

# Chest X-Ray findings and visual quantitative assessment of COVID-19 pneumonia

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## Research Article

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# Abstract

## Aim

To assess the most common chest X-Ray findings and distribution in patients with confirmed diagnosis of COVID-19; to verify the repeatability of a radiological severity score, based on visual quantitative assessment; to assess the evolution of chest X-Ray findings at follow-up; to evaluate chest X-Ray sensitivity.

## Methods

We analysed chest X-Rays at baseline of 110 consecutive COVID-19 patients (79 males, 31 females; mean age:  $64 \pm 16$  years) with RT-PCR confirmation, who presented to our ED.

Two radiologists evaluated the imaging findings and distribution.

A severity score, based on the extension of lung abnormalities, was assigned by two other radiologists, independently, to the baseline and follow-up X-Rays, executed in 77/110 cases; interobserver agreement was calculated. Chest X-Ray sensitivity was assessed, with RT-PCR as gold standard.

## Results

Interobserver agreement was excellent for baseline and follow-up X-Rays (Cohen's  $K=0.989$ ,  $p<0.001$ , Cohen's  $K=0.985$ ,  $p<0.001$ , respectively). The mean score at baseline was  $2.87 \pm 1.7$  for readers 1 and 2. We observed radiological worsening in 52/77 (67%) patients, with significantly higher scores at follow-up (mean score:  $4.27 \pm 2.15$  for reader 1 and  $4.28 \pm 2.14$  for reader 2, respectively);  $p<0.001$ .

Ground glass opacities were the most common findings (97/110, 88%). Abnormalities showed bilateral involvement in 67/110 (61%), with prevalent peripheral distribution (48/110, 43.5%).

The X-Ray sensitivity for the detection of COVID-19 infection was 91%.

## Conclusion

Chest X-Ray highlighted imaging findings in line with those previously reported for chest CT. The use of a radiological score can result in clearer communication with Clinicians and a more precise assessment of disease evolution.

## Introduction

Since December 2019, COVID-19 (formerly known as 2019-nCoV) has been spreading from its initial cluster in China and globally, becoming a public health emergency of international concern. As of May 5, 2020, there are 3 517 345 confirmed cases of COVID-19 infections worldwide, in more than 200 countries [1].

Chest computed tomography (CT) has become an essential technique to identify parenchymal abnormalities, in the diagnosis of the disease, follow-up, and assessment of treatment effectiveness [2].

Some authors proposed its use as a first-line triage for COVID-19 infection in epidemic areas, due to its high sensitivity, even higher than real-time polymerase chain reaction from nasopharyngeal swabs [3,4].

However, the American College of Radiology (ACR) does not recommend the use of chest CT to screen patients for COVID-19 infection and advises its use in specific clinical indications [5]. ACR also suggests the use of portable radiography equipment to perform chest X-Rays in COVID-19 patients, when a lung evaluation is medically needed.

Moreover, the increasing number of COVID-19 positive patients worldwide makes the use of chest CT in all patients impossible, both for the huge burden on Radiology Departments, and for the need to dedicate CT scanners to positive or suspected positive patients only, with the application of strict procedures of infection control [6]. In this scenario, the role of chest X-Ray should be assessed. Thanks to its wide availability, rapid execution, low cost, and the possibility of acquisition at the patient bed, chest X-Ray represents an essential tool for the assessment of lung abnormalities in routine and emergency settings.

One recently published article supported the use of chest X-Ray in the study of COVID-19 patients [7]. The authors reported the chest X-Ray findings, at baseline and follow-up, of 64 patients with COVID-19 infection confirmation by reverse transcription polymerase chain reaction (RT-PCR) on swabs, and proposed a radiographic severity score of 0-8, depending on the extent of involvement by consolidation or ground glass opacities (GGO).

