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RESEARCH ARTICLE

RADIOLOGICAL FEATURES OF TYPICAL AND ATYPICAL COVID-19 INFECTION

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Abstract

Background: This study describes thecommon radiological findings in COVID-19 patients and defines the typical and atypical findings seen on chest radiography and computed tomography (CT) in these patients.
Methods:A cross-sectional study of 385 patients diagnosed with COVID-19, aged 18 years or over who presented to King Abdullah University Hospital. Patients with incomplete data were excluded. Data were collected from electronic patient records and analyzed using IBM SPSS Statistics. Statistical significance was set at $P < 0.05$.
Results: The age group with most patients was 31 to 50 years old. The most common COVID-19 symptoms were fever and cough. The most frequent distribution of findings on chest X-rays was peripheral predominant, and the most frequently involved is the left lower zone. The study showed a high prevalence of the typical appearance of COVID-19 on CT scans.
Conclusion: Chest X-rays and CT are vital tools for early diagnosis and management of COVID-19, as patients frequently show typical imaging findings on CT and chest X-rays.

Introduction:-

COVID-19 is an acute infectious respiratory disease caused by infection with the coronavirus subtype SARS- CoV-2, which was first discovered in December 2019 in Wuhan, China. Respiratory droplets are the primary mode of transmission. Following an incubation period of 2 to 14 days (average of 5 days), COVID-19 manifests most of the time with fever and upper respiratory symptoms, mainly dry cough, and dyspnea, but some patients can be asymptomatic [1,2].

Chest radiography (CXR) is the most common modality used in COVID-19 suspected cases and is considered a helpful diagnostic tool to observe the rapid progress of lung abnormalities, especially in patients in the intensive care unit (ICU) [3,4]. CXR is less sensitive in detecting COVID-19 lung disease in comparison with CT: baseline CXR sensitivity was reported to be 69% [5]. CXR features in COVID-19 patients include consolidation, ground-glass opacity (GGO), pulmonary nodules, and reticular-nodular opacities [6]. The most common reported CXR and CT findings are lung consolidation and GGO [7].

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This study explores the course of COVID-19 disease using CXR, describes the typical and atypical chest radiographic findings and correlates these with clinical presentation and disease prognosis.

Materials & Methods:-

This was a cross-sectional, hospital-based study, in which hospital records were reviewed at King Abdullah University Hospital (KAAUH) in Riyadh, Saudi Arabia. After calculating the sample size, we reviewed patient records until we reached our target size of 385 patients. The included patients were diagnosed between February 2020 and April 2021. We included any patient aged 18 years or over-diagnosed with COVID-19 who presented to KAAUH and excluded patients with incomplete data, such as missing CXR for example. Data were collected using an electronic questionnaire designed by the researchers, over three months, from

The sample size was calculated using the following formula:

$$n = \frac{z^2 \times \hat{p}(1-\hat{p})}{\varepsilon^2}$$

$$n = \frac{1.96^2 \times 0.5(1-0.5)}{0.05^2} = 384.16$$

We collected the following information: age, sex, the onset of symptoms, and history of contact with an infected person or travel abroad within 14 days. The data also included blood group, symptoms (suchas fever, cough, shortness of breath), comorbidities (such as diabetes, hypertension, asthma), the initial reverse transcription polymerase chain reaction (RT-PCR) test and CXR findings, and post-COVID-19 complications. CXR findings were divided into GGO, consolidation, or other findings such as pleural effusion. Distribution (diffuse, perihilar predominant, or peripheral predominant) and zonal involvement were also documented. We collected data from chest computed tomography (CT) studies based onthe Radiological Society of North America (RSNA) classification system for COVID-19. We also included whether the patients required oxygen and their clinical status (discharged, admitted to ICU, or deceased).

