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Original Article

Evaluation of performance of chest x-ray in distinguishing intensive care unit need among COVID-19 patients

Yoğun bakım ihtiyacı olan COVID-19 hastalarını ayırt etmede akciğer grafisinin performansının değerlendirilmesi

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Abstract

Aim: To investigate the performance of chest X-ray (CXR) in distinguishing the patients who necessitate intensive care unit (ICU) admission among COVID-19 patients.

Material and Methods: Between April to August 2020, 166 consecutive hospitalized COVID-19 patients who underwent acquisition of CXR within 24 hours of hospital admission were included in the study. Age, gender, number of comorbidities, smoking status and duration of symptoms for all patients were noted. Observer 1 interpreted the radiographic findings of CXRs of all patients. Distribution of radiographic findings were noted. Afterwards, Observer 1 and observer 2 assigned radiographic assessment of lung edema (RALE) score for each CXR independently. Sensitivity, specificity values in distinguishing COVID-19 patients who require ICU for each observer were calculated. Intraclass Correlation Coefficient (ICC) test was used to assess interobserver agreement levels.

Results: Of the included patients, 128 (77.1%) patients were hospitalized only whereas 38 (22.9%) patients had necessity for ICU admission. Using 7.5 for RALE score as a cut-off point in distinguishing COVID-19 patients who need ICU admission Observer 1 had 89.5% and 93% for sensitivity and specificity, respectively; and Observer 2 had 89.5% and 91.4% for sensitivity and specificity, respectively. The ICC value for the interobserver agreement in RALE scores was 0.988 (95% confidence interval: 0.983 – 0.991).

Conclusion: CXR can be helpful in distinguishing COVID-19 patients who necessitates ICU admission and a RALE score higher than 7.5 is indicative for ICU requirement.

Keywords: COVID-19; chest x-ray; intensive care unit

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Öz

Amaç: COVID-19 hastalarından yoğun bakım ünitesi (YBÜ) ihtiyacı olanları ayırt etmede akciğer grafisinin performansının değerlendirilmesi amaçlanmıştır.

Gereç ve Yöntemler: Nisan ve Ağustos 2020 tarihleri arasında, hastaneye yatırılan ve 24 saat içinde akciğer grafisi elde olunan ardışık 166 COVID-19 hastası çalışmaya dahil edildi. Tüm hastaların yaş, cinsiyet, eşlik eden hastalık, sigara içme durumu ve semptom süresi kaydedildi. Birinci gözlemci tüm hastaların akciğer grafilerinde radyolojik bulguları değerlendirdi. Radyografik bulguların dağılımı not edildi. Daha sonra iki gözlemci birbirinden bağımsız olarak tüm akciğer grafilerine akciğer ödemi radyografik değerlendirme (AÖRD) skoru verdi. Her iki gözlemci için COVID-19 hastalarından YBÜ ihtiyacı olanları belirlemede duyarlılık ve özgüllük değerleri hesaplandı. Intraclass Correlation Coefficient (ICC) testi gözlemciler arası uyumluluğu değerlendirmek için kullanıldı.

Bulgular: Hastaların 128'i (%77.1) sadece hastaneye yatırılırken, 38'i (%22.9) YBÜ'ne ihtiyaç duydu. AÖRD skoru için 7.5 eşik değeri olarak kullanıldığında YBÜ gereksinimi olan COVID-19 hastalarını ayırt etmede birinci gözlemci için %89.5 ve %93 duyarlılık ve özgüllük değerleri; ikinci gözlemci için %89.5 ve %91.4 duyarlılık ve özgüllük değerleri bulundu. Gözlemciler arası uyumluluk için ICC değeri 0.988 (%95 güven aralığı: 0.983 – 0.991) olarak bulundu.

Sonuç: Akciğer grafisi YBÜ ihtiyacı olan COVID-19 hastalarını belirlemede yardımcı olabilir ve 7.5'ten büyük AÖRD skoru YBÜ gereksinimini gösterir.