Our aims were: (i) to assess most common X-Ray findings and their distribution in a case series of consecutive patients with a confirmed diagnosis of COVID-19 infection by RT-PCR from nasopharyngeal swab; (ii) to verify the repeatability of the previously proposed severity score [7]; (iii) to assess the evolution of chest X-Ray findings at follow-up; (iv) to evaluate chest X-Ray sensitivity in detecting COVID-19 pneumonia, in a high pre-test probability environment.

## Methods

This retrospective study has been approved by our Institutional Review Board; patients consent was provided.

### Patients

We included in our analysis 110 consecutive patients (79 males, 31 females; mean age:  $64 \pm 16$  years) who presented to our Emergency Department with symptoms suspected for COVID-19 infection and executed a chest X-Ray upon admission (X-Ray 1), with RT-PCR COVID-19 diagnosis confirmation (Charité, Berlin, Germany), executed from oropharyngeal swabs [8]. Days between the onset of symptoms and patient presentation were  $6.6 \pm 3.6$  days (range: 1-15 days).

77/110 (70%) also executed a chest X-Ray follow up at  $5.4 \pm 2.5$  days (X-Ray 2).

## Image acquisition and analysis

All chest X-Rays were acquired according to our standard protocol. 9/110 (8%) X-Rays 1 were acquired in both posteroanterior and laterolateral projections, whereas 101/110 (92%) X-Rays 1 and 77/77 (100%) X-Rays 2 were acquired in the anteroposterior projection using portable X-Ray units.

Lung abnormalities were diagnosed as consolidation, ground glass opacities (GGO), or nodules, according to the Fleischner Society glossary of terms [9], by two experienced radiologists in consensus. Pleural effusion was also recorded.

Distribution of the lung changes was classified into unilateral and bilateral; into peripheral predominance, perihilar predominance, and peripheral + perihilar involvement; into upper zone, lower zone predominance, and without predominance.

A previously proposed severity score, based on the visual assessment of the extent of GGO and consolidation, and consisting of: 0 = no involvement; 1 = <25%; 2 = 25–50%; 3 = 50–75%; 4 =  $\geq$  75% of involvement [7], was assigned for the 187 chest X-Rays by two other experienced radiologists, independently, with a maximum of 4 for each lung, and a maximum global score of 8. Some examples of score assignment are provided in Figure 1.

The mean severity score was calculated for X-Rays 1 and 2.

X-Ray severity score >0 was considered as positive chest X-Ray. To assess sensitivity, the results of X-Ray 1 were compared with RT-PCR (positive in 110/110, 100%).

5/110 patients (4.5%) with negative X-Rays 1, due to high clinical suspicion of COVID–19 infection, underwent a chest CT, while waiting for the results of the swab. Chest CT findings were assessed by two radiologists in consensus.

The increase of the severity score in X-Rays 2, in comparison to X-Rays 1, was considered as a worsening of the radiological findings.

Statistical analysis was performed using SPSS 20 (IBM, Chicago, IL).  $P < 0.05$  was considered statistically significant.

Paired sample test was used to assess the difference between the severity scores of chest X-Ray 1 and 2. Interobserver agreement was assessed through Cohen's  $k$  coefficient.

## Results

### Patients

Patients' clinical presentation is listed in Table 1. The most frequently reported symptom at patients' arrival was fever (88/110, 80%), with a mean temperature of  $37.9\pm 0.7^\circ$ . Oxygen saturation (SpO<sub>2</sub>) range was 77–97% (mean:  $91.7\pm 6.8$ ), 10/110 (9%) patients were in oxygen therapy.

The most common comorbidity was hypertension (32/110, 29%), followed by cardiovascular disease (20/110, 18%) (Table 1). Blood tests are listed in Table 1.

### Image analysis

GGO were the most common finding (97/110, 88%), followed by consolidation (51/110, 46%) (Figure 2); 48/110 (43.5%) chest X-Rays showed both findings. Nodules were not reported. Pleural effusion was observed in 5/110 (4.5%) cases. Chest abnormalities showed bilateral involvement in 67/110 (61%), with a prevalent peripheral distribution (48/110; 43.5%), followed by perihilar and peripheral (35/110, 32%) and by perihilar distribution (16/110, 14.5%).

