR at admission (a) had a score of 5, the highest CXR score during hospitalization was.
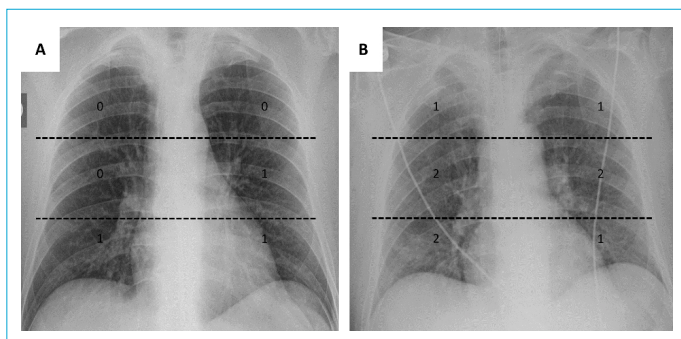

Figure 3. 64 year-old-male with positive-pressure ventilation.
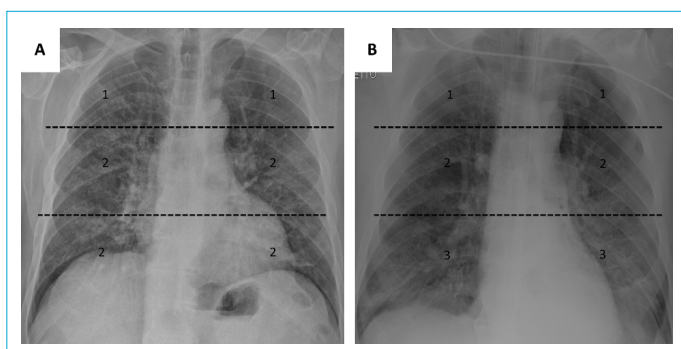CXR at admission (b) had a score of 3, and the pre-ventilation CXR had a score of 9.

Figure 4. 62 year-old-male with invasive ventilation.
CXR at admission (a) had a score of 10 and pre-ventilation CXR had a score of 12.

verity scale CXR scoring system[14, 15] was introduced in our Radiology Department to improve the evaluation of the severity and progression of COVID-19 lung abnormalities.

Therefore, the purpose of this study was to evaluate the added value of this new CXR scoring system in the assessment of disease severity in COVID-19.

In our study, there was a male predominance of positive COVID-19 cases in all three groups, without a significant difference between groups in gender distribution.

In the present study, in patients with low-pressure ventilation, CXR scores at admission were not statistically different from the highest CXR scores during hospitalization (p=0.0738). On the contrary, in patients with positive-pressure and invasive ventilation, CXR scores at admission were significantly lower than the pre-ventilation ones (p<0.0001). These results could suggest that in the latter two groups the higher pre-ventilation CXR scores are related to the higher severity of lung disease progression, while in patients with low-pressure ventilation the lung disease progression is lower.

Interestingly, the admission CXR scores in patients with low-pressure ventilation were lower than in patients with invasive ventilation. This could be explained because patients with a mild clinical course have also a lower initial pulmonary involvement. In support of this hypothesis, patients with a moderate or severe clinical course, in which a positive-pressure or invasive ventilation was needed, had no statistically difference in admission CXR scores (p=0.2027). Based on these results, our CXR score system could have a predictive role in the risk stratification of the disease severity progression.

Moreover, the highest CXR scores in Group A were statistically lower than the pre-ventilation CXR scores in Group B (p=0.0018) and Group C (p=0.0001). This result is also noteworthy because the CXR score system could have an important added value in the selection of patients who need a greater respiratory support (positive-pressure or invasive ventilation).

In each group, CXR scores had a significant negative correlation with Pa/FiO2, probably because a higher or lower CXR score is related to a major or minor lung disease se-

verity and consequent reduction or increment of alveolar gas exchange. Based on this result, CXR score system could have a role in the description of lung disease severity and could have a direct relationship with the lung functional involvement.

Finally, in our work, CXR scores correlate positively with SAPS in patients with invasive ventilation. Consequently, we hypothesized that our CXR scoring system could have a prognostic role in the disease progression in Intensive Care Unit patients. Therefore, our study, as with previous work, confirmed that the radiological quantification of the disease severity and the evaluation of the disease progression with CXR is extremely important in the management and in the choice of the more appropriate respiratory support for infected patients.[14]

These results are similar with other previous studies that investigated the role of chest CT in predicting disease course in COVID-19. Indeed, Wang et al.[19] created a prognostic model, based on the CT visual severity score, with a strong performance in predicting in-hospital complications and Erturk et al.[20] concluded that CT examinations performed early could predict the disease course, allowing to plan of resources, such as ICU beds.

Moreover, using the same scoring system, Borghesi et al. showed a significant positive correlation between the CXR score and age in both males and females and demonstrated that higher CXR scores are strongly associated with in-hospital mortality.[14,15]

This study has some limitations. First, it is a retrospective mono-centric study. Second, this study does not evaluate the CXR scores during the hospitalization, but only at selected different times. Thirdly, radiologists scored the CXR in consensus and the accordance was not evaluated.

