

Radiographic findings in 240 patients with COVID-19 pneumonia

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Abstract

Objective: to analyze the most frequent radiographic features of COVID-19 pneumonia and assess the effectiveness of CXR in detecting pulmonary alterations.

Materials and Methods: CXR of 240 symptomatic patients (70% male, mean age 65 ± 16 years), with SARS-CoV-2 infection confirmed by RT-PCR were retrospectively evaluated. Patients were clustered in four groups based on the number of days between symptom onset and CXR: A (0-2 days) 49 patients, B (3-5) 75 patients, C (6- 9) 85 patients and D (>9) 31 patients. Alteration's type (reticular/opacification/consolidation) and distribution (bilateral/unilateral, upper/middle/lower fields, peripheral/central) were noted. Statistical significance was tested using chi-squared test.

Results: among 240 CXR, 60 (25%) were negative (A 36.7%, B 28%, C 18.8%, D 16.1%). Opacification was observed in 124/180 (68.8%), reticular alteration in 113/180 (62.7%), consolidation in 71/180 (39.4%). Consolidation was significantly less frequent ($p<0.01$). Distribution among groups was: reticular alteration (A 70.9%, B 72.2%, C 57.9%, D 46.1%), opacification (A 67.7%, B 62.9%, C 71%, D 76.9%), consolidation (A 35.5%, B 31.4%, C 47.8%, D 38.5%). Alterations were bilateral in 73.3%. Upper, middle and lower fields were involved in 36.7%, 79.4%, 87.8%. Lesions were peripheral in 49.4%, central in 11.1% or both in 39.4%. Upper fields and central zones were significantly less involved ($p<0.01$).

Conclusions: the most frequent lesions in COVID-19 patients were opacification (intermediate/late phase) and reticular alteration (early phase) while consolidation gradually increased over time. The most frequent distribution was bilateral, peripheral, with middle/lower predominance. Overall rate of negative CXR is 25%, progressively decreased over time.

Introduction

Since December 2019, when the first cluster of cases of coronavirus disease 2019 (COVID-19) was reported in Wuhan, Hubei province, China, the widespread transmission of coronavirus type 2 (SARS-CoV-2) has reached pandemic proportions[1]. The manifestations of SARS-CoV-2 infection in humans range from mild respiratory symptoms to severe acute respiratory syndrome[2][3]. According to the WHO, several molecular assays based on reverse transcription-polymerase chain reaction (RT-PCR) for the individuation of SARS-CoV-2 genes are recommended for the confirmation of COVID-19[4]. The role of imaging in the diagnosis of COVID-19 is still under debate. Several early radiological studies emphasized the role of radiological imaging in the early detection and management of COVID-19. These studies analyzed and described the chest computed tomography (CT) findings at the presentation and at different times throughout the disease course[5][6]. During the subsequent outbreak in the western world, chest X-ray (CXR), together with arterial blood gas analysis and clinical presentation, in patients positive to RT-PCR, was recommended as a useful and easily available tool to support the initial diagnosis and for the subsequent management of COVID-19 patients[7]. Nonetheless, no comprehensive data addressing

CXR findings in COVID-19 are currently available in literature. Also, the role of lung ultrasound is probably valuable but still unclear[8].

In order to create reasonable imaging workflows, it is important to evaluate the diagnostic potential of CXR and that radiologists become familiar with the presentation pattern of COVID-19 in CXR. Our study aimed to evaluate the effectiveness of CXR in detecting the presence of pulmonary alterations at different time points from the onset of symptoms and to identify the type and distribution of radiographic alterations and their frequency at different times throughout the disease course of COVID-19 pneumonia.

Materials And Methods

Patients

The inclusion criteria of this retrospective study were: 1- Patients with confirmed SARS-CoV-2 infection; the SARS-CoV-2 infection was confirmed by real-time reverse transcriptase-polymerase chain reaction (RT-PCR) on nasal-pharyngeal swab or broncho-alveolar lavage (BAL) specimens, according to international guidelines(4). 2- knowledge of the precise date of onset of symptoms. Symptoms considered linked to the onset of viral pneumonia were fever ($>37,5^{\circ}\text{C}$) cough, dyspnea(2). Asymptomatic patients were excluded from the study.3- Patients who underwent CXR examination.

All Patients underwent CXR and RT-PCR on the day of admission in the Emergency Department.