Lower zone predominance was found in 60/110 (54.5%) patients, no zone predominance, with diffuse involvement was observed in 50/110 (45.5%), whereas no lower zone predominant involvement was detected.

Inter-observer agreement was excellent both for X-Rays 1 and X-Rays 2 (Cohen's K = 0.989,  $p < 0.001$ , Cohen's K = 0.985,  $p < 0.001$ , respectively). The mean score for X-Rays 1 was  $2.87\pm 1.7$  for both readers 1 and 2.

31/110 (28%) showed mild findings with a total severity score of 1 or 2 for both readers. 6/110 (5.4%) patients had scores of 7 or 8, for both readers.

We observed radiologic findings worsening in 52/77 (67.5%) of patients (Figure 3); X-Rays 2 showed significantly higher scores than X-Rays 1 (mean score:  $4.27\pm 2.15$  for reader 1 and  $4.28\pm 2.14$  for reader 2, respectively);  $p < 0.001$ . 17/77 (22%) X-Rays 2 showed stability and 8/77 (10%) showed an improvement of imaging findings.

100/110 (91%) patients had positive chest X-Rays 1. Therefore, in our case series, chest X-Ray at baseline showed sensitivity for the detection of COVID–19 infection of 91%. In patient with negative X-Ray who underwent chest CT, 4 out of 5 (80%) chest CT showed lung abnormalities [3/4 (75%) patients showed areas of crazy paving pattern; 3/4 (75%) showed patchy GGO; 1/4 (25%) showed consolidation] (Figure 4), whereas 1 out of 5 (20%) was negative.

## Discussion

Thanks to its wide availability, rapid execution, and low cost, chest X-Ray can be considered as a first-line tool in the assessment of lung abnormalities, also in the context of COVID–19 emergency.

The study by Wong et al retrospectively assessed the performance of chest X-Ray in COVID-19 infection, on 64 patients, who executed chest X-rays at baseline and follow-up, for a total of 255 examinations [7]. They observed that consolidation was the most common finding (47%), followed by GGO (33%); chest abnormalities were bilateral in 50% of cases, with a peripheral distribution in 41% of cases and prevalent involvement of the lower zones in 50%. Pleural effusion was found in 3% of patients. They also proposed a radiograph score for a quantification of the consolidation and GGO according to their extension: 0 = no involvement; 1 = <25%; 2 = 25–50%; 3 = 50–75%; 4 = >75% involvement, but in their study the score was assigned by two radiologists in consensus, therefore the inter-observer reliability was not analysed. At baseline, 41% of patients had a severity score of 41%, and no patient had a score > 6.

In their case series, 31% of patients had a normal baseline X-Ray, with reported a sensitivity of 69%, when compared to RT-PCR, and the presence of one patient with falsely negative chest X-Ray, when compared to CT.

In our study, GGO were the most common findings (88%), followed by consolidation (51/110, 46%), and this is in line with the features previously observed on chest CT [10–14].

Pleural effusion was observed in 5/110 (4.5%) of cases.

Chest X-Rays baseline abnormalities showed bilateral involvement in 67/110 (61%), with a prevalent peripheral distribution (48/110; 43.5%), followed by perihilar and peripheral (35/110, 32%) and by perihilar distribution (16/110, 14.5%), and a predilection for the lower zones. Therefore, we confirmed that chest X-Ray findings and distribution are similar to those previously reported for chest CT [10–16].

In our case series, X-Ray showed a high value of sensitivity, higher than the one reported by Wong et al [7]. The possible explanation of this difference has been recently provided by the Fleischner Society [17]: the sensitivity of chest X-Ray is variable according to the community norms and public health directives, in countries where patients are encouraged to present early in the course of their disease, as in China, X-Ray showed limited value, whereas in a context where patients are recommended to stay at home till advanced symptoms, chest X-Ray is generally positive at the time of presentation.