The role of CXR, in this new viral pneumonia, could be further enhance using this 18-points scoring system and, above all, radiologists will able to provide clear and relevant information to aid in the management of patients with CO-VID-19 disease. This score could be an added value in the evaluation of COVID-19 severity, it could have a predictive role in the risk stratification of lung involvement and, therefore, in the selection of patients who need a stronger respiratory support; finally, it could have a prognostic role in the disease progression in Intensive Care Unit patients.

We believe that, in the current emergency setting and, later, during follow-up of the disease, this CXR scoring system could be a useful diagnostic tool in the assessment of lung abnormalities in COVID-19.

However, further similar prospective multi-centric studies are needed to confirm our hypothesis.

References

1. Zhu N, Zhang D, Wang W, Li X, Yang B, Song J, et al.China Novel Coronavirus Investigating and Research Team. A novel Coronavirus from patients with pneumonia in China, 2019. N Engl J Med 2020;382:727–33.
2. Sun P, Lu X, Xu C, Sun W, Pan B. Understanding of COVID-19 based on current evidence. J Med Virol 2020;92:548–51.
3. Zu ZY, Jiang MD, Xu PP, Chen W, Ni QQ, Lu GM, Zhang LJ. Coronavirus disease 2019 (COVID-19): a perspective from China. Radiology 2020;296:E15–E25.
4. Bernheim A, Mei X, Huang M, Yang Y, Fayad ZA, Zhang N, et al. Chest CT findings in Coronavirus disease-19 (COVID-19): Relationship to duration of infection. Radiology 2020;295:200463.
5. Pan F, Ye T, Sun P, Gui S, Liang B, Li L, et al. Time course of lung changes at chest CT during recovery from Coronavirus disease 2019 (COVID-19). Radiology 2020;295:715–21.
6. Rubin GD, Ryerson CJ, Haramati LB, Sverzellati N, Kanne JP, Raoof S, et al. The role of chest imaging in patient management during the COVID-19 pandemic: a multinational consensus statement from the Fleischner Society. Chest 2020; 158:106–16.
7. Zhang HW, Yu J, Xu HJ, Lei Y, Pu ZH, Dai WC, et al. Corona virus international public health emergencies: implications for radiology management. Acad Radiol 2020;27:463–7.
8. Cozzi D, Albanesi M, Cavigli E, Moroni C, Bindi A, Luvarà S, et al. Chest X-ray in new Coronavirus disease 2019 (COVID-19) infection: findings and correlation with clinical outcome. Radiol Med 2020;125:730–7.
9. ACR Recommendations for the use of Chest Radiography and Computed Tomography (CT) for Suspected COVID-19 Infection. American College of Radiology 2020. Available at: https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Recommendations-for-Chest-Radiography-

and-CT-for-Suspected-COVID19-Infection. Accessed Nov 29, 2021.

10. Lone SA, Ahmad A. COVID-19 pandemic - an African perspective. Emerg Microbes Infect 2020;9:1300–8.

11. Wong HYF, Lam HYS, Fong AH, Leung ST, Chin TW, Lo CSY, et al. Frequency and distribution of chest radiographic findings in patients positive for COVID-19. Radiology 2020;296:72–8.

12. Toussie D, Voutsinas N, Finkelstein M, Cedillo MA, Manna S, Maron SZ, et al. clinical and chest radiography features determine patient outcomes in young and middle-aged adults with COVID-19. Radiology 2020;297;197–6.

13. Liu X, Zhou H, Zhou Y, Wu X, Zhao Y, Lu Y, Tan W, Yuan M, Ding X, Zou J, Li R,. Temporal radiographic changes in COVID-19 patients: relationship to disease severity and viral clearance. Sci Rep 2020;10:10263.

14. Borghesi A, Maroldi R. COVID-19 outbreak in Italy: experimental chest X-ray scoring system for quantifying and monitoring disease progression. Radiol Med 2020;125:509–13.

15. Borghesi A, Zigliani A, Masciullo R, Golemi S, Maculotti P, Farina D, et al. Radiographic severity index in COVID-19 pneumo-nia: relationship to age and sex in 783 Italian patients. Radiol Med 2020;125:461–4.

16. Fraiman JB. Chest CT and Coronavirus disease (COVID-19): a more complete review. AJR Am J Roentgenol 2020;215:W35.

17. De Barry O, Obadia I, El Hajjam M, Carlier RY. Chest-X-ray is a mainstay for follow-up in critically ill patients with covid-19 induced pneumonia. Eur J Radiol 2020;129:109075.

18. Schiaffino S, Tritella S, Cozzi A, Carriero S, Blandi L, Ferraris L, et al. Diagnostic performance of Chest X-Ray for COVID-19 pneumonia during the SARS-CoV-2 pandemic in lombardy, Italy. J Thorac Imaging 2020;35:105–6.

19. Wang X, Hu X, Tan W, Mazzone P, Mireles-Cabodevila E, Han X, et al. Multicenter study of temporal changes and prognostic value of a CT visual severity score in hospitalized patients with Coronavirus disease (COVID-19). AJR Am J Roentgenol 2020;217:83–92.

20. Erturk SM, Durak G, Ayyildiz H, Comert RG, Medetalibeyoglu A, Senkal N, et al. A Covid-19: correlation of early chest computed tomography findings with the course of disease. J Comput Assist Tomogr 2020;44:633–9.