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The role of chest X-ray in coronavirus disease 2019 (COVID-19) infection: findings and correlation with clinical outcome

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Abstract. – OBJECTIVE: It is possible to diagnose coronavirus disease 2019 (COVID-19) faster and more accurately with chest X-ray (CXR) and chest computed tomography (CT) than with reverse transcriptase PCR (RT-PCR) tests. The aim of this study was to verify the possibility of reducing the use of CT in diagnosis and follow-up of COVID-19 infection by using CXR.

PATIENTS AND METHODS: A total of 326 COVID-19 patients who were hospitalized in Ankara City Hospital were included in this retrospective study.

RESULTS: A total of 326 patients were RT-PCR positive for COVID-19 infection; 178 were male (54.6%) and 148 were female (45.4%), with a median age of 45. Considering the results, the baseline CXR sensitivity in our experience was approximately 72%. The CXRs of 113 patients with abnormal CT were divided into 2 groups, the CXR normal and abnormal groups, and were then compared. In the 1st group with abnormal CXR, the mean age, the number of patients over 65 years old, and the comorbidity rate were higher. Additionally, it was determined that the number of patients requiring respiratory support and intensive care unit (ICU) admission in this 1st group was higher than in the 2nd group (with normal CXR). Most of the patients who died (91%, 10/11) were in Group 1. In the group with normal CXR, no patients in the critically ill category needed invasive or non-invasive mechanical ventilators.

CONCLUSIONS: CXR can help in detecting clinically moderate and severe cases of COVID-19. CXR can assist clinicians in patient management and treatment planning regarding the clinical course, respiratory support, ICU need, and mortality and can help them prepare for potential negative outcomes.

Key Words:
COVID-19, Chest radiography, Clinical outcome.

Abbreviations

ARDS = acute respiratory distress syndrome; COVID 19 = Coronavirus Disease 2019; CT = computed tomography; CXR = chest X-ray; WHO = World Health Organization; GGO = ground-glass opacities; ICU = intensive care unit; RT-PCR = reverse transcriptase PCR; ARDS = acute respiratory distress syndrome; SpO_2 = oxygen saturation; PaO_2 = partial oxygen pressure; COPD = chronic obstructive pulmonary disease.

Introduction

A radiological evaluation is necessary for rapid assessment of thoracic involvement in patients with suspected coronavirus disease 2019 (COVID-19), especially when waiting for reverse transcriptase PCR (RT-PCR) results in the emergency room. The most commonly used radiological imaging techniques are chest X-ray (CXR) and chest computed tomography (CT)[1,2].

CT scanning has some disadvantages, especially in younger patients, such as the high exposure to radiation, but it also requires mandatory disinfection procedures. For this reason, if there is no absolute medical necessity, using CXR instead of CT can guide patient management. CXR yields faster results than RT-PCR, especially by using portable X-ray units, which reduces the movement of patients and in this way minimizes the risk of cross-infection[3-5].

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There are limited studies[6-8] that discuss the radiographic findings and clinical role of CXR in COVID-19 infection. This retrospective study was conducted to analyze the CXR and CT radiographic findings and their relationship to clinical outcomes in patients confirmed to be RT-PCR positive for COVID-19.

Patients and Methods

Study Design and Participants

This retrospective study was carried out in Ankara City Hospital set apart as the main pandemic response center in Ankara. All patients older than 18 years who were hospitalized with a diagnosis of COVID-19 infection between March 15, 2020, and June 15, 2020, were included in the study. The clinical data of 380 patients have been obtained. A total of 54 patients who had RT-PCR negative were excluded. A total of 326 COVID-19 cases had an RT-PCR positive for COVID-19 infection.

Only COVID-19 patients with a definite diagnosis were included in the study. The diagnosis was confirmed with RT-PCR for SARS-CoV-2, which was performed based on the protocol established by the World Health Organization (WHO) interim guidelines[9]. The outcome was expressed as discharged or hospitalized patients in a medicine department or an intensive care unit (ICU).

Patients with a negative SARS-CoV-2 test, even if they had typical CT findings, and those who were still in the hospital at the moment of the final date of follow-up (if no death or discharge) were excluded.

