COVID-19 outbreak in Italy: Experimental chest x-ray scoring system for quantifying and monitoring disease progression

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Short Report

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Abstract

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is a new virus recently isolated from humans. SARS-CoV-2 was discovered to be the pathogen responsible for a cluster of pneumonia associated with severe respiratory disease occurred in December 2019 in China. This novel pulmonary infection, formally called coronavirus disease 2019 (COVID-19), has spread rapidly in China and beyond. On 8 March 2020, the number of Italians with SARS-CoV-2 infection was 7375 with a 48% hospitalization rate.

At present, chest computed tomography imaging is considered the most effective method for detection of lung abnormalities in early-stage disease and for quantitative assessment of severity and progression of COVID-19 infection. Although chest x-ray (CXR) is considered not sensitive for the detection of pulmonary involvement in the early stage of disease, we believe that, in the current emergency setting, CXR can be a useful diagnostic tool for monitoring the rapid progression of lung abnormalities in infected patients, particularly in intensive care units.

In this article we present our experimental CXR scoring system that we are applying in hospitalized patients with COVID-19 pneumonia to quantify and monitor the severity and progression of this new infectious disease. We also present the results of our preliminary validation study on a sample of 100 hospitalized patients with SARS-CoV-2 infection for whom the final outcome (*recovery or death*) was available.

Introduction

Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV–2) is a new virus recently isolated from humans. This new virus is a betacoronavirus that belongs to the Orthocoronavirinae subfamily of the Coronaviridae family [1, 2]. SARS-CoV–2 was discovered to be the pathogen responsible for a cluster of pneumonia associated with severe respiratory disease occurred in December 2019 in China, in Wuhan (the capital of the province of Hubei) [1]. This novel pulmonary infection, formally called Coronavirus Disease 2019 (COVID–19) [3], has spread rapidly in many other Chinese provinces and beyond [2, 4].

On 21 February 2020, SARS-CoV–2 infection was also detected in Northern Italy. Since then, the number of SARS-CoV–2 infection cases has grown exponentially. On 8 March 2020, the number of Italians with SARS-CoV–2 infection was 7375 with a 48% hospitalization rate (18% in intensive care unit) and a 5% mortality rate.

At present, the reference standard to make a definitive diagnosis of SARS-CoV–2 infection is the reverse-transcription-polymerase-chain-reaction assay [5].

Radiological imaging plays a crucial role in the detection and management of COVID–19 patients. Computed tomography (CT) imaging is considered the most effective method for detection of lung abnormalities, particularly in the early stage of disease [4, 6–12]. Moreover, serial chest CT imaging with

different time intervals (from three to seven days) is also effective to assess the disease evolution (from initial diagnosis of COVID–19 to patient discharge) [6, 7, 13].

However, the increasing number of hospitalized patients and the consequent increase of radiological examinations make the constant use of chest CT scan (from diagnosis to discharge) difficult to sustain over time. Therefore, in our Radiology Department we are trying to limit the use of CT imaging for monitoring patients with confirmed infection.

Although chest x-ray (CXR) is considered not sensitive for the detection of pulmonary involvement in early-stage disease [4, 14], we believe that, in the current emergency setting, CXR (standard or beside) can be a useful diagnostic tool for monitoring (*"day after day")* the rapid progression of lung abnormalities in COVID–19, particularly in critical patients admitted to intensive care units.

The radiological quantification of severity and progression of lung abnormalities is of great importance to define the appropriate clinical management and respiratory support for infected patients. At the present time, two different CT scoring systems and one CXR scoring system were used to quantify the pulmonary involvement in COVID–19 infection [6, 7,11]. This CXR scoring system is a simple five-point grading tool that was proposed in 2015, and it was designed for non-radiologist clinicians [15]. The goal of this scoring system was to facilitate the clinical grading of CXR reports into five different severity categories in hospitalized patients with acute respiratory infection.

Therefore, to the best of our knowledge, there are no published papers in which a dedicated CXR grading system for COVID–19 pneumonia has been designed for radiologists.