This article also highlighted that the equipment portability is an important advantage of chest X-Ray, which eliminates the risk of COVID-19 transmission along the transport route to the CT scanner and in the CT suite [17].

A different severity scoring system for chest X-Ray has recently been proposed by Borghesi and Maroldi [18]. The authors proposed a lung division into six zones on frontal chest projection, with attribution of a score based on the types of abnormalities: 0 = no lung abnormalities; 1 = interstitial infiltrates; 2 = interstitial and alveolar infiltrates (interstitial predominance); 3 = interstitial and alveolar infiltrates (alveolar predominance), with a possible maximum global score of 18. This score showed high inter-observer agreement and had significant correlation with the patients' outcome, being higher in patients who died than those who were discharged.

The same score was also applied in another study [19] on 783 Italian patients, and proved to have significant correlation with sex (males had significantly higher scores than females), and age (males aged  $\geq 50$  years and females aged  $\geq 80$  years showed the highest scores).

This study has several limitations. First, in our institution chest CT was not routinely executed in COVID-19 patients, therefore a gold standard imaging was not available for comparison. Second, as we selected only COVID-19 positive patients in our case series, we assumed no false positive or true negative patient was present.

Third, the timing of the baseline X-Ray acquisition in relation to the onset of the symptoms was inhomogeneous, as well as the timing of execution of the follow-up X-Ray, however we can consider that this inhomogeneity is representative of the current clinical situation.

In conclusion, our results support the role of chest X-Ray as a first-line tool in COVID-19 patients' management, due to its high sensitivity at baseline assessment, in a high pre-test probability environment.

The use of a radiological score can result in clearer communication with Clinicians and a more precise assessment of disease evolution and treatment effects.

## Declarations

Compliance with Ethical Standard

Disclosure of potential conflicts of interest

The authors declare that they have no conflict of interest.

Ethics approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Our IRB approved this retrospective study and patients provided informed consent.

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## Table

<b>Symptoms upon admission</b>	<b>Number of patient (%)</b>
Fever	88/110 (80%)
Cough	85/110 (77%)
Dyspnea	45/110 (41%)
Hemoptysis	1/110 (0.9%)
Chest pain	1/110 (0.9%)
Conjunctivitis	1/110 (0.9%)
Gastrointestinal symptoms	0/110 (0%)
<b>Comorbidities</b>	<b>Number of patient (%)</b>
Diabetes	9/110 (8%)
Hypertension	32/110 (29%)
Chronic obstructive pulmonary disease	9/110 (8%)
Asthma	3/110 (2.7%)
Cardiovascular diseases	20 /110 (18%)
Neoplasia	10 /110 (9%)
<b>Blood tests</b>	
White blood cells	mean 7 ± 4 per $\mu$ L NR 4.19-9.35 per $\mu$ L
Platelets	225 ± 111 per $\mu$ L NR 169-359 per $\mu$ L