Collected data were encoded and entered into a Microsoft Excel workbook and analyzed using IBM SPSS Statistics, Version 22. We used percentages for categorical variables (such as sex, symptoms, presence of complications, etc.) and a chi-square test to assess the relationship between clinical presentation, ICU admission, and CXR and CT scan findings with other variables. Statistical significance was set at $P < 0.05$.

Results:-

We included 385 patients: 240 females (62.3%) and 145 males (37.7). Among them, 40.5% fell in the age range from 31 to 50 years old, 37.6% were aged from 51 to 60 years, and 21.8% were below 30 years old (Table 1).

Table 1:- Patient demographics.

Variable	**No.(%)**
Age	
30orbelow	84(21.8)
31-40	84(21.8)
41-50	72(18.7)
51-60	54(14)
>60	91(23.6)
Sex	
Male	145(37.7)
Female	240(62.3)
Nationality	
Saudi	321(83.4)
Non-Saudi	64(16.6)
Healthcareprovider	59(15.3)

Among the patients, 345 (89.6%) were symptomatic, and 40 (10.4%(were asymptomatic. The most common symptoms were fever (54%), cough (51%), and shortness of breath (41%). The majority of the patients had a history of contact, 160 (41.6%), and only 10 (2.6%) had a history of travel abroad within 14 days. The most common comorbidities were hypertension (45.7%) and diabetes (25.7%). The most common blood group was group O, 31 (44.9%), and the majority, 63 (91.3%) were Rh-positive (Table 2).

Table2:- Clinicalpresentation.

Variable	**No.(%)**
Clinicalpresentation	
Fever	210(54.5)
Cough	200(51.9)
Shortnessofbreath	158(41)
Generalweakness	101(26.2)
Headache	91(23.6)
Diarrhea	69(17.9)
Sorethroat	61(15.8)
Vomiting	41(10.6)
Chestpain	36(9.4)
Abdominalpain	33(8.6)
Runnynose	30(7.8)
Lossoftaste/smell	26(6.8)
Asymptomatic	40(10.4)
Comorbidity	176(45.7)
Hypertension	101(26.2)
Diabetes	99(25.7)
Asthma	44(11.4)
Cardiovasculardisease	21(5.5)
Smoking	10(2.6)
Bloodtype	
A	17(24.6)
B	19(27.5)
AB	2(2.9)
O	31(44.9)
Rhstatus	
positive	63(91.3)
negative	6(8.7)
Historyoftravelabroadwithin14days	10(2.6)
Historyofcontact	160(41.6)

Data on oxygen requirement were available for 363 patients: 238 (65.6%) did not require oxygen, 97 (26.7%) required nasal cannula/nonrebreather, and 28 (7.7%) required intubation (Table 3).
Regarding clinical status: about two-thirds, 255 (66.2%) were admitted to the COVID-19 isolation ward; 57 (14.8%) were admitted to the ICU(intensive care unit); 5 (1.3%) died, and 68 (17.7%) were discharged from the emergency room (Table 3).

Table 3:- Oxygen requirement and clinical status.

Variable	**No.(%)**
Oxygenrequirement(n=363)	
Intubation	28(7.7)
Nasalcannula/nonrebreather	97(26.7)
Didnotrequireoxygen	238(65.6)
Clinicalstatus(n=385)	
AdmittedtoCOVID-19isolationward	255(66.2)
AdmittedtoICU	57(14.8)

Deceased	5(1.3)
Dischargedfromemergencyroom	68(17.7)

ICU: intensive care unit.

The total number of ICU admissions was 57 (14.8%), and the higher proportion was in the age range of 51 to 60 years old, with 15 patients (26.3%). There was a significant association between ICU admission and comorbidity with hypertension, diabetes, and cardiovascular disease (P=0.000). We also found a significant association between ICU admission and having symptoms of fever and shortness of breath (P=0.000).

The number of patients who had a positive initial RT-PCR test was 371 (96.4%). We found a significant association between having a positive RT-PCR test and ICU admission (P=0.002). Additionally, 166 (43.1%) patients had positive findings in their first CXR. A significant association was also found between having positive findings in the first CXR and admission to ICU (P=0.000).