The aim of this short communication is to present our experimental CXR scoring system that we are applying in hospitalized patients with COVID–19 pneumonia. We also assessed the validity of this CXR scoring system on a sample of 100 hospitalized patients with SARS-CoV–2 infection for whom the final outcome (*recovery or death)* was available

Materials And Methods

CXR Scoring System

Based on current knowledge about the common chest CT finding in COVID-19 pneumonia (ground-glass opacity with or without patchy consolidation) [4, 6-8, 10-12] we have designed a dedicated CXR scoring system for hospitalized patients with SARS-CoV-2 infection (confirmed by RT-PCR).

Our CXR scoring system for COVID-19 pneumonia includes two steps of imaging analysis.

The first step is to divide the lungs into six zones on frontal chest projection (posteroanterior or anteroposterior projection according to the patient position) (Fig. 1):

- Upper zones (*A and D*): above the inferior wall of the aortic arch

- Middle zones (*B and E*): below the inferior wall of the aortic arch and above the inferior wall of the right inferior pulmonary vein (i.e. the hilar structures)
- Lower zones (*C and F*): below the inferior wall of the right inferior pulmonary vein (i.e. the lung bases)

For technical reasons (for example bedside CXR in critical patients), it may be difficult to identify some anatomical landmarks. In these cases, we recommend dividing each lung into three equal zones.

The second step is to assign a score (from 0 to 3) to each zone based on the lung abnormalities detected on frontal chest projection as follows (Fig 2):

- Score 0: no lung abnormalities
- Score 1: interstitial infiltrates
- Score 2: interstitial and alveolar infiltrates (interstitial predominance)
- Score 3: interstitial and alveolar infiltrates (alveolar predominance)

The scores of the six lung zones are then added to obtain an overall "*CXR SCORE*" ranging from 0 to 18.

The "CXR SCORE" is entered at the end of the descriptive report. Near to the overall score, the partial score of each zone (from A to F) is also entered between square brackets.

Other CXR findings (such as pleural effusion, pulmonary vessel enlargement etc.), not included in the scoring system, are recorded in the descriptive part of the CXR report

An example of our CXR report is shown below:

> CHEST X-RAY
> Symmetrical lung expansion
> Interstitial and alveolar infiltrates in the middle and lower zones of both lungs, greater to the left side.
> No pleural effusion.
> Mediastinum and heart size within normal limits.
> *CXR SCORE: 10 [022033]*

Validation study sample and statistical analysis

To assess the validity of our CXR scoring system, we selected 100 hospitalized patients with SARS-CoV-2 infection for whom the final outcome (*recovery or death*) was available. The selected sample was obtained from a search in our departmental digital archive between March 4, 2020 and March 16, 2020. All CXR reports containing the new scoring system were retrieved. For each patient, only the CXR report containing the highest score was considered for the validation study. The frontal chest projection linked to these 100 CXR reports were independently read by an experienced thoracic radiologist who reassigned the score for each CXR exam.

To determine the agreement between radiologists in applying the new CXR scoring system, the first score of each CXR examination was compared with the second score reassigned by the experienced thoracic radiologist. To assess this agreement, the weighted kappa and 95% confidence interval (CI) were calculated. We use the weighted kappa (specifically the linear weighted kappa) because the CXR score system was designed on an 18-point continuous-ordinal scale and the degree of disagreement between the scores had a different weight. The Mann-Whitney U-test was also used to compare the CXR scores with the final outcome (*recovery or death*) of the selected patients. We used this non-parametric test because the CXR score was not normally distributed. The statistical analyses were performed using commercial software (MedCalc Statistical Software version 19, Ostend, Belgium). *P*-values of <0.05 were considered statistically significant.

Results

The score entered in the 100 CXR reports ranged from 0 to 16 (median, 6.5; interquartile range, 2–11). The CXR score reassigned by the thoracic radiologist ranged from 0 to 15 (median, 7; interquartile range, 3–10). The CXR scoring agreement was very good (k_w, 0.82; 95% CI, 0.79–0.86). For both semi-quantitative analyses (retrieved from report, and performed by the thoracic radiologist), the CXR score was significantly higher in patients who died than those discharged from the hospital ($p \leq 0.002$).

Discussion

In this article we presented our original CXR scoring system for COVID–19 pneumonia. This severity scoring system is designed exclusively for semi-quantitative assessment of severity and progression of pulmonary involvement in hospitalized patients with COVID–19 infection (Fig. 3). It is quite simple and can be easily replicated in other clinical realities.

