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Original Article

Utility of the serial portable chest x-ray for the diagnosis and quantification of COVID-19 patients

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الملخص

أهداف البحث: لتحديد دور الأشعة السينية المحمولة التسلسلية في التشخيص والتقدير الكمي لمرضى كوفيد-19 المؤكدين المنومين في مستشفى الرعاية الثالثية.

طرق البحث: تم إجراء دراسة استعادية في معهد داو للأشعة، جامعة داو للعلوم الصحية. تمت دراسة الحالات الإيجابية المؤكدة لكوفيد-19 من نوفمبر 2020 إلى يناير 2021 بدراسة استعادية. تم استرداد معلومات البيانات حول التركيبة السكانية للمرضى والخصائص السريرية ونتائج الأشعة السينية على الصدر والنتائج من خلال السجل الطبي الإلكتروني. تمت مقارنة خط الأساس ونتائج الأشعة السينية للصدر للمتابعة باستخدام درجة شدة الأشعة السينية على الصدر. تم استخدام الانحدار اللوجستي متعدد المتغيرات لتقييم العلاقة بين خصائص المرضى ونتائج المرضى.

النتائج: اشتملت الدراسة على 329 مريضا بمتوسط عمر 56.43 ± 13.10 سنة (المدى 16-85 سنة). كان الدمج المحيطي وعتامة الزجاج الأرضي (89.4٪) أكثر نتائج الأشعة السينية شيوعا تليها مشاركة الرئة الثنائية (79.0٪) والاندماج المحيط/عتامة الزجاج الأرضي (69.9٪). من بين المرضى الذين تم إدخالهم، خرج 61.4 ٪ من المرضى، و 49.5 ٪ من المرضى لديهم مدة إقامة مطولة ≤10 أيام، وتوفي 37.7 ٪ من المرضى. بعد تعديل خصائص جميع المرضى، أظهر النموذج متعدد المتغيرات عدم وجود فرق كبير في درجة شدة الأشعة السينية للصدر فيما يتعلق بنتائج المريض. ارتبط المرضى الذين تم إدخالهم في وحدة العناية المركزة، ودعم العلاج بالأكسجين، وضغط إيجابي ثنائي المستوى في المسالك الهوائية، وجهاز التنفس الصناعي بشكل كبير بنتيجة الخروج من المستشفى، والإقامة المطولة في المستشفى، والوفاة.

الاستنتاجات: كان الاستصحاف المحيطي وعتامة الزجاج الأرضي أكثر اكتشافات الأشعة السينية للصدر شيوعا في مرضى كوفيد-19 المقبولين. لم يلاحظ أي اختلاف كبير في درجة شدة الأشعة السينية للصدر في النتيجة الأولية للخروج، والإقامة المطولة في المستشفى، والوفاة. ليس هناك حاجة لإجراء أشعة سينية يومية للصدر في المرضى في المستشفى حتى يتم طلبها في حالة تفاقم الأعراض أو التدخل الهام مثل التنبيب الرغامي.

الكلمات المفتاحية: الأشعة السينية للصدر؛ مدة الإقامة؛ كوفيد -19؛ المرضى المنومين؛ محمول؛ درجة الخطورة؛ النتيجة الأولية

Abstract

Objective: To determine the role of the serial portable chest X-ray in the diagnosis and quantification of patients with confirmed COVID-19 admitted to a tertiary care hospital.

Methods: A retrospective study was conducted at Dow Institute of Radiology, Dow University of Health Sciences. Confirmed positive cases of COVID-19 from November 2020 to January 2021 were retrospectively studied. Patients' demographics and clinical characteristics, chest X-ray findings, and outcomes were retrieved through electronic medical records. Baseline and final follow-up chest X-rays findings were compared by using chest X-ray severity score. Multivariable logistic regression was used to evaluate the relationship between patients' characteristics and patient outcomes.

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Results: The study included 329 patients with a mean age of 56.43 ± 13.10 years (range 16–85 years). Peripheral consolidation and ground glass opacities (89.4%) were the most common X-ray findings followed by bilateral lung involvement (79.0%) and perihilar consolidation/ ground glass opacities (69.9%). Among the patients who were admitted, 61.4% were discharged, 49.5% had prolonged length of stay ≥10 days, and 37.7% died. After adjustment of all patients' characteristics, the multivariate model showed no significant difference in chest X-ray severity score in relation to the patient's outcome. Patients who were admitted to the intensive care unit, and received oxygen support, bilevel positive airway pressure, and a ventilator were significantly associated with the outcome of being discharged, prolonged hospital stay, and death.

Conclusion: Peripheral consolidation and ground glass opacities were the most common chest X-ray findings in admitted COVID-19 patients. No significant difference in chest X-ray severity score was noted in the primary outcome of being discharged, prolonged hospital stay, and death. There is no requirement for daily chest X-rays in hospitalized patients until required in the condition of worsening symptoms or significant intervention such as endotracheal intubation.