The positive CXR findings were found within one to three days from symptom onset in 111 patients (61.7%). Findings included GGO, 92 (23.9%), and consolidation, 79 (20.5%). None of the patients showed pleural effusion on the x-ray. Peripheral predominant was the most common distribution, reported in 65 patients (53.3%).

Regarding the location of pathology, the most common was the left lower zone (76.4%) and right lower zone (63.2%); the upper zones were the least to show findings. There was a statistically significant association between having hypertension and diabetes and positive x-ray findings (Table 4).

Table 4:- Association between ICU admission and other variables.

Variable	**ICUadmission**		**Pvalue**
	Yes	No	
Age			
30orbelow	3(5.3)	81(24.7)	0.000
31-40	7(12.3)	77(23.5)	
41-50	10(17.5)	62(18.9)	
51-60	15(26.3)	39(11.9)	
>60	22(38.6)	69(21)	
Sex			
Male	26(45.6)	119(36.3)	0.179
Female	31(54.4)	209(63.7)	
Nationality			
Saudi	54(94.7)	267(81.4)	0.013
Non-Saudi	3 (5.3)	61 (18.6)	
Health care provider	4 (7)	55 (16.8)	0.059
Blood type			
A	2 (40)	15 (23.4)	0.078
B	1 (20)	18 (28.1)	
AB	1 (20)	1 (1.6)	
O	1 (20)	30 (46.9)	
History of travel abroad within 14 days	0 (0)	10 (3)	0.370
History of contact	24 (42.1)	136 (41.5)	0.928
Clinical presentation			
Fever	38 (66.7)	172 (52.4)	0.046
Cough	36 (63.2)	164 (50)	0.066
Shortness of breath	40 (70.2)	118 (36)	0.000
General weakness	14 (24.6)	87 (26.5)	0.756
Headache	9 (15.8)	82 (25)	0.131
Diarrhea	11 (19.3)	58 (17.7)	0.769
Sore throat	9 (15.8)	52 (15.9)	0.990
Vomiting	4 (7)	37 (11.3)	0.336

Chest pain	4 (7)	32 (9.8)	0.512
Abdominal pain	7 (12.3)	26 (7.9)	0.303
Runny nose	3 (5.3)	27 (8.2)	0.596
Loss of taste/smell	2 (3.5)	24 (7.3)	0.398
Asymptomatic	1 (1.8)	39 (11.9)	0.021
Comorbidity	47 (82.5)	129 (39.3)	0.000
Hypertension	34 (59.6)	67 (20.4)	0.000
Diabetes	34 (59.6)	65 (19.8)	0.000
Asthma	6 (10.5)	38 (11.6)	0.817
Cardiovascular disease	11 (19.3)	10 (3)	0.000
Smoking	2 (3.5)	8 (2.4)	0.647
Positive initial RT-PCR test	50 (87.7)	321 (97.9)	0.002
Positive first chest x-ray	36 (63.2)	130 (39.6)	0.000
Oxygen requirement	51 (89.5)	74 (22.6)	0.000
Positive subsequent chest x-ray	42 (73.7)	103 (31.4)	0.000
Chest Complications	35 (61.4)	27 (8.2)	0.000
The patient underwent a CT scan	15 (26.3)	9 (2.7)	0.000

RT-PCR: reverse transcription polymerase chain reaction; CT: computed tomography.

Twenty-five patients underwent chest CT scans, most of them due to clinical deterioration; however, only 22 of the scans were included in the analysis. Seventeen (77.2%) scans showed typical findings for coronavirus disease, according to RSNA classification, and 2 (9.1%) showed atypical findings. No significant association was found between typical or atypical CT findings for COVID-19 in symptomatic patients and ICU admission (Table 5).

Table5:- Chest x-rayfindings.