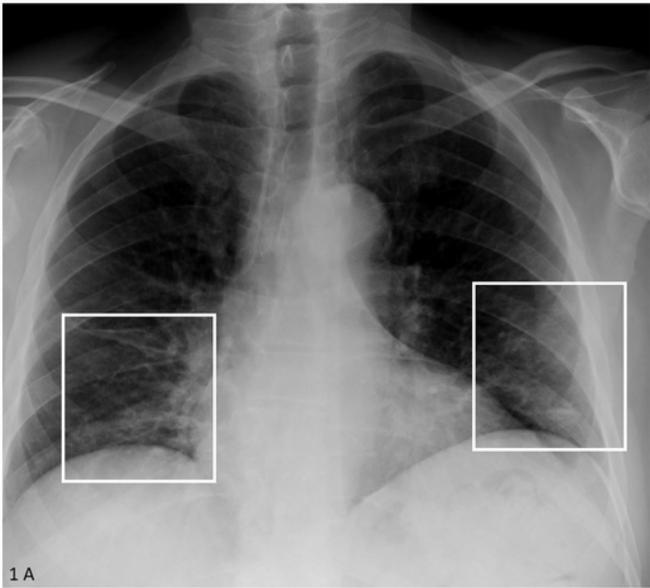
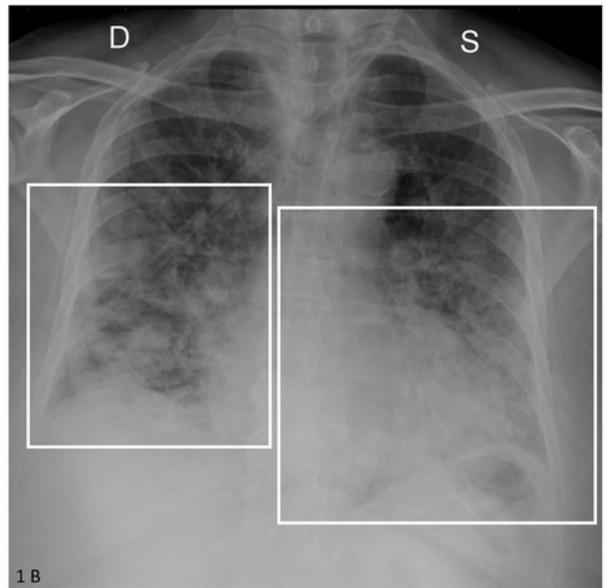
D-dimer	1535 ± 5500 ng/mL NR 250-500 ng/mL
Lactate dehydrogenase	mean: 375 ± 178 U/L NR: 135-225 U/L
C-reactive protein	mean: 104 ± 97 mg/L NR: 0-5 mg/L
Fibrinogen	634±85 mg/dL NR: 270-470 mg/dL

Table 1

Symptoms at patients' arrival, comorbidities, and blood tests.