Keywords: Chest X-ray; COVID-19; Hospitalized patients; Portable; Primary outcome; Severity score

Introduction

Coronavirus disease 2019 (COVID-19) has become a pandemic that spread rapidly with different variants.[1,2] Various medical techniques for assessing suspected cases are being utilized, which are crucial to effectively impede the spread of the virus. Imaging procedures are one such technique and based on the latest scientific evidence, the role of X-ray imaging is considered significant in the current situation.[3,4] X-rays are performed daily in some hospitals, especially in the intensive care unit (ICU), according to the protocols set up by primary physicians.[5,6] However, the requirement of daily portable chest X-ray in hospital-admitted COVID-19 patients needs scrutiny due to associated characteristics in terms of enhanced resource engagement, higher financial impact, increased workload/ time management, and efficacy in the longer term. Furthermore, frequent X-rays can also lead to increased radiation doses for the patients.

Radiological studies about COVID-19 have mainly centered on computed tomography (CT) findings as it is comparatively more sensitive for the diagnosis and follow-up of COVID-19 patients compared to chest radiography.[7–10] However utilization of the CT scan as a primary diagnostic tool would result in increased workload on radiologic facilities, and it would also be challenging for institutes to follow strict precautionary measures and disease control guidelines in CT scan work stations.[11] The American College of Radiology supported the same fact which implies that the necessary decontamination process of CT scan area after examination of COVID-19 patient may impede provisioning of other radiological facilities and recommends that the spread of disease may be reduced with the use of chest radiography.[12] Different hospitals in Britain and Italy used chest radiography as an initial investigation tool because of the cumbersome turnaround time for real-time reverse transcription polymerase chain reaction (RT-PCR) to diagnose severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).[11,13] The excessive spread of COVID-19 has negatively influenced the economy of developing countries with inadequate health facilities.[14] Therefore Pakistan and other developing countries with restricted resources cannot replace chest radiography with CT scan examination in the present pandemic situation.

As the number of COVID-19 patients increases in Pakistan, it is necessary for all clinicians of different specialties to recognize the chest radiograph findings of COVID-19, as it is also a routine investigation tool for other purposes. The disease profile has evolved rapidly over a period of time and continues to do so. Previous studies have shown a spectrum of significant imaging findings such as alveolar pattern, consolidation, bilateral lung involvement, and pleural effusion in asymptomatic patients and on the other hand, critically ill patients with no significant radiological manifestations.[3,15] The current diagnostic criterion for COVID-19 is the positive result of RT-PCR.[16] Portable chest X-rays can obviate the need for a CT scan and thus reduce the risk of high radiation exposure. It will also help to reduce the risk of cross infection to departmental radiological staff from exposure to positive COVID-19 patients.

This study was conducted to determine whether daily chest X-ray during a hospital stay has any impact on COVID-19 disease management and to determine if serial portable chest X-rays has a role in predicting the clinical outcomes of discharge, prolonged hospital stay, or death. To the best of our knowledge, this is the first and only study conducted in a large public sector hospital specified by the government for COVID-19 in Karachi.

Materials and Methods

A retrospective study was conducted at Dow Institute of Radiology, Dow University of Health Sciences (DUHS) from November 2020 to January 2021 after approval from the ethical review committee of DUHS (IRB-1869/DUHS/ Approval/2020). All patients with confirmed cases of COVID-19 by a validated specific SARS-CoV-2 nucleic acid test (RT-PCR) or by electron microscopy or viral

Table 1: Baseline characteristics of patients (n = 329).

Characteristics	Mean ± SD
Age	56.43 ± 13.10
Days since symptom onset	4.27 ± 1.29
	n (%)
Sex	
Female	97 (29.5)
Male	232 (70.5)
Contact history	
Yes	71 (21.6)
No	258 (78.4)
Travel history	
Yes	10 (3.0)
No	319 (97.0)
Presence of comorbidities	
CLD	2 (0.6)
DM	11 (3.4)
HTN	28 (8.5)
COPD	2 (0.6)
Place of admission	
Ward	203 (61.7)
HDU	35 (10.6)
ICU	91 (27.7)
Treatment	
None	130 (39.5)
Oxygen only	83 (25.2)
BiPAP	49 (14.9)
Ventilator	67 (20.4)
Outcome at last day of admission	
Discharge	202 (61.4)
LAMA	3 (0.9)
Prolonged length of stay ≥10 days	163 (49.5)
Death	124 (37.7)

SD: standard deviation; n: frequency; CLD: chronic liver disease; DM: diabetes mellitus; HTN: hypertension; COPD: chronic obstructive pulmonary disease; HDU: high-dependency unit; ICU: intensive care unit; BiPAP: bilevel positive air pressure; LAMA: leaving against medical advice

Table 2: Chest radiographic findings and distribution on first and last X-ray (n = 329).