We obviously realize that this method required further studies to confirm its validity because its score depends mainly on the quality of the CXR images and the experience of the observers. However, in our preliminary validation study we found that the inter-rater agreement was very good and the CXR score is a useful parameter for predicting mortality in hospitalized patients with SARS-CoV–2 infection.

In conclusion, we consider this scoring tool to be very promising due to its ability to provide, in a very clear and straightforward way, relevant information for clinicians enhancing the role of radiologists in this long and tiring battle against this new viral pneumonia.

Declarations

Funding

The author states that this work has not received any funding

Compliance with ethical standards

Conflict of interest/Competing interests

The authors declare that they have no conflict of interest

Ethical standards

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. This study was submitted to our local ethics committee as a retrospective analysis. Given the retrospective nature of this study and in accordance with current legislation, the need for informed consent for informed consent was waived.

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Figures

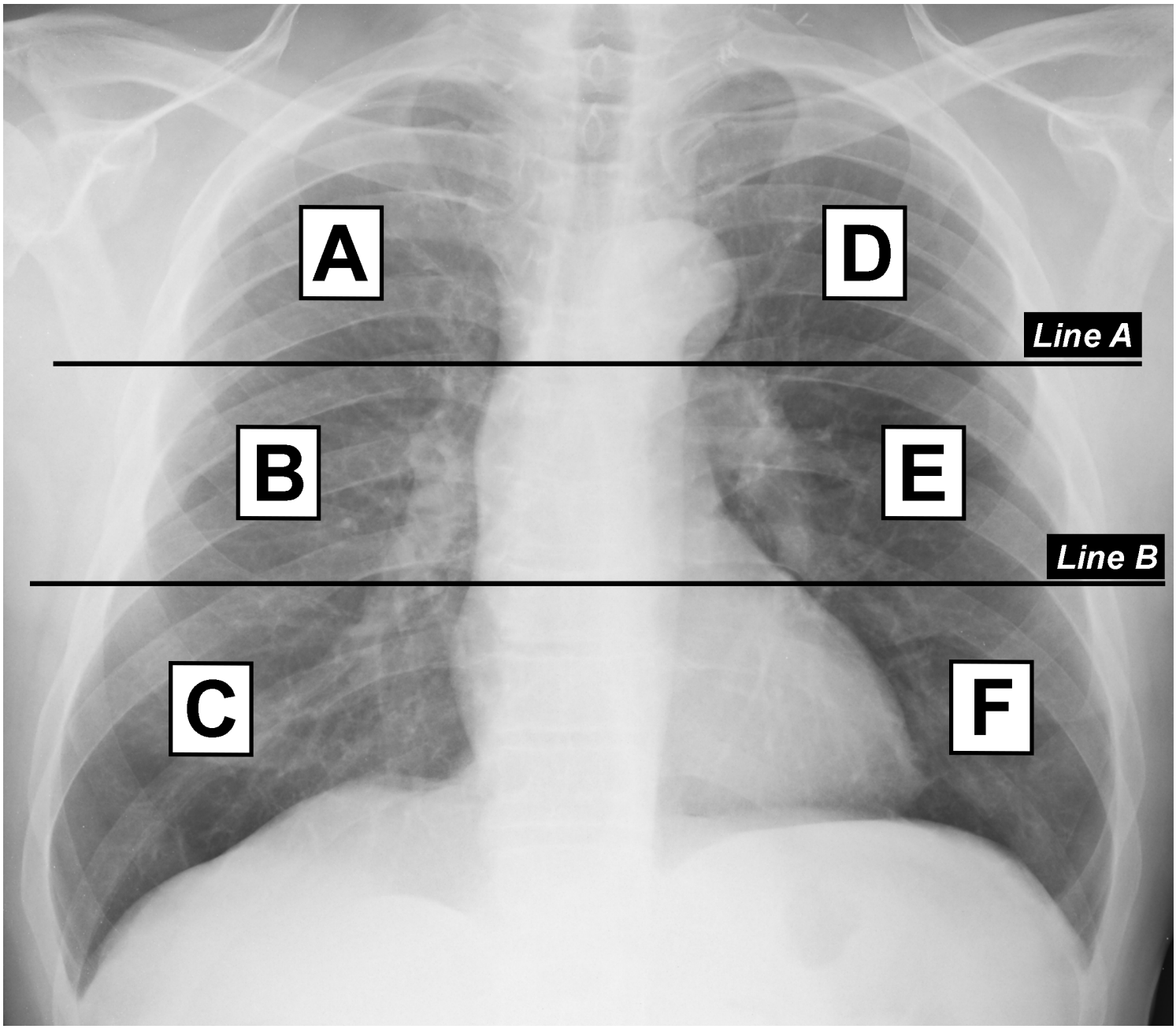

Figure 1

Division of lungs into six zones on frontal chest radiograph. The Line A is drawn at the level of the inferior wall of the aortic arch. The Line B is drawn at the level of the inferior wall of the right inferior pulmonary vein. A and D upper zones; B and E middle zones; C and F lower zones