Two investigators collected the clinical data regarding the time of symptoms onset from the digital archive of the emergency department of all the patients suspect for COVID-19 admitted at IRCCS Fondazione Policlinico San Matteo between February 21 and March 8, 2020.

The same two investigators subsequently noted the results and the date of RT-PCR of each patient.

Informed consent for processing personal data for research purposes was obtained.

Image acquisition and evaluation

All the patients underwent a baseline digital anteroposterior bedside chest radiography at full inspiration using a portable radiography unit (FDR Go, Fujifilm Corporation).

X-Ray examinations were reviewed independently by two experienced thoracic radiologists (RD and LP, with more than 30 and 15 years of experience respectively). Results were compared and, when disagreement was found, final decisions were determined by consensus.

The findings considered in the evaluation of CXR were the presence or absence and the type of pulmonary alterations, and their distribution.

CXR alterations (**Fig. 1**) were defined according to the Fleischner Society's nomenclature, available in the Glossary of Terms for Thoracic Imaging(9):

- reticular alteration, as a collection of innumerable small linear opacities that, by summation, produce an appearance of a net;
- consolidation, as a homogeneous increase in pulmonary parenchymal attenuation that obscures the margins of the vessels and airway walls;
- opacification, as a slight increase in pulmonary parenchymal attenuation, less attenuating than a consolidation, hence not classifiable as a consolidation.

The distribution of alterations was classified as unilateral or bilateral.

Within each hemithorax, the vertical distribution of the lesions was evaluated on the basis of the involvement of the upper, middle and lower field. The middle field was defined as the lung area delimited by (included between) two horizontal lines at the level of the superior and inferior hilar horns respectively; the superior field was defined as the lung area included between the horizontal line at the level of the upper hilar horn and the apical pleura; the lower field was defined as the lung area included between horizontal line at the level of the inferior hilar horn and the diaphragm.

The horizontal distribution of the lesions was evaluated on the basis of the involvement of the peripheral zone only, the central zone only or both. Central zones were defined as the central area within 2 cm from the lobar bronchial structures as far as visible; peripheral zones were defined as the remaining lung area between the central zones and the pleura[10].

Patient's subgrouping

The patients were clustered in four groups based on the number of days between the onset of symptoms and the chest radiography: group A (patients with chest radiographs acquired 0-2 days from the onset of symptoms), group B (patients with chest radiographs acquired 3-5 days from the onset of symptoms), group C (patients with chest radiographs acquired 6-9 days from the onset of symptoms), group D (patients with chest radiographs acquired over 9 days from the onset of symptoms).

Statistical analysis

Statistical analyses were performed using MedCalc for Windows, version 15.0 (MedCalc Software, Ostend, Belgium). Continuous variables were expressed as mean \pm SD values. The frequency of the radiographic findings was expressed as the number of occurrences and (percentage) in every single cluster. Frequencies in the different groups were compared using the chi-squared test; p values <0.05 were considered significant.

Results

Patients characteristics

Among 305 patients initially considered, 60 patients were excluded because symptoms onset was uncertain and 5 patients because asymptomatic.

A total of 240 patients was considered, among them 169 (70%) were men and 71 (30%) were women.

The average age was 65 ± 16 years (range 16-97 years).

Group A included 49 patients, 32 (65%) men and 17 (35%) women, mean age was 66 ± 16.8 years (range 26-88 years). Group B included 75 patients, 52 (69%) men and 23 (31%) women, mean age was 63 ± 17.2 years (range 16-97 years). Group C included 85 patients, 62 (73%) men and 23 (27%) women, mean age was 63 ± 14.5 years (range 28-84 years). Group D included 31 patients, 23 (74%) men and 8 (26%) women, mean age was 67 ± 9.2 years (range 45-89 years).

Table 1

	All Patients (n=240)	Group A (n=49)	Group B (n=75)	Group C (n=85)	Group D (n=31)
Mean age, SD	65 ± 16.3	66 ± 16.8	63 ± 17.2	63 ± 14.5	67 ± 9.2
Sex					
Men	169 (70%)	32 (65%)	52 (69%)	62 (73%)	23 (74%)
Women	71 (30%)	17 (35%)	23 (31%)	23 (27%)	8 (26%)

Chest radiography evaluation

Among the total of 240 patients, 180 (75%) had at least one alteration in one lung field. In 60/240 patients (25%) CXR was normal without any lesion. CXR showed at least one alteration in at least one lung field in 31/49 patients (63%) in group A, in 54/74 patients (72%) in group B, in 69/85 patients (81%) in group C, and in 26/31 patients (83%) in group D. The negative rate of chest radiographs was 18/49 (36.7%) in group A, 21/75 (28%) in group B, 16/85 (18.8%) in group C, and 5/31 (16.1%) in group D.