Findings	First Chest X-ray	Last Chest X-ray
	n (%)	n (%)
Normal	27 (8.2)	24 (7.3)
Unilateral consolidation	42 (12.8)	39 (11.9)
Bilateral consolidation	261 (79.3)	260 (79.0)
Pleural effusion	11 (3.3)	11 (3.3)
Peripheral distribution	284 (86.3)	294 (89.4)
Perihilar distribution	232 (70.5)	229 (69.9)
Zone involvement		
Right upper zone	84 (25.5)	77 (23.4)
Right mid zone	226 (68.7)	200 (60.8)
Right lower zone	284 (86.3)	269 (81.8)
Left upper zone	52 (15.8)	46 (14.0)
Left mid zone	225 (68.4)	193 (58.7)
Left lower zone	280 (85.1)	279 (84.8)
Severity score		
Median (Q1−Q3)	4.00 (2.00−4.00)	4.00 (2.00−4.00)
Course of disease		
Progression	91 (27.7)	
Regression	120 (36.5)	
Stable	118 (35.9)	

Q1: first quartile; Q3: third quartile.

culture, admitted to hospital wards, high-dependency units (HDUs), and ICUs who attended the radiology department for portable chest X-ray were retrospectively studied. Patients admitted to the hospital who underwent a portable chest X-ray for any disease other than COVID-19 were excluded. Data of all patients meeting the inclusion criteria were retrieved through electronic medical records. Information regarding demographic and clinical characteristics such as age, sex, clinical symptoms, comorbidities, duration of hospitalization, the need for oxygen support, bi-level positive pressure ventilation (BiPAP)

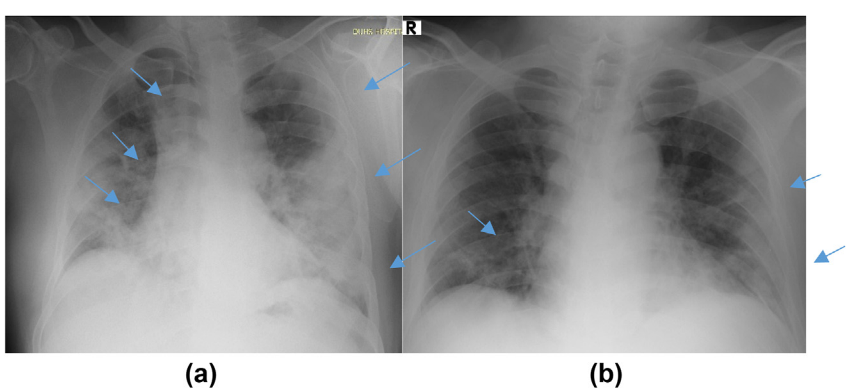

Figure 1: Chest radiographs of a 58-year-old male with positive COVID-19 RT-PCR (a) Chest X-ray on the day of admission showed patchy peripheral and central consolidations and ground glass opacities involving bilateral upper, mid, and lower zones with a chest X-ray severity score of 6. (b) Chest X-ray at discharge showed interval improvement with patchy ground glass opacities in left mid and bilateral lower zones in peripheral distribution, and the severity score was reduced to 3.

Table 3: Characteristics of patients with study outcomes (n = 329).