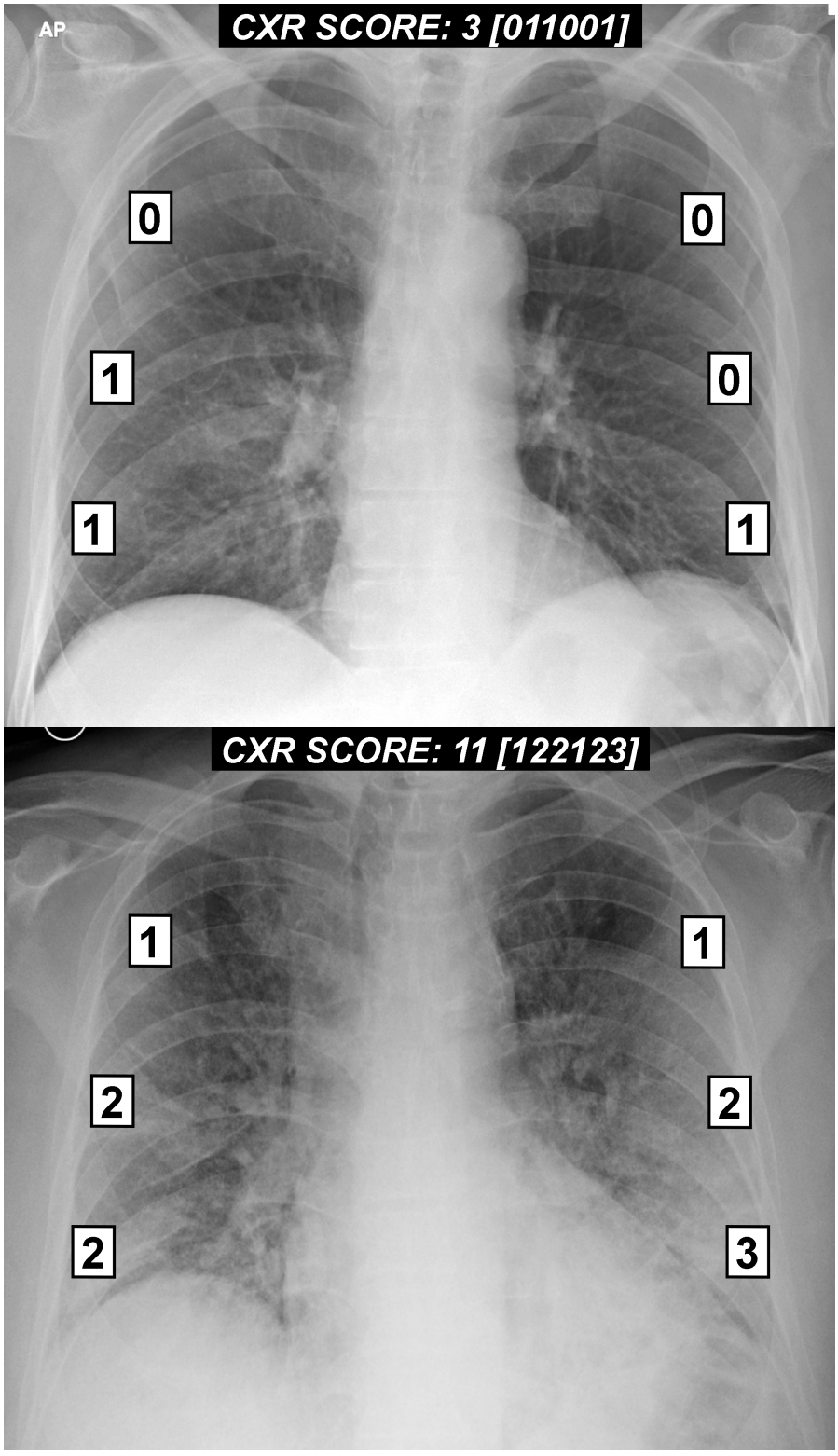

Figure 2

Examples of CXR scoring system in two different patients with COVID-19 pneumonia

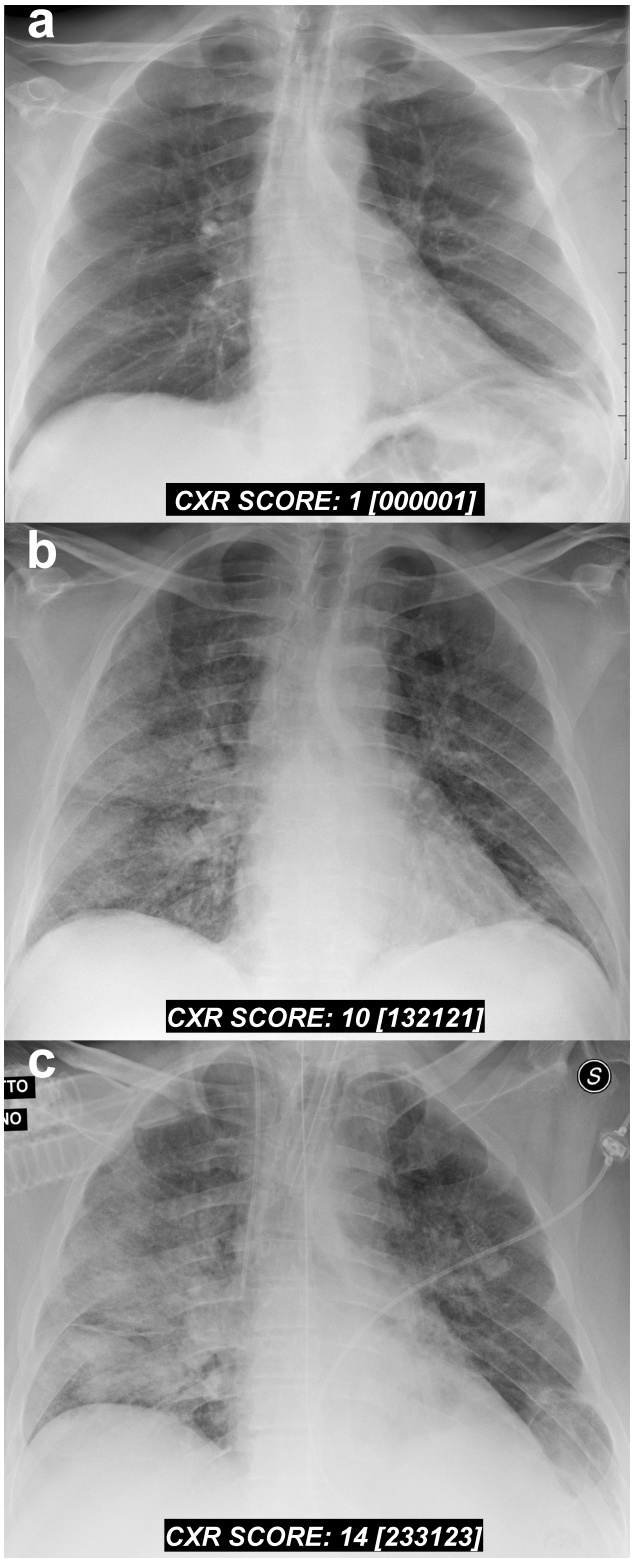

Figure 3

Serial chest x-ray findings in a 72-year-old male patient with COVID-19 pneumonia. a Baseline frontal chest radiograph performed on the day of admission (one day after onset of fever). b, c The radiographic follow-up performed four and five days after hospitalization shows rapid progression of the lung disease.