Alterations were bilateral in 132/180 patients (73.3%) and unilateral in 48/180 (26.6%); 24 in the left lung and 24 in the right lung.

Opacification, alone or in combination with other alterations, was present in 124/180 patients (68.8%); reticular alteration, alone or in combination with other findings, was present in 113/180 patients (62.7%); consolidation, alone or in combination with other findings, was present in 71/180 patients (39.4%).

Opacification and reticular alteration were significantly more frequent than consolidation ($p < 0.01$ in both cases).

Table 2

	All Patients (n=240)	Group A (n=49)	Group B (n=75)	Group C (n=85)	Group D (n=31)
Negative chest radiography	60 (25%)	18 (36.7%)	21 (28%)	16 (18.8%)	5 (16.1%)
Positive chest radiographs	All Patients (n=180)	Group A (n=31)	Group B (n=54)	Group C (n=69)	Group D (n=26)
Bilateral Alterations	132 (73.3%)	25 (80.6%)	36 (66.6%)	51 (73.9%)	20 (76.9%)
Pleural effusion	12 (6.6%)	2 (6.4%)	4 (7.4%)	4 (5.8%)	2 (7.7%)
Reticular alteration (Total)	113 (62.7%)	22 (70.9%)	39 (72.2%)	40 (57.9%)	12 (46.1%)
Opacification (Total)	124 (68.8%)	21 (67.7%)	34 (62.9%)	49 (71%)	20 (76.9%)
Consolidation (Total)	71 (39.4%)	11 (35.5%)	17 (31.4%)	33 (47.8%)	10 (38.5%)
Reticular alteration alone	27 (15%)	5 (16.1%)	13 (24.1%)	7 (10.1%)	2 (7.7%)
Opacification alone	38 (21.1%)	5 (16.1%)	11 (20.3%)	14 (20.3%)	8 (30.8%)
Consolidation alone	8 (4.4%)	1 (3.2%)	0	5 (7.2%)	2 (7.6%)
Reticular alteration + Opacification	44 (24.4%)	10 (32.2%)	13 (24.1%)	15 (21.7%)	6 (23.1%)
Reticular alteration + Consolidation	21 (11.6%)	4 (12.9%)	7(12.9%)	8 (11.5%)	2 (7.6%)
Opacification + Consolidation	21 (11.6%)	3 (9.6%)	4 (7.4%)	10 (14.4%)	4 (15.4%)
Reticular alteration + Opacification + Consolidation	21 (11.6%)	3 (9.6%)	6 (11.1%)	10 (14.4%)	2 (7.6%)

The upper fields were involved in 66/180 patients (36.6%), the middle fields in 143/180 (79.4%), the lower fields in 158/180 (87.7%). A significantly higher frequency of involvement of the lower fields compared to the middle fields, and of the lower and middle fields compared to the upper fields was observed ($p < 0.01$ in all cases).

Table 3

Alterations (alone or in combination)		
	p value	CI 95%
Reticular 113/180 (62.7%) > Consolidation 71/180 (39.4%)	<0.01	13.0% – 32.9%
Opacification 124/180 (68.8%) > Consolidation 71/180 (39.4%)	<0.01	19.3% – 38.8%
Opacification 124/180 (68.8%) > Reticular 113/180 (62.7%)	=0.2	-3.6% – 15.8%
Lung fields involvement		
Field Involvement	p value	CI 95%
Middle 143/180 (79.4%) > Upper 66/180 (36.7%)	<0.01	33.0% – 51.2%
Lower 158/180 (87.8%) > Upper 66/180 (36.7%)	<0.01	41.9% – 58.9%
Lower 158/180 (87.8%) > Middle 143/180 (79.4%)	=0.03	0.7% – 16.0%
Zones involvement		
	p value	CI 95%
Peripheral 89/180 (49.4%) > Central 20/180 (11.1%)	<0.01	29.3% – 46.5%
Both 71/180 (39.4%) > Central 20/180 (11.1%)	<0.01	10.2% – 26.4%
Peripheral 89/180 (49.4%) > Both 71/180 (39.4%)	=0.06	-0.3% – 20%

The exclusive involvement of the peripheral zones was observed in 89/180 patients (49.4%); the involvement of both peripheral and central zones was observed in 71/180 patients (39.4%); the exclusive involvement of the central zones was observed in 20/180 patients (11.1%). The exclusive involvement of the central zones was significantly less frequent than the exclusive peripheral zones involvement and than both peripheral and central zones involvement (p <0.01 in both cases).