Anahtar kelimeler: COVID-19; akciğer grafisi; yoğun bakım ünitesi

Introduction

Undisputedly, the coronavirus disease 2019 (COVID-19) pandemic has had unprecedented effects on global healthcare systems in 2020 and the exact end of this pandemic is still unpredictable. Almost all countries attempted to develop strategies in their healthcare organizations for potential patient surges and maintaining the quality of patient care. The COVID-19 disease mainly affects the respiratory tract. Symptoms of the disease may vary in range of asymptomatic to fatal and it can progress rapidly [1-3]. The severity of the disease may cause admission to intensive care unit (ICU) which ordinarily has limited numbers of beds in healthcare systems. In this context, as the magnitude of the pandemic can demonstrate spikes, ICU management comprises one of the key points of the healthcare strategies developed for COVID-19 pandemic [4]. Therefore, detecting the COVID-19 patients who need ICU admission in a timely manner has paramount importance.

Although the reference standard for the diagnosis of COVID-19 infection is reverse transcription polymerase chain reaction (RT-PCR) test imaging, particularly chest CT, can play a pivotal role in containment of the disease especially in regions where testing kits are in short supply or turnaround times are lengthy [5-7]. Furthermore, it has been reported that features extracted from radiologic examinations can be helpful in predicting prognosis and clinical outcome of the disease [8-11]. Due to its high sensitivity CT scans were in focus of vast majority of the studies which investigated the role of imaging in COVID-19 pandemic. However, despite its lower sensitivity in comparison to CT scans, chest X-ray (CXR) has advantages of low radiation dose to patients and portability which can limit disease transmission [7]. Several studies also demonstrated that CXR can be helpful in the setting of pandemic [12,13]. Moreover, one recent study reported that CXR is a reproducible imaging tool to evaluate COVID-19 infection and can be useful in predicting clinical outcome of the patients [11]. Therefore, in the current study, we aimed to investigate the performance of CXR in distinguishing the patients who necessitate ICU admission among COVID-19 patients.

Material and methods

The institutional ethics committee approved this retrospective study. The requirement for the written informed consent was waived by institutional ethics committee. Between April to August 2020, our hospital database was searched for all hospitalized COVID-19 patients who underwent acquisition of CXR within 24 hours of hospital admission. Negative RT-PCR test, no available CXR within 24 hours of hospital admission and unavailability of complete demographic data were used as exclusion criteria. 174 consecutive laboratorially confirmed and hospitalized COVID-19 patients were included in the study.

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8 patients were excluded from the study due to poor diagnostic CXR image quality. Therefore, final study cohort consisted of 166 laboratorially confirmed COVID-19 patients. Age, gender, number of comorbidities, smoking status and duration of symptoms (time interval between symptom onset and hospital admission) for all patients were noted. Patients were divided into subgroups according to their ages (<65 years and ≥65 years), smoking status (never smoked, active smoker, former smoker), and number of comorbidities (none, 1, and ≥2).

A radiologist (Observer 1) who had 10 years of experience in CXR interpretation assessed all CXRs of the included patients. The radiologist was aware that patients were laboratorially confirmed COVID-19 patients, however was blinded to all other demographic and clinical data of the patients. Observer 1 determined the distribution patterns of the lung abnormalities were as follows: a.) unilateral or bilateral; b.) upper zone, lower zone or both zones; c.) central, peripheral or both areas. Presence of pleural effusion was also noted. Afterwards, the Observer 1 used a radiographic assessment of lung edema (RALE) score [14-16] for each CXR in range of 0 (no pathological abnormality) to 48 (complete pathological involvement of both lungs) to assess the disease severity quantitatively (Figures 1 and 2). To assess the reproducibility of the RALE scores, a second radiologist (Observer 2) who had 9 years of experience in CXR interpretation evaluated all CXRs for only RALE score assessment in a separate session independently. Observer 2 was also blinded to all demographic and clinical data of the patients except COVID-19 positivity.