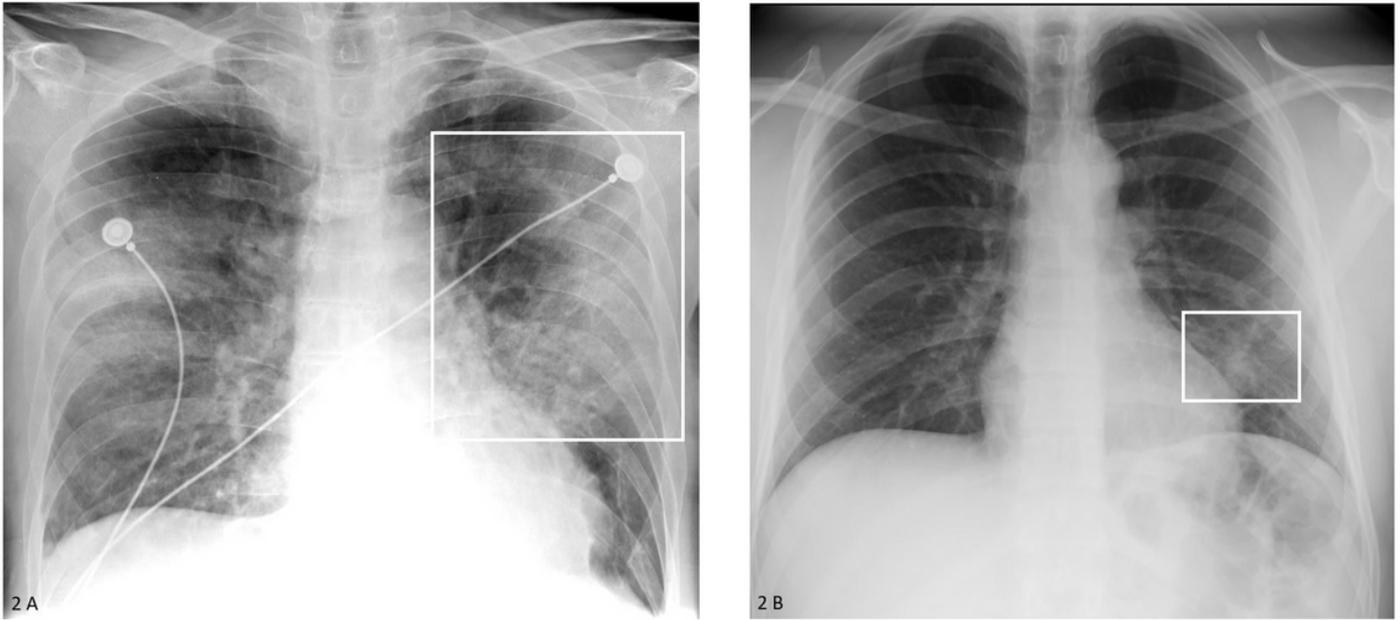
NR= Normal range

## Figures

**A****B****C****D****Figure 1**

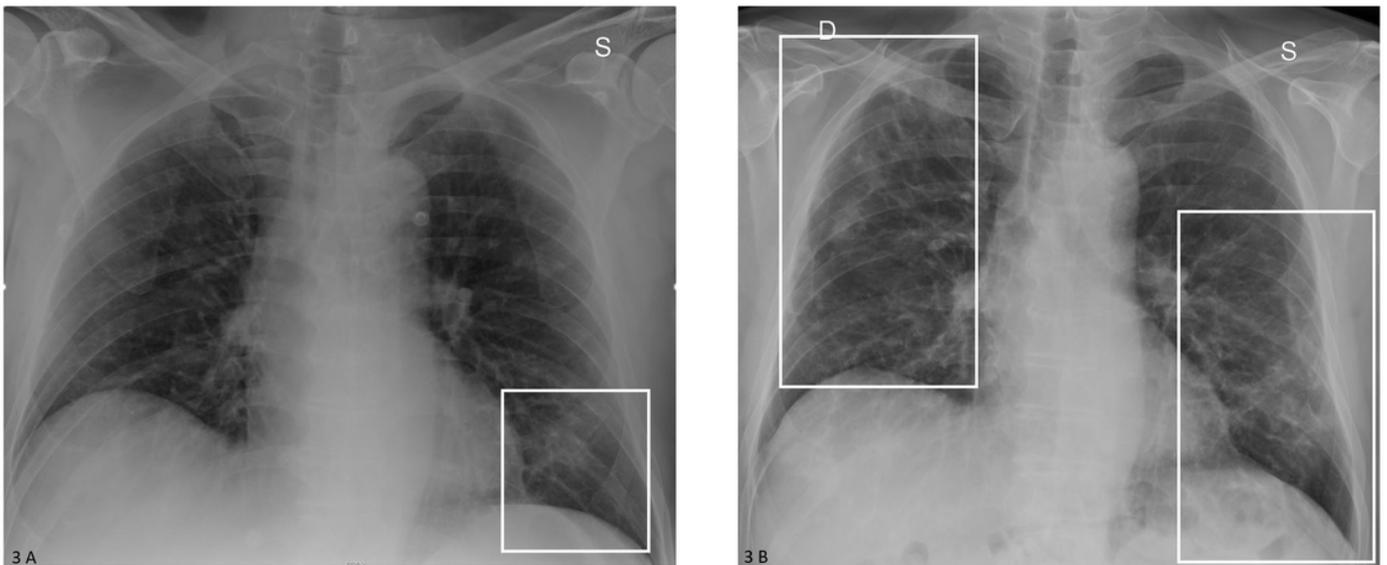
Examples of chest X-Ray severity scores assignment. A: bilateral GGO involving the lower lung zones (white rectangles). On both left and right lung the involvement is <25%; therefore, the score is 1 + 1 with a total score of 2. B: bilateral involvement, with GGO and consolidations (white rectangles). On both left and right lung the involvement is <75%; therefore, the score is 3 + 3 with a total score of 6. C: bilateral

involvement (white rectangles), with extension on the left side >75%. D: bilateral involvement (white rectangles), with extensive consolidations, >75% on both left and right lungs. The score is 4+4=8.