Pleural effusion was observed in 12/180 patients (6.6%), unilateral in all cases, 7 on the right side, 5 on the left side.

Chest radiography evaluation – subgroups

Bilateral alterations were present in 25/31 patients (80.6%) in group A, in 36/54 patients (66.6%) in group B, in 51/69 patients (73.9%) in group C, and in 20/26 patients (76.9%) in group D; when alterations were unilateral, no significant difference was observed between left and right lung.

Opacification, alone or in combination with other alterations, was present in 21/31 patients (67.7%) in group A, in 34/54 patients (62.9%) in group B, in 49/69 patients (71%) in group C, and in 20/26 patients (76.9%) in group D.

Reticular alteration, alone or in combination with other alterations, was present in 22/31 patients (70.9%) in group A, in 39/54 patients (72.2%) in group B, in 40/69 patients (57.9%) in group C, and in 12/26 patients (46.1%) in group D.

Consolidation, alone or in combination with other alterations, was present in 11/31 patients (35.5%) in group A, in 17/54 patients (31.4%) in group B, in 33/69 patients (47.8%) in group C, and in 10/26 patients (38.5%) in group D. **Fig. 2a - d, Fig. 3**

The specific frequency of the different alterations and their associations are summarized in **Table 2**.

The upper fields were involved in 12/31 patients (38.7%) in group A, in 19/54 (35.2%) in group B, in 25/69 (36.2%) in group C, and in 10/26 (38.5%) in group D; the middle fields were involved in 27/31 patients (87.1%) in group A, in 41/54 (75.9%) in group B, in 56/69 (81.1%) in group C, and in 19/26 (73.1%) in group D; the lower fields were involved in 28/31 patients (90.3%) in group A, in 46/54 (85.2%) in group B, in 60/69 (86.9%) in group C, and in 24/26 (92.3%) in group D.

The exclusive involvement of the peripheral zones was observed in 19/31 patients (61.3%) in group A, in 26/54 (48.1%) in group B, in 28/69 (40.6%) in group C, and in 16/26 (61.5%) in group D; the involvement of both peripheral and central zones was observed 11/31 patients (35.5%) in group A, in 21/54 (38.9%) in group B, in 31/69 (44.9%) in group C, and in 8/26 (30.8%) in group D; the exclusive involvement of the central zones was observed 1/31 patients (3%) in group A, in 7/54 (12.9%) in group B, in 10/69 (14.5%) in group C, and in 2/26 (7%) in group D. **Fig. 4**

Discussion

In early clinical experience, chest CT has been considered the most reliable imaging modality to support the diagnosis in suspect cases of COVID-19[11]. Chest CT showed high sensitivity in detecting ground-glass opacity (GGO), which is considered a typical finding in COVID-19 pneumonia and in some cases may be the only alteration present in the early phases of the disease[3][12]. CXR was not recommended as a first-line imaging examination due to its low sensitivity in detecting alterations[5][11].

Conversely, recent statements of several influential radiological societies[7][13][14][15][16][17][18] recommend that CT should not be used as a first-line tool to support the diagnosis of COVID-19, and encourage the use of CXR in combination with RT-PCR test.

In our knowledge, our study is the first to address this issue and systematically describe the CXR findings in COVID-19 pneumonia in a vast population[19]. In our experience, the overall rate of normal CXR findings in patients with positive RT-PCR was 25%, versus an overall rate of normal chest CT of 0-22%[20][21][22] reported in the literature, showing a rate of negative CXR just slightly higher compared to the rate of negative chest CTs.

Bernheim et al. reported the percentage of normal chest CT in patients clustered on the base of the timing of symptoms onset and observed a rapid decrease from 56% at 0-2 days, to 9% at 3-5 days and 4% at 6-12 days[20]. Clustering our patients on the base of the timing of symptoms onset, the rate of normal CXR progressively decreased from 36.7% (0-2 days after the onset of symptoms) to 28% (3-5 days), 18.8% (6-9 days) and 16.1% (>9 days).

Based on these results, despite the intrinsic limits of CXR in comparison to chest CT, the rate of negatives CXR seems to be surprisingly lower than the rate of negative chest CTs in the first two days after the onset of symptoms; nevertheless, the percentage of negative chest CTs is constantly lower in the subsequent time intervals[20].