Variable	**No.(%)**
Description(n=385)	
Consolidation	79(20.5)
Ground-glassopacity	92(23.9)
Unremarkable	241(62.6)
Pericardialeffusion	1(0.3)
Pleuraleffusion	0(0)
Distributionoffindings(n=122)	
Diffuse	28(23)
Perihilarpredominant	36(29.5)
Peripheralpredominant	65(53.3)
Lobarinvolvement(n=144)	
Rightupperzone	7(4.9)
Rightmiddlezone	60(41.7)
Rightlowerzone	91(63.2)
Leftupperzone	13(9)
Leftmiddlezone	61(42.4)
Leftlowerzone	110(76.4)

The majority of the patients did not develop chest complications, 323 (83.9%). However, 62 patients (16.1%) developed chest complications, almost all requiring oxygen, and 24 (6.2%) underwent CT scans. The most common complication was superimposed pneumonia, 42 (10.9%) Three patients (0.8%) developed pulmonary embolism, and other documented complications included lung fibrosis, pulmonary edema, respiratory failure, heart failure, and thrombocytopenia(Table 6). There was a significant association between positive CT scan findings and developing post-COVID-19 complications (P=0.017).

Table 6:- Chest CT scan findings

Variable	**No.(%)**
CTscanfinding(n=22)[a]	

Typicalappearance	17(77.2)
Indeterminateappearance	3(13.6)
Atypicalappearance	2(9.1)
Didthepatientdevelopchestcomplications?(n=385)	
No	323(83.9)
Superimposedpneumonia	42(10.9)
ARDS	6(1.6)
Pulmonaryembolism	3(0.8)
Heartfailure	2(0.5)
Cametohospitalwithblack/coffeegroundvomiting	1(0.3)
Lungfibrosis	1(0.3)
Pneumoniaandpulmonaryfibroticchanges	1(0.3)
PulmonaryedemaandNSTEMI	1(0.3)
Respiratorydistress	1(0.3)
Sinusbradycardia	1(0.3)
Thrombocytopenia	1(0.3)
Type1respiratoryfailure	1(0.3)
Ventricularfibrillation	1(0.3)

ARDS: acuterespiratorydistresssyndrome;NSTEMI:non–ST-segmentelelevationmyocardialinfarction.
a: AccordingtotheRadiologicalSocietyofNorthAmericachestCTclassificationsystemforcoronavirusdisease.

Discussion:-

In this study, 385 cases of COVID-19 disease were reviewed. We found that the commonest presenting symptoms were fever, cough, and shortness of breath, which is similar to the findings of a cohort study[8]. More than half of our patients developed symptoms one to three days before having a CXR with positive findings, thus they were managed early. Our findings agree with previous studies in this regard.

During the COVID-19 pandemic, radiologic imaging was the rule in early diagnosis and management. In our study, 50% of the patients had an unremarkable CXR. However, among 122 CXRs, more than half showed findings with a peripheral predominant distribution, 23% showed GGOs, and 20.5% showed consolidation. In a study done in 2020 by Rehab et al. with 350 COVID-19 patients, CXR was found to be a good predictor for the course of the disease, and the commonest x-ray finding was consolidation, reported in 81.3%, and GGOs, seen in 32.5% [9]. However, in their study, a small number of patients showed pulmonary nodules and pleural effusion, which were not seen in our sample. In another study of 64 patients with COVID-19 disease, consolidation was the most common finding on CXR (47%), followed by GGOs (33%); and a peripheral predominant pattern was seen in 41%. Few cases showed pleural effusion (3%) [5].

In our sample, the most common distribution of findings on CXR was lower lobe, seen in 201 patients: the most frequent distribution according to the RSNA classification is bilateral lower zone consolidation. Also, among our sample, the left lower lobe was more commonly affected than the right, 110 vs. 91 patients. This contrasts with a study among 88 patients with COVID-19 disease in which the right lower lobe was more commonly affected (70% vs. 50%) [10].