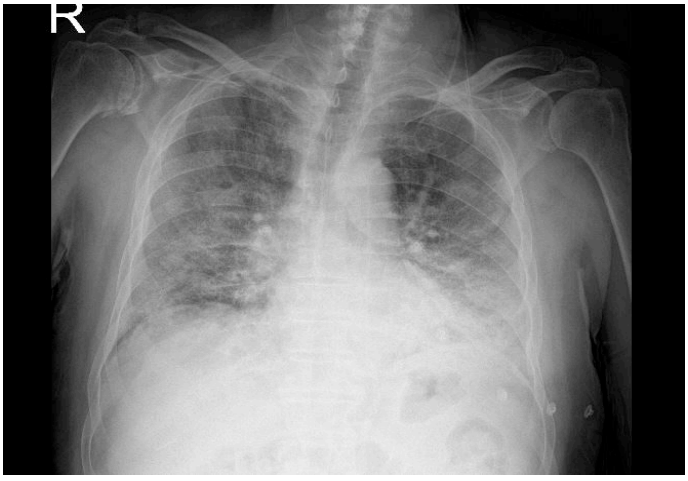

Figure 1. Chest X-ray (CXR) of a 75 years old male COVID-19 patient who admitted to intensive care unit. CXR demonstrates bilateral patchy ground glass opacities with accompanying consolidation at left lower zone. Radiographic assessment of lung edema score was assigned as 20 and 21 for Observer 1 and observer 2, respectively.

Figure 2. Chest X-ray (CXR) of a 64 years old male COVID-19 patient who admitted to intensive care unit. CXR demonstrates bilateral consolidations. Radiographic assessment of lung edema score was assigned as 27 and 24 for Observer 1 and observer 2, respectively.

Statistical Analysis

All statistical analyses were performed using SPSS software version 22.0 (IBM Corp, Armonk, NY). Continuous variables were presented as mean ± SD whereas categorical variables were presented as percentage values. Kolmogorov-Smirnov test was used to assess the normality of data distribution. Mann Whitney U test was used to compare differences between groups. Pearson Chi-Square test was used to compare categorical variables of independent groups. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) in distinguishing patients who need ICU admission were calculated for RALE scores of each observer. Area under the receiver operating characteristic curve (AUROC) for each observer and 95% confidence intervals (CI) were calculated. Intraclass Correlation Coefficient (ICC) test was used to assess interobserver agreement levels. The ICC test results was interpreted as poor for values less than 0.5; moderate for values between 0.5 and 0.75; good for values between 0.75 and 0.9; excellent for values higher than 0.9 [17]. A P value of 0.05 was used as treshold for statistical significance.

Results

A total of 166 laboratorially confirmed COVID-19 patients were included in the study. The mean age of the patients was 48.37 ± 17.91 years (range: 19-89 years). Of these patients, 128 (77.1%) patients were hospitalized only whereas 38 (22.9%) patients had necessity for ICU admission. The mean

of symptom duration was 4.57 ± 3.61 days (median: 4 days, range: 1-20 days). The most of the patients (73/166, 44%) had no pre-existing comorbidities whereas 44 (26.5%) patients had ≥2 pre-existing comorbities. The most of the patients (85/166, 51.2%) were never smoked. Table 1 represents the demographic data of the included COVID-19 patients. Age (P <0.001), pre-existing comorbidities (P <0.001) and smoking status (P = 0.001) had significant associations with ICU admission. Table 2 represents the distribution of patients according to subgroups and ICU admission.