In our radiographic series, the most frequent alterations were opacification and reticular pattern, alone or in combination with other alterations, resembling the radiographic appearance described in other coronavirus-related pneumonia[23][24][25]. In the first 5 days from the onset of the symptoms reticular alteration was slightly more frequent than opacification, while after this period, opacification came to be predominant. Consolidation was constantly less frequent than the other two alterations, especially in the early phase of the disease.

Our data suggest that early alterations are predominantly reticular, intermediate alterations are predominantly opacifications with a period of overlap between these two, whereas consolidations increase in the late phase.

Considering the distribution of the lesions on both the lungs and on the axial and vertical plane, our results are in line with the data reported in CT studies in the literature [3][12][22].

In the majority of our patients, the alterations were bilateral, and in patients with unilateral lesions, no predominance was observed between left and right.

The exclusive peripheral involvement and the combination of peripheral and central distribution were significantly more frequent than exclusive central distribution, without significant modifications of their proportions in the different time intervals.

Several studies reported a predominant, although not significant, localization of the lesions in the lower lobes[11][20]; our results confirm this observation and measured a significantly higher frequency of involvement of the lower fields compared to the middle fields, and of the lower and middle fields compared to the upper fields.

Our patients had a higher mean age than those reported in literature, reflecting demographic differences between China and the western countries.

The purpose of this study was to analyze and describe the type, frequency, and distribution of CXR findings in COVID-19 pneumonia. Therefore, the main limitation of the study is the lack of data about the specificity of the CXR findings in COVID-19 towards its main differential diagnoses (other viral pneumonia, interstitial lung disease, cardiogenic pulmonary edema, acute lung injury).

Even though not yet validated in larger studies, our results indicate that CXR could be at least comparable to chest CT in detecting lung alterations in the first two days of COVID-19. The most frequent CXR lesions were reticular alteration and opacification, the first prevailing in the early phase, the following prevailing in the late phase. Consolidation was less frequent but, in agreement with other studies observations, showed an increasing trend over time[12][20].

Our observations are consistent with previous CT studies about the bilateral, peripheral, middle and lower field predominant pattern of distribution of the lesions[12][20][22]. In a pandemic scenario, with a high number of inpatients and a growing number of suspect cases, CXR should be considered as a feasible and easy-to-use method to assess lung involvement. Our results confirm the most recent recommendations, to employ CXR as a first-line imaging modality in the diagnostic workflow of patients with suspected COVID-19 pneumonia.

Declarations

IRB approval for the study:

Object: the study on chest radiography in COVID-19 patients proposed by the U.O.C. Radiology

We inform you that the study in question was authorized by executive decree n. 0269 of 15/04/2020 and, therefore, can be considered formally started.