Characteristics	Discharged patients		p-value	Prolonged length of stay ≥10 days		p-value	Deceased patients		p-value
	No	Yes		No	Yes		No	Yes	
	n (%)	n (%)		n (%)	n (%)		n (%)	n (%)	
Age (mean ± SD)	55.06 ± 14.20	57.28 ± 12.32	0.135[a]	56.57 ± 11.87	56.28 ± 14.28	0.838[a]	57.45 ± 12.32	54.73 ± 14.19	0.067[a]
Days since symptom onset (mean ± SD)	4.20 ± 1.35	4.31 ± 1.25	0.435[a]	4.37 ± 1.30	4.17 ± 1.28	0.176[a]	4.33 ± 1.26	4.17 ± 1.34	0.286[a]
Sex									
Female	41 (42.3)	56 (57.7)	0.377	34 (35.1)	63 (64.9)	<0.001	56 (57.7)	41 (42.3)	0.268
Male	86 (37.1)	146 (62.9)		132 (56.9)	100 (43.1)		149 (64.2)	83 (35.8)	
Contact history									
Positive	27 (38.0)	44 (62.0)	0.903	36 (50.7)	35 (49.3)	0.940	44 (62.0)	27 (38.0)	0.953
Travel history									
Positive	7 (70.0)	3 (30.0)	0.038	1 (10.0)	9 (90.0)	0.743	3 (30.0)	7 (70.0)	0.032
Presence of comorbidities									
CLD	1 (50.0)	1 (50.0)	0.743	1 (50.0)	1 (50.0)	0.993	1 (50.0)	1 (50.0)	0.721
DM	5 (45.5)	6 (54.5)	0.641	5 (45.5)	6 (54.5)	0.641	6 (54.5)	5 (45.5)	0.595
HTN	10 (35.7)	18 (64.3)	0.733	18 (64.3)	10 (35.7)	0.122	18 (64.3)	10 (35.7)	0.811
COPD	1 (50.0)	1 (50.0)	0.743	2 (100.0)	–	0.159	1 (50.0)	1 (50.0)	0.721
Place of admission									
Ward	38 (18.7)	165 (81.3)	<0.001	127 (62.6)	76 (37.4)	<0.001	166 (81.8)	37 (18.2)	<0.001
HDU	20 (57.1)	15 (42.9)		7 (20.0)	28 (80.0)		15 (42.9)	20 (57.1)	
ICU	69 (75.8)	22 (24.2)		32 (35.2)	59 (64.8)		24 (26.4)	67 (73.6)	
Treatment									
None	20 (15.4)	110 (84.6)	<0.001	93 (71.5)	37 (28.5)	<0.001	110 (84.6)	20 (15.4)	<0.001
Oxygen only	22 (26.5)	61 (73.5)		42 (50.6)	41 (49.4)		63 (75.9)	20 (24.1)	
BiPAP	28 (57.1)	21 (42.9)		12 (24.5)	37 (75.5)		22 (44.9)	27 (55.1)	
Ventilator	57 (85.1)	10 (14.9)		19 (28.4)	48 (71.6)		10 (14.9)	57 (85.1)	
Findings									
Normal	18 (66.7)	9 (33.3)	0.002	8 (29.6)	19 (70.4)	0.024	11 (40.7)	16 (59.3)	0.016
Unilateral consolidation	20 (47.6)	22 (52.4)	0.205	20 (47.6)	22 (52.4)	0.709	23 (54.8)	19 (45.2)	0.287
Bilateral consolidation	90 (34.4)	172 (65.6)	0.002	139 (53.1)	123 (46.9)	0.062	172 (65.6)	90 (34.4)	0.013
Pleural effusion	4 (36.4)	7 (63.6)	0.877	5 (45.5)	6 (54.5)	0.736	7 (63.6)	4 (36.4)	0.926
Peripheral distribution	103 (36.3)	181 (63.7)	0.029	148 (52.1)	136 (47.9)	0.131	182 (64.1)	102 (35.9)	0.095
Perihilar distribution	84 (36.2)	148 (63.8)	0.168	122 (52.6)	110 (47.4)	0.232	148 (63.8)	84 (36.2)	0.391
Zone involvement									
Right upper zone	23 (27.4)	61 (72.6)	0.014	39 (46.4)	45 (53.6)	0.392	61 (72.6)	23 (27.4)	0.024
Right mid zone	82 (36.3)	144 (63.7)	0.201	120 (53.1)	106 (46.9)	0.156	145 (64.2)	81 (35.8)	0.305
Right lower zone	99 (34.9)	185 (65.1)	<0.001	153 (53.9)	131 (46.1)	0.002	186 (65.5)	98 (34.5)	0.003
Left upper zone	15 (28.8)	37 (71.2)	0.115	21 (40.4)	31 (59.6)	0.113	37 (71.2)	15 (28.8)	0.152
Left mid zone	83 (36.9)	142 (63.1)	0.314	110 (48.9)	115 (51.1)	0.448	142 (63.1)	83 (36.9)	0.613
Left lower zone	99 (35.4)	181 (64.6)	0.004	144 (51.4)	136 (48.6)	0.399	181 (64.6)	99 (35.4)	0.037

Severity score									
Median (Q1−Q3)	4.00 (2−4)	4.00 (2−5)	0.005[b]	4.00 (2−4)	4.00 (2−5)	0.854†	4.00 (2−5)	4.00 (2−4)	0.021[b]
Course of disease									
Progression	29 (31.9)	62 (68.1)	0.275	50 (54.9)	41 (45.1)	0.400	63 (69.2)	28 (30.8)	0.253
Regression	51 (42.5)	69 (57.5)		55 (45.8)	65 (54.2)		70 (58.3)	50 (41.7)	
Stable	47 (39.8)	71 (60.2)		61 (51.7)	57 (48.3)		72 (61.0)	46 (39.0)	

Q1: first quartile; Q3: third quartile; SD: standard deviation; n: frequency; CLD: chronic liver disease; DM: diabetes mellitus; HTN: hypertension; COPD: chronic obstructive pulmonary disease; HDU: high-dependency unit; ICU: intensive care unit; BIPAP: bilevel positive air pressure.
p-value calculated using Chi-square analysis.
[a] p-value calculated using the Student's *t*-test.
[b] p-value calculated using the Mann−Whitney test.

and ventilator support, and patient's outcome on the last day of hospital stay of being discharged, duration of hospitalization, death and leaving against medical advice (LAMA) were reviewed and retrieved. Study outcomes (dependent variables) were categorized as binary variables for analysis and were defined as:

1. Discharged: patients who had been discharged from the hospital after getting appropriate treatment by a primary physician were labeled as 'Yes = 1' and others were labeled as 'No = 0'.
2. Prolonged length of stay ≥10 days: patients who had a prolonged stay of greater than 10 days in the hospital were labeled as 'Yes = 1' and others were labeled as 'No = 0'.
3. Death: patients who passed away during their hospital stay were labeled as 'Yes = 1' and others were labeled as 'No = 0'.
4. LAMA: patients who left the hospital against the advice of their primary physician were labeled as 'Yes = 1' and others were labeled as 'No = 0'.

Sample size

The OpenEpi sample size calculator was used to estimate the sample size with a confidence interval of 95% and a margin of error of 5%. Reported abnormal findings on a portable CXR were found in 69% of a Chinese population.[17] The estimated sample size was 329.