Patients with severe and critical illnesses were candidates for ICU follow-up based on the WHO COVID-19 disease severity classification. Patients with pneumonia and one of the following >30 breaths/min, severe respiratory distress, or oxygen saturation (SpO_2) <90% on room air, were considered to have severe disease. Patients were considered to have critical disease if they had acute respiratory distress syndrome (ARDS) or other respiratory failure requiring mechanical ventilation, septic shock, and/or organ failure requiring ICU follow-up[10].

The decision of ICU admission was made by intensive care specialists. The ICU admission criteria were respiratory rate ≥30, SpO_2 <90% or partial oxygen pressure (PaO_2) <70 mmHg on room air despite nasal oxygen support at a rate of 5 lt/min or higher, or PaO_2/fraction of inspired oxygen (FiO_2) <300.

Collecting and Processing Data

To collect the data, a special form was created for COVID-19 patients, and it contained information about the patients at admission and follow-up. The parameters included in the special patient forms were age, sex, comorbid diseases, symptoms of fever and dyspnea, and SpO_2 at admission.

The forms also included the following laboratory and radiological tests: complete blood counts, serum biochemistry, C-reactive protein (CRP), procalcitonin (PCT), ferritin, D-dimer chest CXR, and chest CT. The clinical outcomes were defined as the requirement of ICU admission or discharge from the hospital. All the laboratory records in the patient files were completed from the hospital database.

Imaging Analysis

The chest CXR patterns of the COVID-19 patients were analyzed by two radiologists with 4 and 22 years of experience in chest imaging.

The Following Chest CXR and CT Abnormalities Were Recorded

The present study was comprised of the CXR results of 132 patients. A total of 132 CXRs (n: 72, 54.5%) were abnormal. CT was performed in 131 of the 326 patients, and among 131 CTs, 16 were normal and 115 were abnormal, whether the lesions were unilateral (right lung or left lung) or bilateral and peripheral, central or perihilar. The specific findings included ground glass opacity, consolidation, nodules, reticular-nodular opacities, vascular congestion signs, cardiomegaly, and pleural effusion. Zonal predominance (upper, middle, or lower zone) of the findings was also noted[7,11]. Radiographic characteristics, including consolidation, ground-glass opacities (GGO), pulmonary nodules, and reticular-nodular opacities, were diagnosed according to the Fleischer Society glossary of terms[12].

Statistical Analysis

The data obtained were analyzed using SPSS software for Windows, version 24 (IBM Corp., Armonk, NY, USA). Quantitative variables were presented with the mean, standard deviation, and median values, while continuous data were presented with the median, minimum, and maximum values because of skewed distributions; categorical data were described with frequencies and percentages.

Relationships between categorical variables were evaluated using the Chi-square or Fisher's exact test. Mann-Whitney or Kruskal-Wallis tests were applied to compare continuous variables. The effect of all variables on mortality was assessed by logistic regression analysis. Two-tailed *p*-values of <0.05 were defined as statistically significant.

Results

Clinical Characteristics

There were 326 patients who were RT-PCR positive for COVID-19 infection in total: 178 males (54.6%) and 148 females (45.4%), with an age range of 18-93 years and a median age of 45 years. Most of the patients (82.5%) were below the age of 65.

A total of 110 (33.7%) patients had comorbid conditions such as diabetes, hypertension, coronary artery disease, chronic renal disease, and chronic obstructive pulmonary disease (COPD) (Table I).

Table I. Baseline descriptive characteristics of the cases.

Variables	n: 326
Age (median, min-max)	45 (18-93)
<65 years (n,%)	(269, 82.5)
Gender (n,%)	
Female	148 (45.4)
Male	178 (54.6)
Total patients with comorbidities conditions (n,%)	110 (33.7)
Hypertension	58 (17.7)
Diabetes mellitus	35 (10.7)
Chronic kidney disease	17 (5.2)
Coronary artery disease	17 (5.2)
Chronic obstructive pulmonary disease	15 (4.6)
White blood cells ($X10^9$/L) (median, min-max)	5,230 (1,200-59,290)
Lymphopenia (n,%)	114 (42.9)
CRP (mg/L) (median, min-max)	10 (1-880)
Procalcitonin µg/L (median, min-max)	0.03 (0-2)
Ferritin µg/L (median, min-max)	122 (5-1,566)
D-dimer mg/L (median, min-max)	0.4 (0-35)
ICU admission (n,%)	
No	284 (87.1)
Yes	42 (12.9)
Deceased (n,%)	
No	314 (96.3)
Yes	12 (3.7)

