RESEARCH ARTICLE

Diagnostic Performance of Standard and Inverted Grey-Scale CXR in Detection of Lung Lesions in COVID-19 Patients: A Single Institute Study in the Region of Abu Dhabi

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Abstract:
Purpose:
This study aimed at evaluating the diagnostic performance of standard greyscale and inverted greyscale Chest X-ray (CXR) using Computed Tomography (CT) scan as a gold standard.

Methods:
In this retrospective study, electronic medical records of 120 patients who had valid CXR and High-resolution CT (HRCT) within less than 24 hours after having a positive COVID-19 RT-PCR test during the period from May 19th to May 23rd, 2020, in a single tertiary care center were reviewed.

PA chest radiographs were presented on 2 occasions to 5 radiologists to evaluate the role and appropriateness of standard greyscale and inverted greyscale chest radiographs (CXR) when images are viewed on high-specification viewing systems using a primary display monitor and compared to computed tomography (CT) findings for screening and management of suspected or confirmed COVID-19 patients.

Results:
Ninety-six (80%) patients had positive CT findings, 81 (67.5%) had positive grey scale CXR lesions, and 25 (20.8%) had better detection in the inverted grey scale CXR. The CXR sensitivity for COVID-19 pneumonia was 93.8% (95% CI (86.2% - 98.0%) and the specificity was 48.7% (95% CI (32.4% - 65.2%). The CXR sensitivity of detecting lung lesions was slightly higher in male (95.1% (95% CI (86.3% - 99.0%)) than female (90.0% (95% CI (68.3% - 98.8%)), while the specificity was 48.0% (95% CI (27.8% - 68.7%) and 50.0% (95% CI (23.0% - 77.0%) in males and females, respectively. However, no significant difference was detected in ROC area between men and women.

Conclusion:
The sensitivity of detecting lung lesions of CXR was relatively high, particularly in men. The results of the study support the idea of considering conventional radiographs as an important diagnostic tool in suspected COVID-19 patients, especially in healthcare facilities where there is no access to HRCT scans.

CXR shows high sensitivity for detecting lung lesions in HRCT confirmed COVID-19 patients. Better detection of lesions was noted in the inverted greyscale CXR in 20.8% of cases, with positive findings in standard greyscale CXR.

Conventional radiographs can be used as diagnostic tools in suspected COVID-19 patients, especially in healthcare facilities where there is no access to HRCT scans.

Keywords: COVID-19, Coronavirus, Ground-glass opacity, X-ray, Computed tomography, HRCT, RT-PCR test.

Article History
Received: May 06, 2021
Revised: October 10, 2021
Accepted: October 20, 2021

1. INTRODUCTION

The pandemic caused by the novel coronavirus named COVID-19 or SARS-CoV-2 was first reported in China in December 2019, followed by widespread in all other countries in the world. Millions of confirmed cases have been found in the world [1]. COVID-19 clinical spectrum varies from...
asymptomatic or mild symptoms in most cases to Severe Acute Respiratory Syndrome (SARS), which may lead to death.

Most countries worldwide adopt molecular assays to screen for COVID-19 infection based on WHO guidelines [2]. Suspected COVID-19 patients are often seen in the emergency department; therefore, developing new strategies to rapidly diagnose COVID-19 patients is the current challenge as the gold standard RT-PCR results need several hours and have more than 5% false-negative rates [3, 4]. There are multiple typical features of chest HRCT that help in the treatment plan of suspected COVID-19 patients till the RT-PCR results are available such as bilateral, peripheral ground-glass opacities with or without consolidations predominantly affecting posterior segments [5]; however, the challenge of continuous infection control between the cases and the huge burden for the radiology departments should be taken into consideration [6].

Chest X-ray is widely available in emergency departments, particularly to complete the assessment of patients with respiratory symptoms or sepsis with minimal risk of cross-infection as the surface of the portable unit can be cleaned easily. Moreover, COVID-19 patients manifest with characteristic chest x-ray imaging features, which are helpful for the early detection of COVID-19 pneumonia changes as well as reflecting the severity of disease and following it up by comparing pre and post-treatment changes [7]. However, the diagnostic performance of CXR in COVID-19 patients is not yet thoroughly investigated. This study aimed to evaluate the diagnostic performance of standard greyscale and inverted grey-scale CXR with CT scan as a gold standard in COVID-19 patients.