Radiograph analysis

Initially, all chest X-rays were evaluated and scored by a team of radiologists including a senior resident, and two junior radiologists. Then the chest X-ray findings and severity scores were finalized by the consensus of one senior radiologist and one senior pulmonologist having more than 10 years of experience. Reporting was done as per the standard guidelines set by the Radiological Society of North America.[18] Common radiological chest X-ray reporting features of consolidation, haze, airspace shadowing, nodular densities, and pleural effusions were included. The radiological lung changes were further categorized into zonal predominance, unilateral, bilateral, pleural effusions, peripheral distribution, and perihilar distribution as described by Wong et al.[17] The chest X-ray severity score was used to evaluate the progression and regression of COVID-19 disease as previously described.[19]

Chest X-ray severity score

The radiograph was scored by dividing the lung field into six zones: 1- right upper zone, 2 - right mid zone, 3 - right lower zone, 4 - left upper zone, 5 - left mid zone, and 6 - left lower zone. In each zone, 1 point was given if opacity/infiltrates were present and 0 point was given if opacity/infiltrates were absent. The maximum and minimum scores were 6 and 0, respectively. Serial chest X-rays of patients were evaluated and scoring of the initial and last X-ray was done, hence the progression and regression of the disease were noted. An initial X-ray was performed at the time of admission of COVID-19 patients in the hospital and the last

Table 4: Factors associated with outcome discharge (n = 329).

Characteristics	Discharged patients			
	OR (95% CI)	p-value	aOR (95% CI)	p-value
Age	1.01 (0.99−1.03)	0.136	1.01 (0.99−1.04)	0.099
Days since symptom onset	1.07 (0.90−1.27)	0.434	−	−
Sex				
Male	Ref.		−	−
Female	0.80 (0.49−1.30)	0.377		
Contact history (Ref. No)	1.03 (0.60−1.77)	0.903	−	−
Travel history (Ref. No)	0.25 (0.06−1.01)	0.053	0.46 (0.07−3.08)	0.425
Presence of comorbidities				
DM (Ref. No)	0.75 (0.22−2.51)	0.642	−	−
HTN (Ref. No)	1.15 (0.51−2.57)	0.733	−	−
Place of admission				
Ward	Ref.		Ref.	
HDU	0.17 (0.08−0.36)	<0.001	0.34 (0.09−1.30)	0.117
ICU	0.07 (0.04−0.13)	<0.001	0.23 (0.08−0.63)	0.004
Treatment				
None	Ref.		Ref.	
Oxygen only	0.50 (0.25−0.99)	0.049	0.57 (0.27−1.21)	0.145
BiPAP	0.13 (0.06−0.28)	<0.001	0.23 (0.07−0.77)	0.018
Ventilator	0.03 (0.01−0.07)	<0.001	0.08 (0.02−0.30)	<0.001
Findings				
Normal (Ref. No)	0.14 (0.05−0.39)	<0.001	0.92 (0.06−14.26)	0.954
Unilateral consolidation (Ref. No)	0.49 (0.25−0.96)	0.040	1.42 (0.10−19.49)	0.791
Bilateral consolidation (Ref. No)	3.20 (1.85−5.54)	<0.001	1.96 (0.14−27.29)	0.614
Pleural effusion (Ref. No)	2.91 (0.61−13.71)	0.176	3.82 (0.79−18.50)	0.095
Peripheral distribution (Ref. No)	3.50 (1.67−7.32)	0.001	1.59 (0.46−5.54)	0.461
Perihilar distribution (Ref. No)	1.55 (0.96−2.50)	0.069	0.68 (0.32−1.47)	0.334
Severity score				
0−2 score	Ref.		Ref.	
3−6 score	2.54 (1.60−4.06)	<0.001	1.96 (0.91−4.19)	0.083
Course of disease				
Regression	Ref.		Ref.	
Progression	1.58 (0.89−2.79)	0.116	1.51 (0.60−3.78)	0.379
Stable	1.12 (0.66−1.87)	0.676	1.09 (0.52−2.26)	0.815

OR: crude odds ratio; aOR: adjusted odds ratio for variables had $p \leq 0.250$ in univariate analysis.
DM: diabetes mellitus; HTN: hypertension; HDU: high-dependency unit; ICU: intensive care unit; BIPAP: bilevel positive air pressure.

follow-up chest X-ray was performed on the last day of the hospital stay.

Statistical analysis

Data analyses were performed using the Statistical Package for Social Science, version 22. Descriptive statistics were reported as frequencies and proportions for categorical data including sex, contact and travel history, comorbidities, chest X-ray findings, course of disease progression, the need for ventilator support and outcome, i.e. discharge, LAMA, prolonged hospital stay, and death. Normality was checked by using the Shapiro−Wilk test for continuous variables including age, days since symptom onset, and severity score. Median and interquartile range (Q1−Q3) were reported for non-normal data. Associations between study outcomes and patients' characteristics with chest radiographic findings were assessed by performing chi-square analysis. Whereas, severity scores were compared between study outcomes using the Mann−Whitney test. Univariate and multivariate logistic regression analyses were performed to assess the effect of study variables on study outcomes. The outcome variable LAMA was not included in the regression analysis due to small cases. Three logistic regression analyses were performed separately for each dependent variable (discharge, prolonged hospital stay, death), and results were reported as odds ratios (ORs), 95% confidence intervals (CIs), and p-values. The multivariate model was adjusted only for variables with $p < 0.250$ in univariate analysis, following the Hosmer and Lemeshow protocol.[20] $p < 0.05$ was considered statistically significant.