The median time that elapsed between the onset of symptoms and the result of the RT-PCR was 3 days (min-max: 0-24). PCR positivity was detected in the first week of the symptoms in most of the patients (88.7%, n: 289). The patients had various clinical symptoms and laboratory findings. Fever was present in 27.3% of the patients, and cough was present in 54.9%. The lymphocyte count was reduced in 114/326 (42.9%) patients. Other laboratory parameters are shown in Table I.

While the mean SpO_2 was 95% at the time of admission, the median respiratory rate was 21 per min. It was found that 17.8% of the patients needed oxygen, 6.7% needed high flow, 1.2% needed a non-invasive mechanical ventilator, and 4.6% needed a mechanical ventilator. ICU group included 42/326 (12.9%) patients. Twelve of the 326 (3.7%) patients were deceased (Table I).

CXR Findings

The present study was comprised of the CXR results of 132 patients. A total of 132 CXRs (n: 72, 54.5%) were abnormal. Ground Glass Opacity (GGO) was seen in 57% of the patients, consolidation was seen in 75%, reticular-nodular opacities were seen in 52.7%, nodules were seen in 1.4%, pleural effusion in 7%, vascular congestion signs in 2.7%, and cardiomegaly in 9.7% (Figure 1). Bilateral involvement (82%) was more frequent than unilateral involvement. Right lung involvement was found to be more common in patients with unilateral involvement (right lung n: 10, left lung n: 3). A total of 72 CXRs (40.2%) had a peripheral predominance of abnormalities, twelve CXRs (16.6%) had central abnormalities, and ten CXRs (13.8%) had perihilar abnormalities (Table II).

The patients that had abnormal CXR were evaluated for clinical outcomes. Pneumonia was detected in 47.9% of the patients, critical disease in 5.6%, and severe pneumonia in 46.5%. Mild disease was not detected (Table II).

Chest Computed Tomography (CT) Findings

CT was performed in 131 of the 326 patients, and among 131 CTs, 16 were normal and 115 were abnormal. The most common CT findings were ground glass opacities (n: 92) and consolidation (n: 41). Other lung manifestations were also seen at different rates: reticular pattern (n: 3), tree-in-bud image (n: 3), cardiomegaly (n: 7), pleural effusion (n: 5), and nodules (n: 2). The disease involvement on CT was bilateral in most of the