2. MATERIALS AND METHODS

2.1. Study Population

All suspected and confirmed COVID-19 patients admitted to the emergency department in a single tertiary care center in Abu Dhabi, UAE, who had RT-PCR tests during the period from May 19th to May 23rd, 2020, were eligible for this study. A total of 250 patients were admitted during the study period. Among them, 127 patients with negative RT-PCR results, no x-ray and HRCT of the chest within 24 hours, or had duplicate medical record numbers were excluded. A total of 120 COVID-19 positive patients who had chest X-rays and confirmatory HRCT chest within less than 24 hours from RT-PCR test results were included in the analysis.

The electronic medical records of these 120 patients were retrospectively reviewed. Demographic data on patients’ age and sex were extracted, and chest radiographs were reanalyzed.

Ethics approval was obtained from the local Research Ethics Committee (Abu Dhabi COVID-19 Research Ethics Committee) Ref: DOH/CVDC/2020/1126.

2.2. Imaging Technique and Analysis

Five radiologists interpreted the chest radiographs during two reading sessions in standard view and inverted grey-scale view on a primary display system. Primary display systems are used for the interpretation of medical images, as in radiology. They have to meet strict performance criteria. On the other hand, secondary display systems are used by staff other than radiologists, usually after an interpretative report has been rendered.

Chest x-rays were performed in all patients with the GE AMX Advantax 690 portable machine. All patients had AP seated view unless critically sick or intubated AP supine view was performed. Chest factors = KVP 90/ MAS 2.5 (Normal body build) and Focal film distance (FFD) = 36-40cm. Chest X-ray was considered positive if alveolar opacity, reticular opacity, or both were found on CXR. All findings were compared to HRCT chest done within less than 24 hours. A high-resolution CT scan was performed in all patients with 64-slice multidetector row CT scanners (VCT GE -64). Patients were scanned during breath-hold craniocaudally in the supine position, from the lung apices to the costo-phrenic angles. The acquisition parameters were as follows: tube voltage 120kV, tube current 100-600 mA, dose modulation by smart MA, pitch 1. The slice collimation was 64x 0.625, and the slice width was 0.625 x 0.625. The 1.25 mm or 2.5 mm thick images were reconstructed using a lung window and a high-frequency reconstruction algorithm, then stored in the PACS system. An air purifier was fixed inside the scanner room, and COVIDCIDE wipes were used to disinfect the scanner after the completion of each examination. Sensitivity and specificity were used to assess accuracy based on the presence or absence of lung changes. Patients with positive lung lesions were manifested with patchy ground-glass opacity, linear opacities, or consolidations.

2.3. Statistical Analysis

Descriptive statistics of patients’ demographic (age, sex) and imaging (X-ray, CT) characteristics are reported as means (standard deviation (SD)), numbers, and relative frequencies. The diagnostic performance of standard greyscale CXR was estimated using CT results as a gold standard. Specificity, sensitivity, positive predictive value, negative predictive value, and total accuracy of chest X-ray were estimated. The receiver-operating characteristic (ROC) curve analysis was used to calculate the area under the curve (AUC). The analysis was performed using STATA version 16.1 (Stata Corp, College Station, TX, USA), and a p-value less than 0.05 was defined as statistical significance.

3. RESULTS

3.1. Demographic and Imaging Data

The analysis included 120 confirmed cases of COVID-19. The majority of patients were male (86; 71.7%) with a mean age of 46.9 years (standard deviation 13.7 years) (Table 1). Ninety-six (80%) patients had positive CT findings, 81 (67.5%) had positive greyscale CXR lesions, and 25 (20.8%) had better detection in the inverted greyscale CXR (Table 1).
Table 1. Demographic Characteristics and Imaging Findings of the Patients.

<table>
<thead>
<tr>
<th>-</th>
<th>COVID 19 Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>120</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>86 (71.7)</td>
</tr>
<tr>
<td>Women</td>
<td>34 (28.3)</td>
</tr>
<tr>
<td>Age, years (mean (SD))</td>
<td>46.9 (13.7)</td>
</tr>
<tr>
<td>Age groups</td>
<td></td>
</tr>
<tr>
<td>18 – 39 years</td>
<td>35 (29.2)</td>
</tr>
<tr>
<td>40 – 49 years</td>
<td>42 (35.0)</td>
</tr>
<tr>
<td>50 – 59 years</td>
<td>23 (19.2)</td>
</tr>
<tr>
<td>60+ years</td>
<td>20 (16.7)</td>
</tr>
<tr>
<td>Greyscale CXR lesions</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>81 (67.5)</td>
</tr>
<tr>
<td>No</td>
<td>39 (32.5)</td>
</tr>
<tr>
<td>Inverted greyscale lesions</td>
<td></td>
</tr>
<tr>
<td>Same findings</td>
<td>95 (79.2)</td>
</tr>
<tr>
<td>Better detection</td>
<td>25 (20.8)</td>
</tr>
<tr>
<td>CT findings</td>
<td></td>
</tr>
<tr>
<td>Positive</td>
<td>76</td>
</tr>
<tr>
<td>Negative</td>
<td>20</td>
</tr>
</tbody>
</table>