Results

Table 1 shows patients' clinical characteristics, comorbidities, and outcomes. A total of 329 confirmed positive cases of COVID-19 admitted to the hospital were reviewed with a mean age of 56.43 ± 13.10 years (range 16−85 years). The mean number of days from symptom onset was 4.27 days (standard deviation 1.29), and the majority of patients were male. The most common comorbidities among the patients were hypertension followed by diabetes mellitus. Ninety-one patients were admitted to the ICU and thirty-five patients were admitted to the HDU. Among these, 67/329 (20.4%) patients were

Table 5: Factors associated with outcome prolonged stay (n = 329).

Characteristics	Prolonged length of stay ≥10 days			
	OR (95% CI)	p-value	aOR (95% CI)	p-value
Age	0.99 (0.98−1.01)	0.837	–	–
Days since symptom onset	0.88 (0.75−1.05)	0.175	0.99 (0.79−1.24)	0.975
Sex				
Male	Ref.		Ref.	
Female	2.44 (1.49−3.99)	<0.001	0.78 (0.40−1.55)	0.494
Contact history (Ref. No)	0.98 (0.57−1.65)	0.940	–	–
Travel history (Ref. No)	9.64 (1.21−77.00)	0.033	2.15 (0.32−14.47)	0.428
Presence of comorbidities				
DM (Ref. No)	1.22 (0.36−4.08)	0.744	–	–
HTN (Ref. No)	0.53 (0.23−1.19)	0.127	0.38 (0.12−0.90)	0.019
Place of admission				
Ward	Ref.		Ref.	
HDU	6.68 (2.78−16.04)	<0.001	3.12 (0.82−11.87)	0.094
ICU	3.08 (1.84−5.16)	<0.001	3.23 (1.19−8.75)	0.021
Treatment				
None	Ref.		Ref.	
Oxygen only	2.45 (1.38−4.35)	0.002	1.51 (0.71−3.19)	0.285
BIPAP	7.75 (3.64−16.47)	<0.001	3.63 (1.11−11.91)	0.033
Ventilator	6.35 (3.30−12.20)	<0.001	14.96 (4.20−53.18)	<0.001
Findings				
Normal (Ref. No)	1.76 (0.75−4.16)	0.192	0.85 (0.05−14.60)	0.914
Unilateral consolidation (Ref. No)	1.54 (0.78−3.03)	0.212	0.73 (0.05−10.91)	0.825
Bilateral consolidation (Ref. No)	0.56 (0.32−0.96)	0.036	0.68 (0.04−10.37)	0.786
Pleural effusion (Ref. No)	1.23 (0.36−4.11)	0.736	–	–
Peripheral distribution (Ref. No)	0.71 (0.35−1.44)	0.343	–	–
Perihilar distribution (Ref. No)	0.86 (0.54−1.39)	0.556	–	–
Severity score				
0−2 score	Ref.		Ref.	
3−6 score	0.61 (0.39−0.97)	0.038	0.45 (0.21−1.98)	0.544
Course of disease				
Regression	Ref.		–	–
Progression	0.87 (0.50−1.51)	0.641		
Stable	1.26 (0.76−2.10)	0.366		

OR: crude odds ratio; aOR: adjusted odds ratio for variables had p ≤ 0.250 in univariate analysis.
DM: diabetes mellitus; HTN: hypertension; HDU: high-dependency unit; ICU: intensive care unit; BIPAP: bilevel positive air pressure.

on ventilator support, 49/329 (14.9%) were on BiPAP, and 83/329 (25.2%) patients were on oxygen support. During the study period, more than half of the patients were discharged, half of the patients had prolonged length of stay ≥10 days, and almost 38% of the patients died (Table 1).

First and last follow-up X-ray findings of all patients are reported in Table 2. Only 7.3% of patients had normal findings, and the peripheral distribution of consolidation/ground glass opacities was the most common X-ray finding followed by bilateral lung involvement and perihilar distribution of consolidation/ground glass opacities, whereas pleural effusion was an uncommon finding. Most of the patients showed left lower zone and right lower zone distribution, whereas only 14.0% of patients had left upper zone involvement. Regarding the X-ray severity score, no significant difference in median severity score was found between the first and last chest X-ray. Furthermore, baseline and last follow-up chest X-rays findings were reported and compared to determine if there was progression, regression/improvement, or stability over the treatment time (Fig. 1). It was revealed that 27.7% of patients had progression, 36.5% of patients had improvement in lung changes, and 35.9% of patients had no changes over time.