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Figures

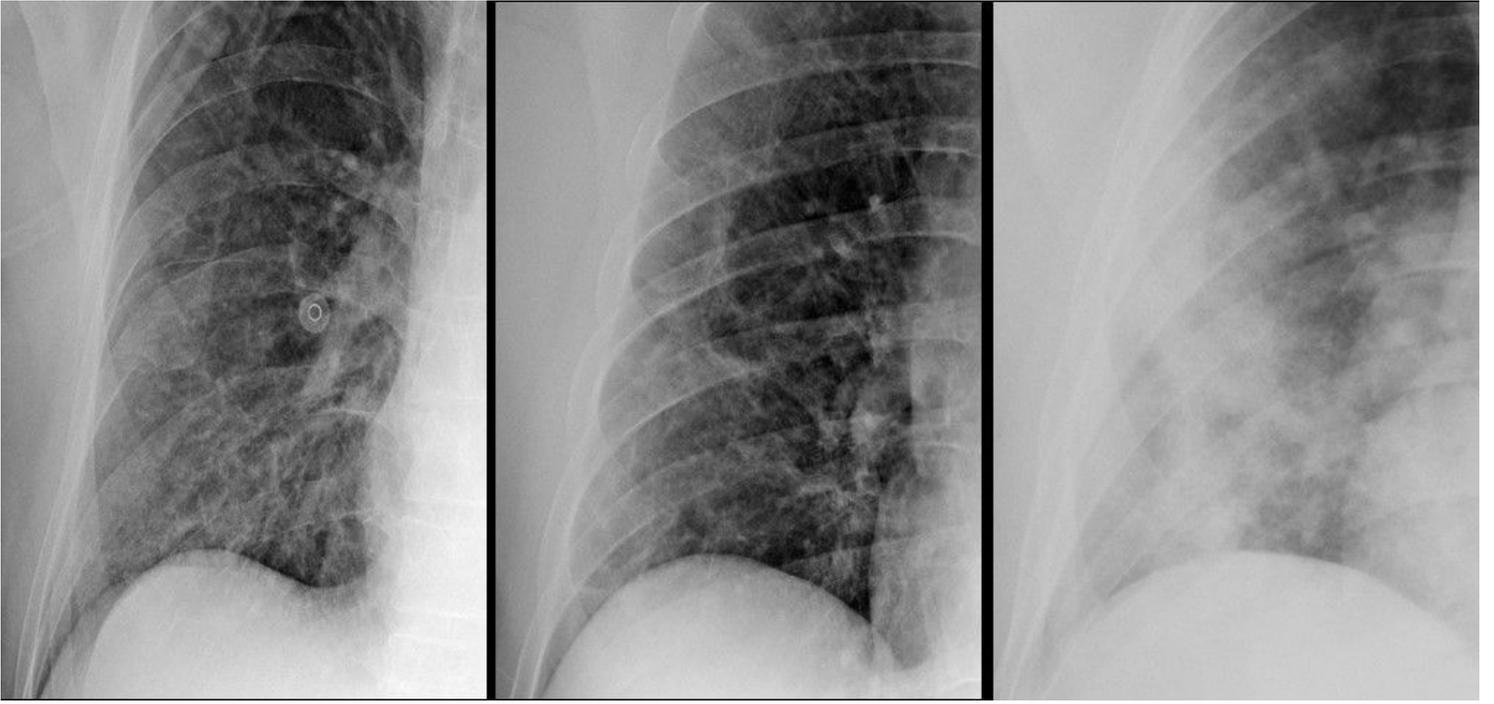


Figure 1

Fig. 1 - The three main radiographic alterations. Left: reticular alteration; middle: peripheral opacification; right: extensive consolidations.

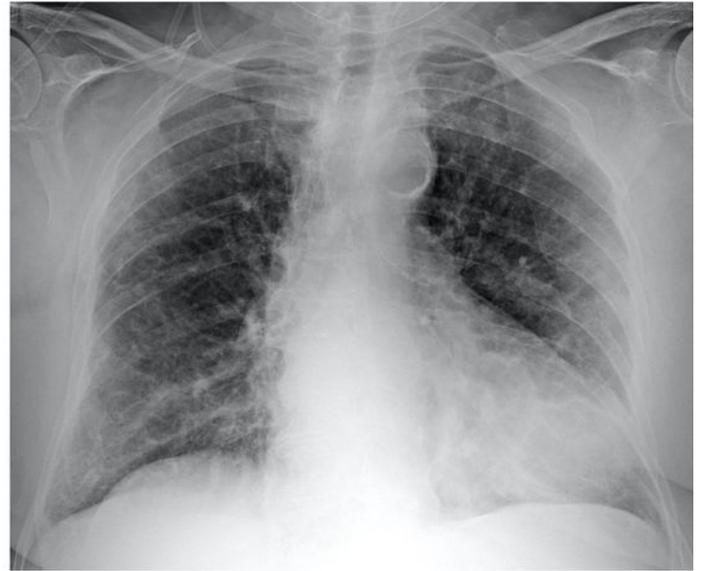
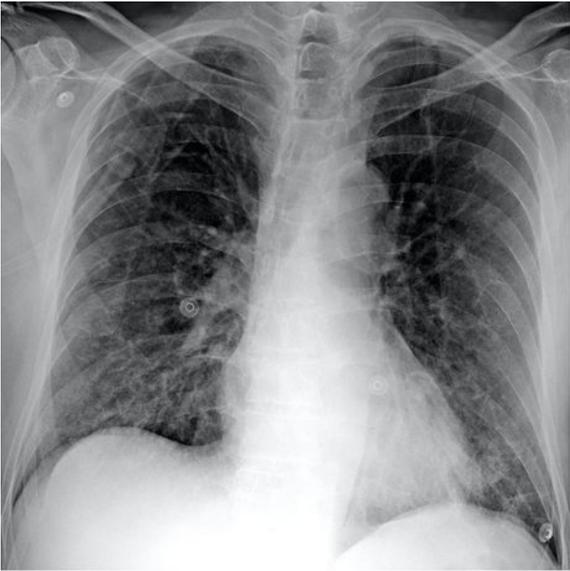