3.2. X-ray Features

Representative chest radiograph of COVID-19 pneumonia in a male patient (Fig. 1) showed subtle ground-glass opacity at the left lower zone with adjacent atelectatic changes, seen as well in inverted greyscale image (B). Axial chest CT (C) and coronal view (D) show bilateral peripheral and central patchy ground-glass opacities.

Another representative CXR of COVID-19 pneumonia (Fig. 2) showed a subtle ground-glass opacity at the base of both lungs with patchy opacity in the left middle zone (A), which was better seen in inverted greyscale image (B). Coronal chest CT images (C, D & E) confirmed the findings.

3.3. X-ray Diagnostic Performance

Using CT results as gold standard, the sensitivity and specificity of standard greyscale CXR were 93.8% (95% CI (86.2% - 98.0%)) and 48.7% (95% CI (32.4% - 65.2%), respectively (Table 2).

Table 2. Diagnostic Performance of Greyscale CXR Lesions with CT as a Gold Standard

<table>
<thead>
<tr>
<th>Gold Standard (CT Findings)</th>
<th>Greyscale CXR Lesions</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Positive</td>
<td>76</td>
<td>20</td>
</tr>
<tr>
<td>Negative</td>
<td>5</td>
<td>19</td>
</tr>
<tr>
<td>Total</td>
<td>81</td>
<td>39</td>
</tr>
</tbody>
</table>

Sensitivity 93.8% (95% CI (86.2% - 98.0%), Specificity 48.7% (95% CI (32.4% - 65.2%), Positive predictive value 79.2% (95% CI (69.7% - 86.8%), Negative predictive value 79.2% (95% CI (57.8% - 92.9%), ROC area 0.713 (95% CI (0.629 – 0.796)).

Five cases out of 81 showed false-positive results in CXR, and 20 cases out of 39 showed false-negative results. ROC area of standard greyscale CXR to CT was 0.713 (95% CI (0.629 - 0.796). The inverted greyscale showed similar findings compared to standard greyscale CXR in 95 patients (79.2%); however, better detection of lung lesions was noted in 25 patients (20.8% of the cases). The CXR sensitivity of detecting lung lesions was better in male (95.1% (95% CI (86.3% - 99.0%)) than female (90.0% (95% CI (68.3% - 98.8%)), while the specificity was 48.0% (95% CI (27.8% - 68.7%)) and 50.0% (95% CI (23.0% - 77.0%)) in males and females, respectively.
In some cases, the chest x-ray may show unilateral air space opacities involving a single lobe; this may still raise the possibility of COVID-19 pneumonia as it is challenging to identify all pneumonic changes on a limited CXR; in such cases, HRCT chest can help and may show the typical bilateral peripheral pneumonic changes, as seen in (Fig. 1).

Better detection of lesions in inverted greyscale images was noted in 20.8% of the cases (Fig. 2); however, the remaining cases showed similar detection sensitivity on both inverted greyscale images and standard greyscale images (Fig. 1).

The high sensitivity found in our study indicates that CXR correctly identified such lesions in the HRCT COVID-19 positive patients. The false-positive CXR findings could be attributed to the overlapping of soft tissue, which showed ground-glass opacity mimicking COVID-19 changes or old atelectasis.

However, CXR findings in COVID-19 patients might not be specific and can be seen with other infections, including influenza, SARS, MERS, and H1N1 [11, 17].

Our findings showed relatively lower specificity levels of CXR compared to HRCT as a gold standard. Although COVID-19 is considered a serious disease and high specificity would be preferred to avoid making a false negative diagnosis, the low specificity found in this study could be attributed to mild cases not developing lung lesions that could be detected by CXR [18]. Moreover, the United Arab Emirates is undertaking an intensified testing campaign for COVID-19 accompanied by a strong awareness program with early diagnosis and management of the cases. Therefore, many early detected positive COVID-19 cases might need time to develop lung manifestations that can be detected by CXR. A repeated CXR would be warranted in suspected patients.

The study had the advantage of having chest HRCT within less than 24 hours of performing portable chest x-ray for all COVID-19 positive patients, and it also checked for the effect of using inverted greyscale images compared to standard greyscale CXR images. Interestingly, the inverted greyscale CXR showed better detection of lesions in 20.8% of the cases than standard greyscale CXR.