In the present study, only a minority of the patients (2 out of 22) showed atypical imaging findings on chest CT scans (Table 5). This demonstrates the high reliability of CT scans in the diagnosis of COVID-19. The RSNA provides clinicians with an evidence-based guideline for COVID-19 imaging classification, based on the existence of objective CT scan findings [11].

In accordance with the literature, peripheral and bilateral GGOs were the most frequent CT scan findings in our study. GGOs are considered the most relevant and earliest descriptive results for typical COVID-19 appearance in the RSNA classification [12]. In a case series study from Saudi Arabia of 150 patients diagnosed with COVID-19, GGO was the most common radiological finding [13]. It was also found in 88% of COVID-19 patients in a systematic review of 919 patients from China [14]. It is suspected that GGO occurs as a result of a cytokine storm caused by COVID-19 pneumonia. Yet the exact mechanism remains unknown [15]. Moreover, GGO is not specific to COVID-19 infection, as it may indicate acute, subacute, or chronic lung diseases [12]. Other typical chest CT

findings in COVID-19 include the halo sign, which was less frequent than GGO in our study. These results are similar to those reported in other studies [7].

The indeterminate appearance was the second most reported finding in our study, followed by an atypical appearance as the least reported. Comparably, in a retrospective study of 136 patients with positive RT-PCR tests who underwent CT scans, the typical appearance was the most frequent, followed by the indeterminate category according to the RSNA system [16]. Studies indicate that chest CT can be more reliable than RT-PCR in diagnosing COVID-19, because of many variables that may impact the accuracy of the RT-PCR test [17].

These further advocate for the use of CT scan in COVID-19. However, radiation exposure may threaten the safety of radiologists, healthcare workers, and patients. Fang et al. suggested that chest CT can be used as a screening method in patients who have clinical and epidemiological characteristics consistent with COVID- 19 infection, especially when RT-PCR results are negative [18].

Secondary bacterial infection was the most common complication in our study. Similar to the results of a 4- week cohort study in elderly patients [19]. Another retrospective study from China showed that 1 in 7 patients hospitalized with COVID-19 developed severe secondary bacterial pneumonia, and these patients accounted for half of the mortality cases [20]. In COVID-19 patients, the superimposed infection can result from common, community-acquired, or nosocomial pathogens [21]. It is important to identify secondary bacterial infections because they have been associated with poor outcomes and due to concerns about antibiotic overuse [22,23]. However, studies have noted that it can be difficult to distinguish between coinfecting pathogens and COVID-19 [21].

Acute respiratory distress syndrome (ARDS) developed in only 1.6% of our sample. The possibility of under-reporting ARDS cannot be ruled out given the retrospective design of the study. Nevertheless, this figure is comparable with a retrospective analysis of 116,539 discharged COVID-19-positive cases, which found a prevalence of ARDS as low as 3.6%, and also mentioned the possibility of underreporting [24]. While the specific mechanism of ARDS in COVID-19 is unknown, the production of cytokine storms is thought to be one of the main causes [25]. Heart failure and pulmonary embolism were reported at low rates of 0.5% and 0.8%, respectively, in the present study. These rates may be influenced by the relatively short follow-up periods, as such complications may occur after the symptoms of the severe infection have subsided; the patients might have been discharged at that point from the hospital [26].

The major strength of this study is the sample size, 385 COVID-19 patients. Our limitations are the retrospective design and that CT examination was only used in a few cases. Our recommendation is to follow up cases with serial CXR studies for further COVID-19 analysis and monitoring.

Conclusions:-

Chest CT scans and X-rays are vital tools in the early diagnosis and management of COVID-19 patients, as they frequently show typical imaging findings. The imaging findings in our study were largely consistent with those reported in the literature. Identifying imaging characteristics based on the progression of the infection is important for evaluating disease evolution and regression and for predicting prognosis and consequences.

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