Figure 2

Fig. 2a - Chest radiography of a 78-years-old man, acquired within the first 2 days since the onset of symptoms, showing bilateral reticular alteration in the middle and lower fields. Fig. 2b - Group B, usual distribution. Chest radiography of a 79-years-old woman, acquired within 3-5 days since the onset of symptoms, showing bilateral opacifications in the peripheral zones of middle and lower fields. Fig. 2c - Group C, usual distribution. Chest radiography of a 60-years-old woman, acquired within 6-9 days since the onset of symptoms, showing bilateral and symmetrical mixed pattern with opacifications, patchy consolidations and diffuse reticular alteration. Fig 2d - Group D, usual distribution. Chest radiography of a 61-years-old woman, acquired after 10 days since the onset of symptoms, showing bilateral and symmetrical extensive consolidations.

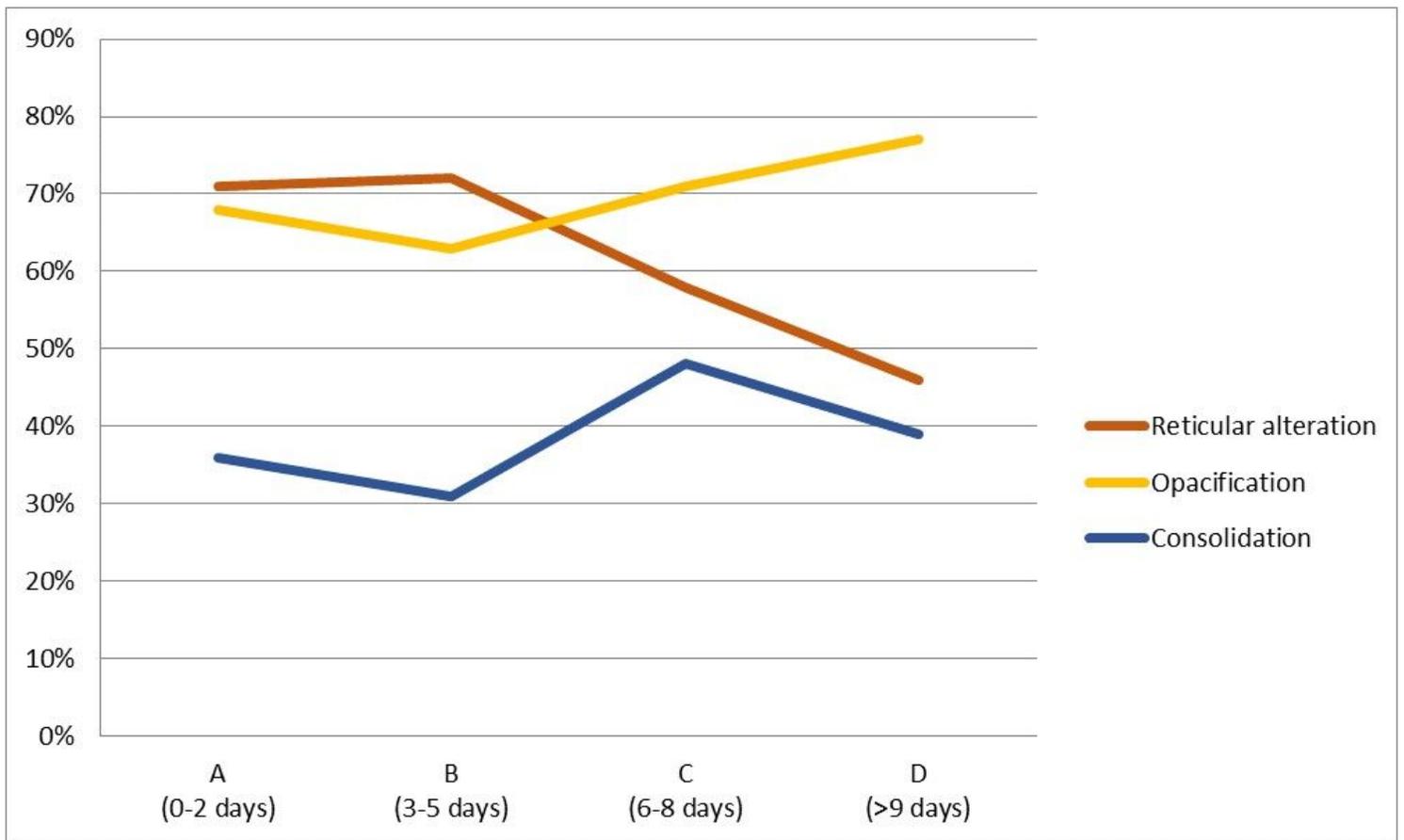


Figure 3

Fig. 3 – Graphic shows the trend of the radiographic alterations in the different groups.