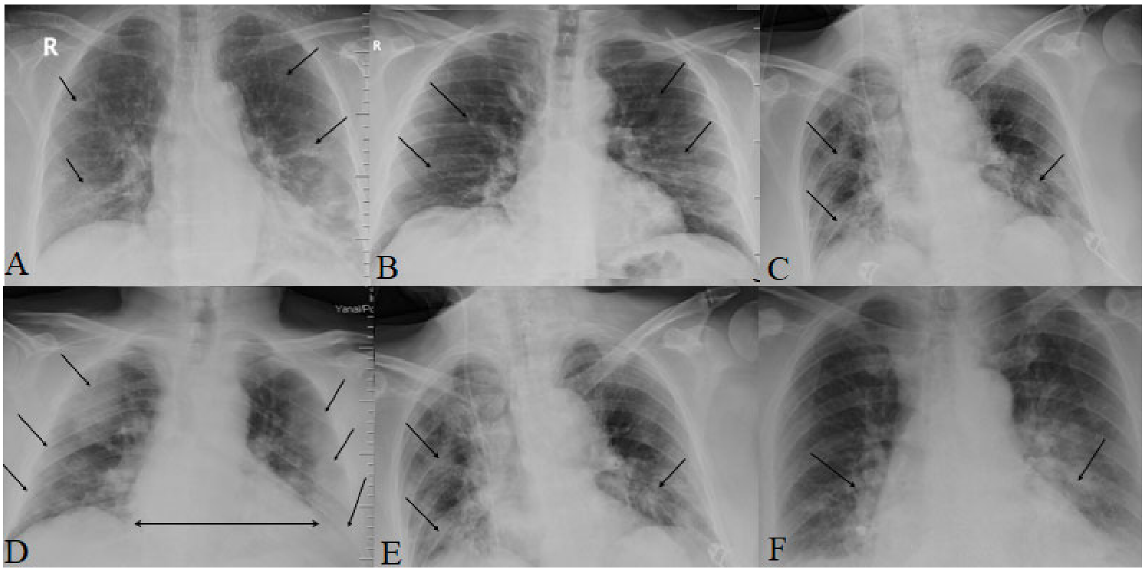

Figure 1. Chest X-Ray findings of Covid-19 pneumonia. **A**, Bilateral and peripheral ground-glass opacities. **B**, Reticular-nodular opacities. **C**, Patchy consolidation. **D**, Peripheral consolidation, pleural effusion and cardiomegaly. **E**, Vascular congestion. **F**, Bilateral and central ground-glass opacities.

patients. It was also found that the right lung was more frequently involved than the left in patients with single lung involvement (right lung n: 15, left lung n: 13, bilateral n: 77). The predominant localization was peripheral (peripheral n: 92, central n: 54, diffuse n: 26).

Table II. Radiographic findings of chest X-rays in COVID-19 patients.

COVID-19 Radiological features	**n**	**%**
Total CXR	132	100
Abnormal CXRs	72	54.5
Reticular-nodular opacities	38	52.7
Ground glass opacities	41	57
Consolidation	54	75
Vascular congestion signs	2	2.7
Cardiomegaly	7	9.7
Nodules	1	1.4
Pleural effusion	5	7
Distribution:		
Peripheral	29	40.2
Central	12	16.6
Perihilar	10	13.8
Diffuse	32	44.4
Lower zone	22	30.5
Upper zone	9	12.5
Right lung	10	13.8
Left lung	3	4.1
Bilateral	59	81.9
Abnormal CXR in severe pneumonia (SARI)	33	46.5
Abnormal CXR in pneumonia	34	47.9
Abnormal CXR in critical disease	4	5.6
Abnormal CXR in mild disease	0	0

Evaluation of the Effect of CXR on Clinical Outcomes in 113 Patients with Abnormal CT Findings

A total of 113 patients with abnormal CT were divided into 2 groups, the normal and abnormal CXR group, and were compared (Table III). Group 1 (n: 71, 62.9%) included patients with abnormal CXR, and Group 2 (n: 42, 37.1%) included patients with normal CXR (Figure 2). The first group was the one in which CXR also detected the CT findings, and the second group was the group in which CXR findings were not detected. Given the results, the baseline CXR sensitivity is approximately 72% in our experience.

The mean age, number of patients over 65 years of age, comorbidities, and disease severity were significantly higher in the 1st group with CXR findings than in the 2nd group (p<0.05). There were no statistically significant differences in terms of gender (Table III).

It was found that dyspnea, ICU requirements, oxygen, and high flow requirements were significantly higher in the 1st group with CXR involvement than in the 2nd group (p<0.05). Additionally, none of the patients in the 2nd group with normal CXR required invasive and non-invasive mechanical ventilators, and this was also seen in the patients in the critically ill category (p<0.05).

Clinical worsening (SD>30/min or saturation <90) and unresponsiveness to treatment (fever, cough, etc.) were significantly higher in the 1st group. Among the patients who died, 91% (10/11) were in Group 1 (p=0.052).

All patients who had critical illness had abnormal CXR results (Group 1). Most of those with severe pneumonia (94.2%, 33/35) had abnormal CXR results (Group 1). The CXRs of all the 9 patients that had mild clinical symptoms were normal (Group 2) (Table III). It was concluded that while CT is sensitive in patients with mild disease, CXR is insensitive. However, CXR can also help in detecting clinically moderate and severe cases.

In most of the patients who were over 65 years of age (93%, 53/57), CXR abnormalities were detected more frequently, and the clinical manifestations were more severe (pneumonia, severe pneumonia, and critical disease) (Table IV).

When the laboratory parameters of the 1st and 2nd groups were compared, no significant differences were detected in terms of white blood cells; while lymphopenia, CRP, procalcitonin, D-dimer, and ferritin levels were significantly higher in the 1st group (p<0.05). The oxygen saturations that were measured at hospitalization and after hospitalization were found to be statistically significantly lower in the 1st group, while the respiratory rate was higher (p<0.05) (Table V).