Regarding the patient's characteristics and clinical findings in relation to the study outcome (hospital discharge) (Table 3 and Table 4), patients who had a positive travel history were less likely to be discharged from the hospital compared to those with no travel history (3/10, 30%). Patients who were admitted to the wards (165/203, 81.3%) and had no treatment (required no oxygen support, BiPAP, or ventilator) (110/130, 84.6%) were significantly more likely to be discharged from the hospital (Table 3). After multivariate logistic regression, the results showed that among admitted patients, ICU admission was found to be significantly associated with hospital discharge (adjusted OR [aOR]: 0.23, 95% CI: 0.08−0.63; p = 0.004). Similarly, admitted patients who were treated with BiPAP (aOR: 0.23, 95% CI: 0.07−0.77; p = 0.018) and ventilator support (aOR: 0.08, 95% CI: 0.02−0.30; p < 0.001) were less likely to be discharged from the hospital compared to patients who had no treatment during their hospital stay (Table 4).

Findings with study outcome (prolonged length of hospital stay ≥10 days) are reported in Tables 3 and 5. Patients who were female (63/97, 64.9%), admitted to the HDU (28/35, 80.0%), and had treatment of BiPAP (37/49, 75.5%) and

Table 6: Factors associated with death outcome (n = 329).

Characteristics	Deceased patients			
	OR (95% CI)	p-value	aOR (95% CI)	p-value
Age	0.98 (0.96–1.00)	0.068	1.00 (0.98–1.02)	0.694
Days since symptom onset	0.91 (0.76–1.08)	0.285	–	–
Sex				
Male	Ref.			
Female	1.31 (0.81–2.13)	0.268	–	–
Contact history (Ref. No)	1.01 (0.59–1.74)	0.953	–	–
Travel history (Ref. No)	4.02 (1.02–15.87)	0.046	8.98 (0.89–23.51)	0.062
Presence of comorbidities				
DM (Ref. No)	1.38 (0.41–4.64)	0.596	–	–
HTN (Ref. No)	0.91 (0.40–2.03)	0.812	–	–
Place of admission				
Ward	Ref.		Ref.	
HDU	5.98 (2.80–12.77)	<0.001	2.13 (0.54–8.38)	0.278
ICU	12.52 (6.96–22.52)	<0.001	1.02 (0.39–2.66)	0.959
Treatment				
None	Ref.		Ref.	
Oxygen only	1.74 (0.87–3.49)	0.115	2.31 (1.23–4.30)	0.008
BIPAP	6.75 (3.22–14.11)	<0.001	4.19 (1.35–13.00)	0.013
Ventilator	31.35 (13.75–71.44)	<0.001	5.62 (1.82–17.35)	0.003
Findings				
Normal (Ref. No)	4.49 (1.81–11.17)	0.001	0.76 (0.06–9.56)	0.837
Unilateral consolidation (Ref. No)	2.11 (1.08–4.15)	0.029	0.33 (0.03–3.88)	0.385
Bilateral consolidation (Ref. No)	0.34 (0.20–0.59)	<0.001	0.30 (0.02–3.43)	0.338
Pleural effusion (Ref. No)	0.35 (0.07–1.68)	0.192	0.84 (0.19–3.58)	0.816
Peripheral distribution (Ref. No)	0.36 (0.17–0.73)	0.005	1.06 (0.36–3.09)	0.915
Perihilar distribution (Ref. No)	0.68 (0.42–1.10)	0.119	0.94 (0.49–1.77)	0.854
Severity score				
0–2 score	Ref.		Ref.	
3–6 score	0.41 (0.25–0.65)	<0.001	0.89 (0.46–1.73)	0.752
Course of disease				
Regression	Ref.		Ref.	
Progression	0.69 (0.39–1.24)	0.219	0.67 (0.31–1.45)	0.317
Stable	1.11 (0.66–1.87)	0.673	0.76 (0.40–1.42)	0.397

OR: crude odds ratio; aOR: Adjusted odds ratio for variables had $p \leq 0.250$ in univariate analysis; DM: diabetes mellitus; HTN: hypertension; HDU: high-dependency unit; ICU: intensive care unit; BIPAP: bilevel positive air pressure.

ventilator (48/67, 71.6%) were significantly more likely to have prolonged hospital stay (Table 3). After multivariate logistic regression, results showed that patients who had a history of hypertension (aOR: 0.32, 95% CI: 0.12–0.84; p = 0.021) were less likely to have prolonged hospital stay. Whereas among admitted patients, ICU admission (aOR: 3.23, 95% CI: 1.19–8.75; p = 0.021), treatment support of BIPAP (aOR: 3.63, 95% CI: 1.11–11.91; p = 0.033), and ventilator (aOR: 14.96, 95% CI: 4.20–53.18; p < 0.001) were found to be significant predictors of prolonged hospital stay (Table 5).

Moreover, findings with study outcome (deceased patients) are reported in Tables 3 and 6. Patients who had a positive travel history (7/10, 70.0%), were admitted to the ICU (67/91, 73.6%) and had treatment with BIPAP (27/49, 55.1%) and a ventilator (57/67, 85.1%) were significantly more likely to die (Table 3). After multivariate logistic regression, the results showed that patients who had treatment support of oxygen (aOR: 2.31, 95% CI: 1.23–4.30; p = 0.008), BIPAP (aOR: 4.91, 95% CI: 1.35–13.00; p = 0.013) and ventilator (aOR: 5.62, 95% CI: 1.82–17.35; p = 0.003) were significantly associated with mortality during hospital stay (Table 6).