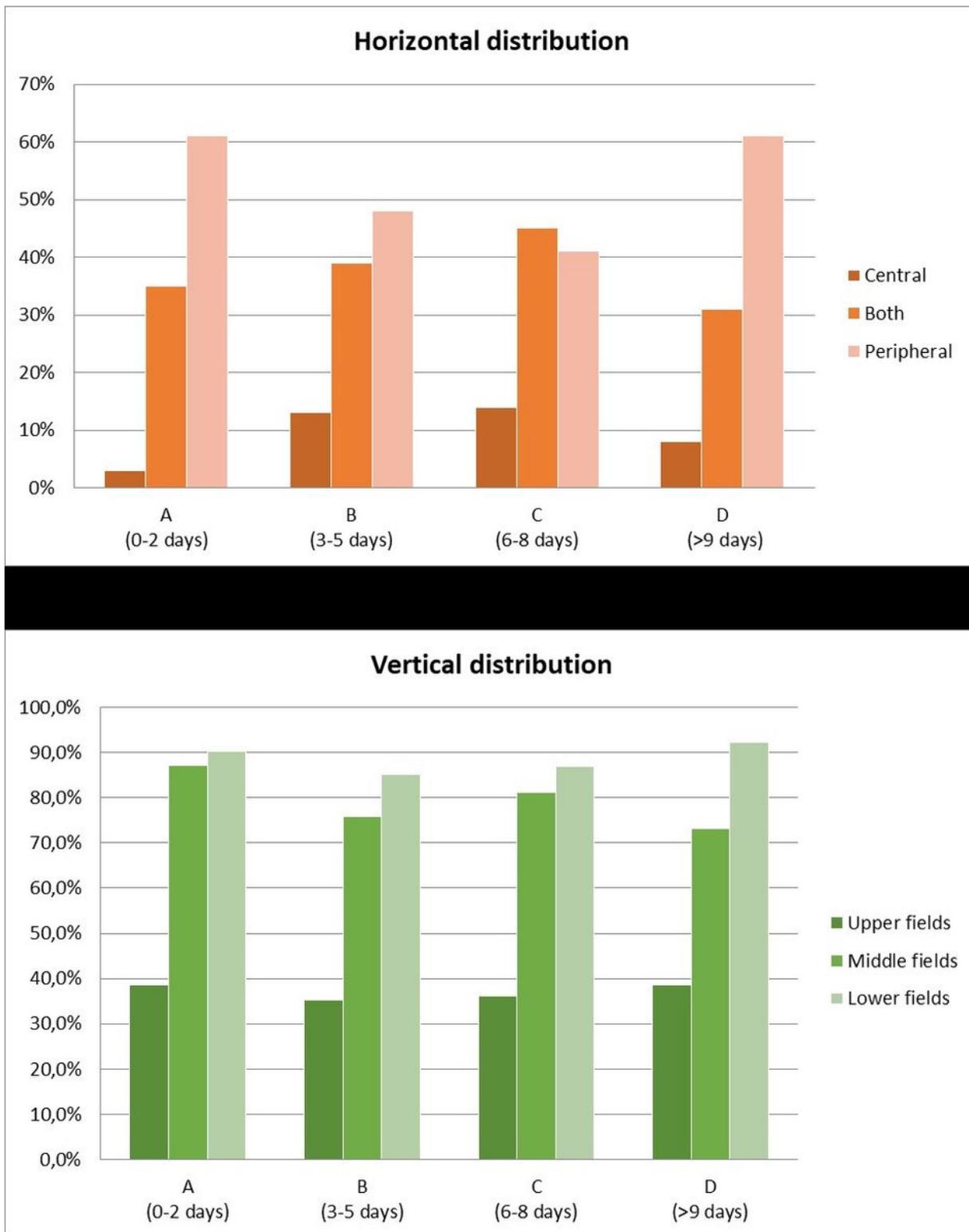


Figure 4

Fig. 4 – Graphs show the distribution of the alterations on the horizontal plane (orange) and on the vertical plane (green) in the different groups.