Discussion

The most commonly reported CXR and CT findings of COVID-19 include lung consolidation and ground glass opacities (GGOs)[13-16]. It was reported that COVID-19 typically causes lung opacities in more than one lobe and is most commonly bilateral, similar to other viral causes of pneumonia[7,14-16]. One of the specific characteristics of COVID-19 pneumonia is the high frequency of peripheral lung involvement[6,8]. In the present study, similar to the literature, the most common findings were GGO and consolidation, and bilateral and peripheral distributions within the CXR and CT findings. In the case of unilateral involvement, the right lung is more frequently affected than the left[6]. This was confirmed in our study, where it was found that the right lung was more frequently involved than the left lung in unilateral involvement in CXR and CT.

It is important for people who have COVID-19 to receive a prompt diagnosis so that they can receive appropriate treatment, isolate themselves, and identify those who are in close contact. It was reported in previous studies[17,18] that the sensitivity of chest CT imaging (97%) is superior to that of RT-PCR (71%) for diagnosing COVID-19. For this reason, CT will help reduce the prevalence of the disease in terms of early diagnosis. CXR is a less sensitive method than CT in detecting COVID-19 lung disease. The present study shows a CXR sensitivity that is substantially in line with the most recent literature (72%), in which a variability between 68 and 90% is described[6,7,18]. However, many recent studies[3,7,18] have shown that CXR may not have the diagnostic power of CT but still has a role in managing the pandemic.

CT has a high sensitivity in diagnosis, but the radiation exposure and the associated increased cancer risk arouse several concerns[19]. When compared to conventional X-rays, the radiation dose received by the patient in CT scans is quite high. In conclusion, although CT has important diagnostic medical benefits, it also poses great risk to patients regarding the development of cancer associated with ionizing radiation. Chest CT has other disadvantages besides radiation, which include the risk of transmission of COVID-19

Table III. Comparison of demographic and clinical parameters results according to normal and abnormal chest X-rays (CXRs) at COVID-19 patients who had abnormal CT.

	Abnormal CT and abnormal CXRs Group1 (n: 71)		Abnormal CT and normal CXRs Group2 (n: 42)		χ^2	*p*
	n	%	n	%		
Age group						
<65 years	39	54.9	40	95.2	20.383	<0.001
≥65 years	32	45.1	2	4.8		
Gender						
Male	46	64.8	28	66.7	0.041	0.839
Female	25	35.2	14	33.3		
Comorbidity						
Yes	41	57.7	13	31	7.593	0.006
No	30	42.3	29	69		
Dyspnea						
Yes	32	45.1	8	19	7.815	0.005
No	39	54.9	34	81		
Disease severity						
Severe pneumonia	33	46.5	2	4.8	38.157	<0.001
Mild disease	0	0	9	21.4		
Critical disease	4	5.6	0	0		
Pneumonia	34	47.9	31	73.8		
ICU* requirement						
Yes	36	50.7	2	4.8	24.956	<0.001
No	35	49.3	40	95.2		
Oxygen requirement						
Yes	31	43.7	6	14.3	10.341	0.001
No	40	56.3	36	85.7		
High flow requirement						
Yes	18	25.4	2	4.8	7.681	0.006
No	53	74.6	40	95.2		
Noninvasive mechanical ventilatory requirements						
Yes	4	5.6	0	0	2.453	0.295
No	67	94.4	42	100		
Invasive mechanical ventilatory requirements						
Yes	13	18.3	0	0	8.690	0.002
No	58	81.7	42	100		
Clinical follow-up						
Response to treatment	36	51.4	36	85.7	13.550	0.001
Clinical deterioration**	23	32.9	4	9.5		
Nonresponse to treatment***	11	15.7	2	4.8		
Mortality						
Survived	60	85.7	40	97.6	4.064	0.052
Deceased	10	14.3	1	2.4		

*ICU: intensive care unit. **Clinical deterioration [respiratory rate (RR) >30/min or oxygen (O_2) saturation <90]. ***Non-response to treatment (persistent fever, cough, etc.).