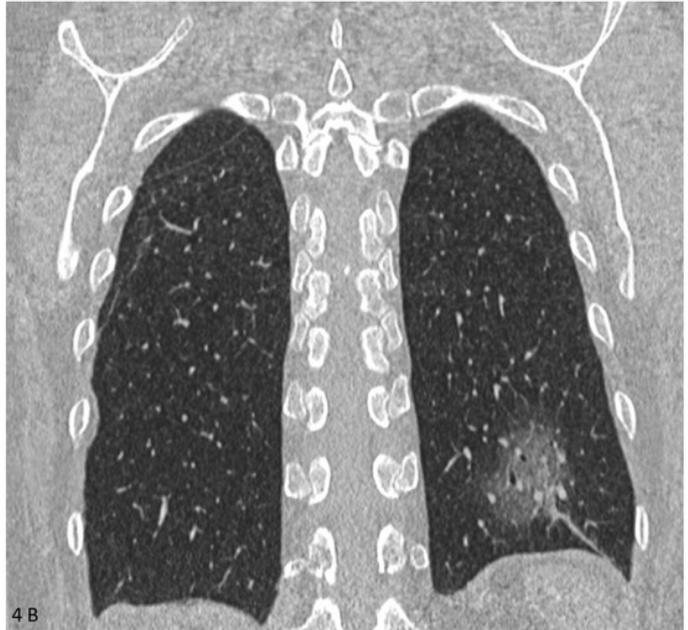
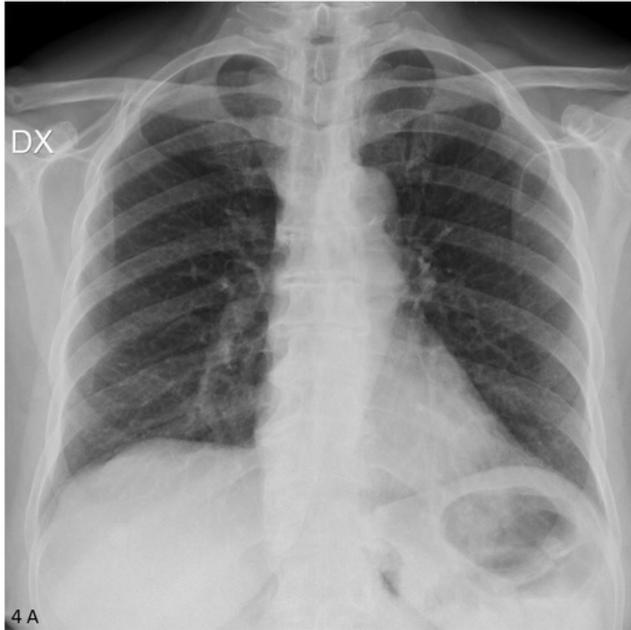
**Figure 2**

Examples of GGO and consolidation. A: extensive GGO are visible in the left lung (white rectangle). Also in the right lung extensive GGO are recognizable, with consolidation in the middle field. B: small paracardiac consolidation in the lower left field (white rectangle)



**Figure 3**

Example of worsening of chest X-Ray findings. A: chest X-Ray showing a focal ground glass opacity (white rectangle) with score 1. B: follow-up chest X-Ray of the same patient, executed 5 days later, showing with bilateral involvement (white rectangles). This second exam showed the increase of GGO on the left side, with involvement  $\leq 50\%$  (score 2), and the appearance of abnormalities also in the right lung, with extensive GGO and patchy consolidations  $>75\%$  (score 4). The score increased from 1 to 6.



#### Figure 4

False negative chest X-Ray and correspondent chest CT. A: chest X-Ray of a 54-year old female patient showing no abnormalities. B: due to the high suspicion of COVID-19 infection, a chest CT was performed 1 hour later, with demonstration of an area of crazy paving pattern in the lower left lobe, well visible on the coronal multiplanar coronal reformation.