Table 1. Demographic data of the included COVID-19 patients

Patient Characteristics	Value
Age (years)	48.37 ± 17.91 (range: 19-89 years)
Gender	
Male	92 (55.4%)
Female	74 (44.6%)
Number of pre-existing comorbidities	
0	73 (44%)
1	49 (29.5%)
≥2	44 (26.5%)
Smoking status	
Never smoked	85 (51.2%)
Active smoker	59 (35.5%)
Former smoker	22 (13.3%)
Symptom duration (days)	4.57 ± 3.61 (range: 1-20 days)

Of the included COVID-19 patients, radiographic abnormalities was found in CXRs of 100 (60.2%) patients whereas CXRs of 66 (39.8%) patients demonstrated no abnormality and were interpreted as normal. There was significant difference in duration of symptoms between the CXR normal (median: 3 days) and CXR abnormal (median: 5 days) groups (P = 0.001). The type of main abnormal finding was ground glass opacity (74/100, 74%) and it was followed by consolidation (26/100, 26%). Among the patients whose CXRs revealed abnormalities, lung involvements demonstrated unilateral and bilateral findings in 19 and 81 patients, respectively. Lung involvements were detected in upper zones, lower zones and both zones in 6, 59, and 35 patients respectively. Distribution patterns of the abnormal findings were in central, peripheral, and both areas in 18, 32, and 50 patients, respectively. Pleural effusion was observed in only 11 patients. Table 3 represents the distribution of the radiographic findings of the included COVID-19 patients.

Table 2. Distribution of patients according to subgroups and intensive care unit (ICU) admission.

Patient Characteristics	Hospitalized (n=128)	ICU (n=38)	P value
Age			
<65	117	15	<0.001
≥65	11	23	
Gender			
Male	72	20	0.694
Female	56	18	
Comorbidities			
None	71	2	<0.001
1	42	7	
≥2	15	29	
Smoking status			
Never	69	16	0.001
Former	10	12	
Active	49	10	

Table 3. Distribution of radiographic findings in COVID-19 patients with abnormal chest X-rays (n=100)

Radiographic finding	Number of patients
Type of main parenchymal abnormality	
Ground glass opacity	74 (74%)
Consolidation	26 (26%)
Affected lungs	
Unilateral	19 (19%)
Bilateral	81 (81%)
Distribution	
Upper	6 (6%)
Lower	59 (59%)
Both	35 (35%)
Distribution	
Central	18 (18%)
Peripheral	32 (32%)
Both	50 (50%)
Pleural effusion	
Yes	89 (89%)
No	11 (11%)

The means of RALE scores were 5.83 ± 8.41 (range: 0-36) and 5.69 ± 8.58 (range: 0-32) for Observer 1 and 2, respectively. If cut-off point was determined as 7.5 for RALE score, in distinguishing COVID-19 patients who need ICU admission the Observer 1 had 89.5%, 93%, 79.1% and 96.7% for sensitivity, specificity, PPV and NPV, respectively; and the Observer 2 had 89.5%, 91.4%, 75.6% and 96.7% for sensitivity, specificity, PPV and NPV, respectively. AUROC values for Observer 1 and Observer 2 were 0.947 (95% CI: 0.899 – 0.995) and 0.938 (95% CI: 0.883 – 0.992), respectively. The ICC value for the interobserver agreement in RALE scores was 0.988 (95% CI: 0.983 – 0.991).

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Discussion

The COVID-19 pandemic has spread all across the world and healthcare systems encountered overwhelming workload. Due to potential patient surges it is extremely important to render quick and accurate decisions in the battle with this pandemic. Because ICU resources are scarce critical care triage is one of the main goal for the management of this outbreak. In this study we found that RALE score assigned based on CXRs obtained within 24 hours of hospital admission can accurately distinguish COVID-19 patients who need admission to ICU. As the results of the current study can be helpful in determining the COVID-19 patients who require ICU admission it may play an important role in critical care triage for clinicians and ICU practitioners.

In the current study we found that older age (≥65 years) and pre-existing comorbidities had significant associations with ICU requirement. These findings are in line with the previous studies [18-21]. There are controversial results in the literature about the association between smoking status and severity of the disease. Zhao et al [22] reported that smoking increases the risk of severe COVID-19 approximately by twofolds. However, Lippi et al [23] reported that active smoking is not associated with severity of the disease. In the current study we found a significant association with the smoking status of the patients and ICU requirement. Interestingly, our findings revealed that 54.5% (12/22) of former smokers admitted to ICU whereas only 16.9% (10%59) of active smokers admitted to ICU. However, former smokers were older (median: 68 years) than the active smokers (median: 46 years) in this study cohort and age may be confounding factor for these results. Future studies are necessary to investigate the complex relationship between the disease severity and smoking status.