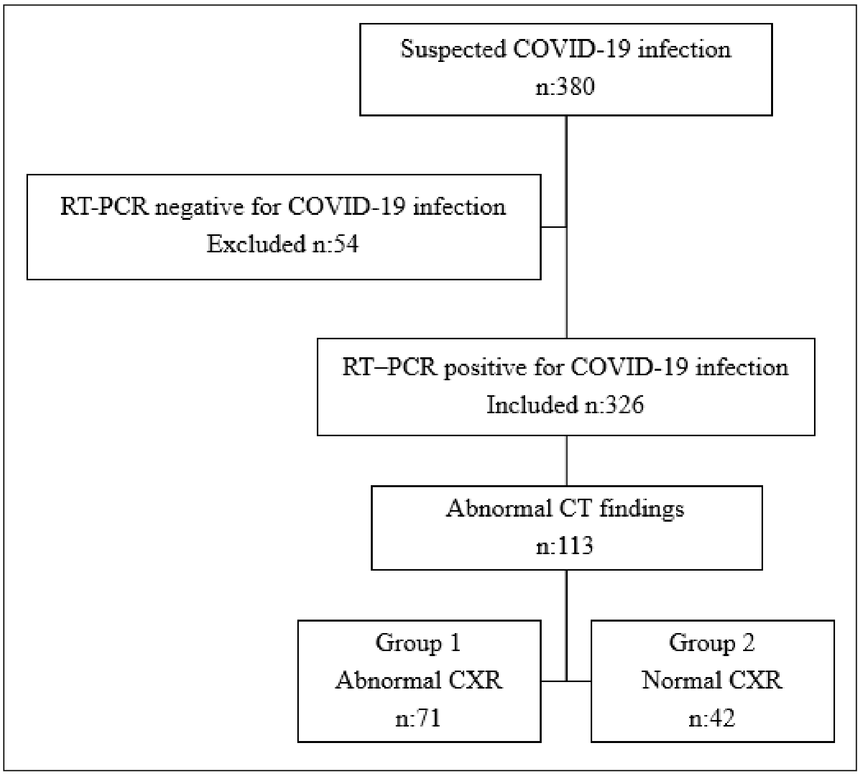

Figure 2. Patient selection flowchart.

Table IV. Evaluation according to disease severity in cases under and over 65 years of age.

	Severe pneumonia	Mild disease	Critical disease	Pneumonia	Total
<65 years	24	100	0	145	269
≥65 years	22	4	5	26	57
Total	46	100	5	171	326

Table V. Comparison of vital signs and laboratory parameters according to normal and abnormal chest X-rays (CXRs) at COVID-19 patients who had abnormal CT.

	Group 1 (n: 71) Abnormal CT and abnormal CXRs	Group 2 (n: 42) Abnormal CT and normal CXRs	Z	*p*
	Median (Min-max)	Median (Min-Max)		
Age	63 (29-81)	36.5 (19-67)	-5.936	<0.001
Oxygen saturation at admission	94 (0.98-98)	96.5 (94-100)	-5.376	<0.001
The lowest oxygen saturation	88 (0.92-96)	94 (88-99)	-6.728	<0.001
Respiratory rate at admission	22 (6-88)	20 (14-26)	-2.366	0.018
Highest respiratory rate	24 (18-40)	22 (18-27)	-4.006	<0.001
White blood cells (x10^9/L)	5,385 (1,200-18,760)	5,290 (2,630-19,900)	-0.168	0.867
Lymphocyte (x10^9/L)	950 (150-2,170)	1,400 (520-4,410)	-35.51	<0.001
CRP (mg/L)	45 (2-880)	5.5 (0-430)	-4.438	<0.001
Procalcitonin (μg/L)	0.09 (0-2)	0.03 (0.02-0.16)	-3.542	<0.001
Ferritin (μg/L)	433 (41-1,566)	97 (0.96-558)	-4.044	<0.001
D-dimer (mg/L)	0.61 (0.19-35)	0.32 (0.1-3.5)	-2.660	0.008

to uninfected health care workers and other patients (cross-contamination), the consumption of personal protective equipment and the need for cleaning, as well as the downtime of radiology rooms[1]. Additionally, because of the convenience of CT in the diagnosis of COVID-19 during the pandemic, an increasing number of radiologists encountered demand for imaging[20]. For these reasons, CT should be avoided except in cases of absolute medical necessity. Algorithms were developed for imaging in this regard[1].