CONCLUSION

The sensitivity of detecting lung lesions of CXR was relatively high, particularly in men. The results of the study support the idea of considering conventional radiographs as an important diagnostic test in suspected COVID-19 patients. The burden imposed by the COVID-19 pandemic on healthcare institutions highlighted the need to use a fast, available, and cost-effective diagnostic tool, like chest x-ray, to prioritize patients' management and predict results. Therefore, CXR can play an important role in the detection of lung changes, while HRCT chest can have a complementary role in evaluating disease severity, progression, and complications [9, 10]. Prior studies on the pattern and frequency of CXR and CT opacities in COVID-19 positive patients have demonstrated that opacities are typically peripheral, basilar, and bilateral in distribution, predominantly affecting the right lower lobe, especially in the early stages of the disease [11 - 13]. Khan SA. reported that the most common finding in CXR was bilateral alveolar infiltrates and consolidation, and the most common pattern on CT was ground-glass opacities and crazy paving [14].

Ng et al. reported that 86% of COVID-19 chest CTs had peripheral lung distribution, and an incidence of 33% of chest CT showed peripheral lung distribution as per Chung et al. study [6, 15]. Zeng F. reported that abnormal infiltrates on CXR in COVID-19 positive patients had good sensitivity, accuracy, and specificity reaching 92%, 92%, and 100%, respectively [16].

4. DISCUSSION

CXR showed a high sensitivity for detecting lung lesions in HRCT confirmed COVID-19 patients [8]. The performance was relatively higher in men than women. To the best of our knowledge, this is the first review and analysis of the diagnostic performance of standard and inverted grey-scale CXR in the detection of lung lesions in COVID-19 patients with a correlation to chest HRCT.

The results of the study support the idea of considering conventional radiographs as an important diagnostic test in suspected COVID-19 patients. The burden imposed by the COVID-19 pandemic on healthcare institutions highlighted the need to use a fast, available, and cost-effective diagnostic tool, like chest x-ray, to prioritize patients' management and predict results. Therefore, CXR can play an important role in the detection of lung changes, while HRCT chest can have a complementary role in evaluating disease severity, progression, and complications [9, 10]. Prior studies on the pattern and frequency of CXR and CT opacities in COVID-19 positive patients have demonstrated that opacities are typically peripheral, basilar, and bilateral in distribution, predominantly affecting the right lower lobe, especially in the early stages of the disease [11 - 13]. Khan SA. reported that the most common finding in CXR was bilateral alveolar infiltrates and consolidation, and the most common pattern on CT was ground-glass opacities and crazy paving [14].

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SARS-CoV-2 = Severe Acute Respiratory Syndrome Coronavirus-2  
WHO = World Health Organization  
RT-PCR = Reverse Transcriptase-Polymerase Chain Reaction  
MERS = Middle East Respiratory Syndrome  
H1N1 = Subtype of Influenza A virus

AUTHORS' CONTRIBUTIONS

Dr. Abeer Ahmed Al Helali contributed to writing original drafts, reviewing, and editing. Dr. Mohamed Ashfaque Kukkady participated in data collection, performing formal analysis, designing methodology, supervising, writing, reviewing, and editing. Dr. Ghufran Aref Saeed contributed to writing original drafts, reviewing, and editing. Dr. Luai Ahmed contributed to designing methodology, performing formal analysis, writing, reviewing, and editing.

ETHICAL APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the Abu Dhabi COVID-19 Research Ethics Committee, with reference number DOH/CVDC/2020/1126.

HUMAN AND ANIMAL RIGHTS

No animals were used in this research. All human research procedures were followed in accordance with the ethical standards of the committee responsible for human experimentation (institutional and national), and with the Helsinki Declaration of 1975, as revised in 2013.

CONSENT FOR PUBLICATION

All authors have participated in the work and have reviewed and agreed with the content of the article.

STANDARDS OF REPORTING

STROBE guidelines and methodologies were followed in this study.

AVAILABILITY OF DATA AND MATERIALS

The data that support the findings of this study are available from the corresponding author [A.A.A.-H], upon reasonable request.

FUNDING

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

We would like to thank Mr. George Roy, senior CT technician, for providing technical information regarding chest HRCT, all the radiographers and CT technicians that have dedicated their effort and time to perform thousands of studies involving COVID-19 patients in ED and isolation wards, and the radiologist staff at the Sheikh Khalifa Medical City for their strong performance during this pandemic crisis to facilitate the patient care.

REFERENCES


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