Discussion

This study has revealed radiographic chest X-ray findings including bilateral lung involvement, peripheral distribution of consolidation, and ground glass opacities with a predominance of mid and lower zone involvement. These findings are consistent with CT scan findings in patients with COVID-19 pneumonia as reported in prior studies.[8–10] According to this study on the first day of admission, the main findings of the chest X-ray were patchy areas of airspace opacification in the bilateral mid and lower zones. Similar findings have been reported in prior studies.[21–23] Exudative fluid accumulation within the alveolar space can be assumed to be the cause of this appearance. On the last day of stay at the hospital, the density of the opacities showed noticeable improvements with a reduction in total zonal involvement in one-third of admitted patients, while two-thirds of the patients either showed no significant change in overall disease and zonal involvement or interval increase in airspace opacification with subsequent increase in the number of zones involved (Table 2). The reason for this variable response is presumed to be due to the different variants of COVID-19 or superadded bacterial infections.

In this cohort, the most frequently affected lobe was the right lower lobe followed by the left lower lobe (Table 2). The same findings were seen in regards to lung involvement in a previous study by Wong et al.[17] Pleural effusion was rarely observed. Lymphadenopathy, cavitation, and pericardial effusion were not observed, in accordance with the literature. In this context, Bai and colleagues concluded that these particular findings were more prevalent in viral pneumonia other than COVID-19.[24]

In a prior study by Toussie et al.,[19] a chest X-ray of minimum severity 2 was subjected to hospital admission, whereas a chest X-ray with a minimum severity score of 3 was an isolated predictor of intubation. In this study, a chest X-ray severity of 3 or more was subjected to either hospital admission, extended stay in the hospital, or ventilation support. No significant difference in chest X-ray severity score was noted in relation to the primary outcome of being discharged and death. This was consistent with a prior study that showed no significant role of radiographic severity score in COVID-19 patients admitted to the hospital.[19,25]

This study revealed that the proportion of COVID-19 positive male patients who required hospital admission was high compared to female patients. A similar finding was reported by Scully et al.,[26] but no statistical difference in chest severity score and mortality rate was noted between males and females. The mortality rate was significantly higher in patients who were admitted to ICU and required oxygen support, BIPAP, or ventilator during their hospital stay. No significant differences were seen regarding primary patient outcomes in patients with diabetes mellitus (Table 3). This is incongruent with other studies that reported diabetes mellitus and hypertension being among the most common factors associated with adverse outcomes.[27]

Besides the above-mentioned findings, our study had the following limitations. As this study was retrospective and done in a tertiary care hospital, a significant number of patients had moderate-to-severe disease and a true picture of changes in mild COVID pneumonia could not be observed. A few patients could not be followed until their final recovery since they were discharged from the hospitals after their symptoms improved. The evaluation was limited due to superimposed findings (like pulmonary edema and technical factors) in portable chest X-rays.[19,28] The strength of the study is that it was conducted in a large public sector hospital specified by the government for COVID-19 with designated three isolation wards and three ICUs. In a low-resource country like Pakistan, investigations of the COVID-19 patients are offered free of cost; therefore we were able to cater to the needs of a large population.

Our study showed that chest X-ray observations in COVID-19 pneumonia patients can be used to monitor disease, and subsequent follow-up could be ensured to hospitalize these patients after the initial screening. However, there is no requirement of conducting daily chest X-rays, unless there is some specific clinical demand or significant intervention like intubation is required.[25,29] This practice will greatly reduce the enhanced financial load and radiation hazards associated with recurrent X-rays as well as CT scans. Moreover, this will also minimize the viral loading in the CT suites, exposure to medical staff, and spread of the virus in a hospital environment.

Conclusion

Peripheral consolidation and ground glass opacities were the most common chest X-ray finding in admitted COVID-19 patients. No significant difference in chest X-ray severity score was noted in relation to the primary outcome of being discharged, prolonged hospital stay, and death. There is no requirement for daily chest X-rays in hospitalized patients until required in the condition of worsening symptoms or significant intervention such as endotracheal intubation.

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Conflict of interest

The authors have no conflict of interest to declare.

Ethical approval

This study was approved by the Ethical Review Committee and institutional review board (IRB) of Dow University of Health Sciences (Approval No. IRB-1869/DUHS/Approval/2020) on 30 Dec 2020. Confidentiality was ensured and the data were used only for the research purpose.

Authors' contributions

SA designed the study, collected and analyzed the data, and was involved in the manuscript writing. FA, MM, MK, and NH participated in analyzing and interpreting the data and reviewing several drafts of the paper. NH is the corresponding author who drafted the manuscript, participated in designing the study, conducted the statistical analyses, and prepared the drafts. SZ and OA participated in the biostatistical analysis and interpretation of the results. All authors critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

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