In the present study, abnormal CXR was found to be statistically significant and higher in the group over 65 years of age. The rate of finding relevant findings in PAAG may be higher because the disease is more severe in the elderly, and there may be more disease involvement. In the multivariate analyses, it was reported that only the Brixia Score (the CXR scoring system to measure lung abnormalities in COVID-19 pneumonia), patient age, and severity of lung abnormalities were strong risk factors for in-hospital mortality and were associated with poor prognosis[21-24].

In another study[8] that examined CXR, in the symptomatic group, 47% of the patients had comorbidities, and 84% had abnormal CXRs. Similarly, in the present study, abnormal CXRs were found in all critically ill patients and most patients with severe pneumonia (94.2%, 33/35). The CXR was normal in all 9 patients that had mild clinical manifestations, and this was statistically significant. CXR has an important role in the basic evaluation of patients with critical and severe disease and a limited role in patients with mild clinical disease. Additionally, patients who had comorbid conditions had a higher rate of abnormal CXR. The value of CXR increases in patients who are symptomatic and who have comorbidities[8].

In the present study, the CXR severity score was not calculated, but the patients who had an abnormal CT were divided into abnormal and normal CXR groups and were compared. In the 1st group with abnormal CT and abnormal CXR, disease severity, ICU need, oxygen need, and invasive and non-invasive ventilator support were more common. The proportion of patients with clinical worsening and unresponsiveness to treatment were also significantly higher in this group. Most of the patients who died (91%) (10/11) were in this group. In a similar study[25] was reported that abnormal CXR findings were also associated with increased risk of mortality and prolonged hospital stay. Another study[26] that examined the value of CXR to predict COVID-19 outcomes, it was reported that a high Brixia Score (the CXR scoring system that measures lung abnormalities in COVID-19 pneumonia) predicted in-hospital mortality for COVID-19[27]. Additionally, Toussie et al[28] reported that the percentage of lung region involvement in CXR is an indicator of the need for ventilator support and intubation. In the present study, in the 2nd group with abnormal CT and normal CXR, no critically ill patients who needed a mechanical ventilator and whose clinical condition was severe were detected. CXR can assist clinicians in patient management and treatment planning regarding the clinical course, need for respiratory support, ICU need, and mortality, helping to prepare for potential negative outcomes.

Limitations

The present study had several limitations. First, the absence of a non-COVID-19 control group due to the retrospective nature of this study limited the evaluation of CXR. The present study also had limited characteristics because of the small amount of data. More studies are needed for the development of radiographic findings in symptomatic patients, the correlation of these radiographic findings with the clinical course of the disease, and the use of CXRs in clinical management.

Conclusions

In the present study, the analysis of CT and CXR radiographic findings and their impact on clinical outcomes in COVID-19 patients confirmed by RT-PCR were described. CXR had a sensitivity of 72%. In the results of the present study, it was concluded that CXR has low sensitivity in asymptomatic patients and those with a mild disease status but can help identify high-risk patients. Additionally, CXR can be used to evaluate symptomatic COVID-19 patients at presentation, make hospitalization decisions, and grade the severity of the disease. It was also determined that CXR is valuable in detecting many critical conditions (mortality, oxygen, ventilator, and ICU needs) clinically.

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Ethics Approval

Ethical approval was obtained from the Ankara City Hospital Ethical Committee before initiating the study (date and number of approval: 21.05.2020, 20-628).

Authors' Contributions

Burcu Ozdemir contributed to the conception and design of the study, acquisition of data, analysis and interpretation of data, drafting the article; validation and final approval of the version of the article to be published. Esragul Akinci, Murathan Koksal, Elif Rodoplu, Adalet Altunsoy, Rahmet Guner, Bircan Kayaaslan, Ayse Kaya Kalem, Imran Hasanoglu, Fatma Eser, Muge Ayhan, Elif Mukime Saricaoglu, Yesim Aybar Bilir, and Belgin Coskun contributed to the conception and design of the study, reviewing and editing the article; supervision; validation and final approval of the version of the article to be published.

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Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author upon request.

Conflict of Interest

The authors declare no conflict of interest.

Informed Consent

Patients informed consent was waived due to the retrospective nature of the study.

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