CXR is relatively low cost imaging technique which is widely used in the evaluation of pneumonias. Although, most of the studies which assess imaging features of COVID-19 pneumonia focused on CT imaging, several studies also reported the radiographic findings of COVID-19 patients. Bilateral consolidations and/or ground glass opacities with a predilection for peripheral and lower zones are the most common findings detected on CXRs of patients with COVID-19 pneumonia [6,10-13]. In the current study the most of the CXRs with abnormal findings demonstrated bilateral lung involvement, and we found that the majority of the CXRs with abnormal findings demonstrated radiographic abnormalities in lower zones (59%); and in both central and peripheral areas (50%). Notably, although all included COVID-19 patients were hospitalized, CXRs of 39.2% (66/166) patients were interpreted as normal. A study which included CXR examinations of 636 symptomatic patients with COVID-19 who admitted to urgent care centers revealed that 58.3% of CXRs were interpreted as normal [24]. On the other hand, Stephanie et. al [12] reported that the sensitivity of CXR in COVID-19 patients increases with symptom duration. In our study symptom duration of patients with normal CXRs (median: 3 days) are significantly shorter than symptom duration of patients with abnormal CXRs (median: 5 days). Although CXRs of symptomatic COVID-19 patients can be normal the difference in symptom duration between patients normal and abnormal CXRs also had potential influence on these results.

It has been demonstrated that CT findings can be helpful to predict critical disease or ICU requirement in COVID-19 patients. Balbi et al [11] reported that CXR also can be helpful to predict the need for ventilatory support or mortality. Cozzi et al [15] investigated the correlation between radiographic findings with clinical outcomes. They interpreted CXRs of 234 COVID-19 patients and reported that RALE score higher than 15 had a correlation with increasing risk of being admitted to ICU. In our study a RALE score higher than 7.5 had high sensitivity (89.5%) and specificity (91.4% - 93%) for both observers in distinguishing COVID-19 patients who need ICU admission. Differences in study cohorts or potential differences in ICU admission criteria between institutions may lead discordant results. Future multinational and multicentric studies may allow us to better understand the role of RALE scores in predicting ICU need.

In the study of Cozzi et al [15] two independent reader assigned RALE scores in COVID-19 patients and found that inter-reader agreement in the assignment of RALE scores was very good (ICC value 0.92). Moreover, Balbi et al [11] reported that another scoring system [25] which was experimentally developed to assess the severity of COVID-19 pneumonia based on CXR findings also demonstrated almost perfect inter-rater agreement (ICC value 0.91) . These results indicate that CXR scoring systems in COVID-19 patients are reproducible. Similarly, in the current study we found an excellent (ICC value

0.988) interobserver agreement for RALE scores. Therefore, our findings are in line with the previous studies.

This study has several limitations. The main limitations of the current study are retrospective design and lack of comparison with CT scans. Moreover, number of included patients is relatively small. As the sensitivity of CT imaging is superior to CXR in COVID-19 patients future studies with a larger number of patients in prospective design which also compare CXRs and CT imaging may be more valuable. Additionally, this study does not provide information about the final outcome (recovery or death) of the patients who admitted to ICU. Therefore, investigations that also provide information about the final outcome of these patients can ensure better understanding of the role of CXR in this pandemic.

Conclusion

The current study revealed that CXR can be helpful in distinguishing COVID-19 patients who necessitates ICU admission and a RALE score higher than 7.5 is indicative for ICU requirement.

Declaration of conflict of interest

The authors received no financial support for the research and/or authorship of this article. There is no conflict of interest

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