Chest radiographs in Coronavirus Disease 2019 (COVID-19)

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ABSTRACT

Objectives: To recognize the radiographic patterns of coronavirus disease 2019 (COVID-19) in Malaysia.

Materials and Methods: Chest radiographs of patients confirmed with COVID-19 in Hospital Tawau, Sabah, Malaysia were retrospectively analyzed by two radiologists. The radiographic pattern, distribution among subgroups and evolution of the disease over time were determined.

Results: Among the 82 patients studied, 65 (79.3%) were males. Mean age of our cohorts was 37 ± 15 years. Baseline chest radiographs were abnormal in 37 patients (45.1%). Over half (52.9%) of the symptomatic patients had abnormal baseline radiograph. Among the children, patients with comorbidities, and patients 60 years of age and above, the abnormal radiographs were 14.3%, 71.4% and 69.3% respectively. Ground glass opacities were the commonest abnormal radiographic feature (35.4%), were peripherally located (35.4%) with predilection for the lower zones (29.3%). Most radiographic abnormalities were multifocal (20.7%) and frequently located in the left lung (19.5%). Radiographic recovery was observed in 15 of 18 patients (83%). Computed tomography (CT) scan demonstrated greater extent of the disease than observed in radiographs of the same patient.

Conclusions: COVID-19 pneumonia presented with a specific radiographic pattern in our cohort of patients, comprising of ground glass opacities in peripheral and basilar distribution, affecting a single lung field and was observed in both symptomatic and asymptomatic patients. Chest radiograph is a useful adjunct screening tool, and in combination with clinical and epidemiological assessment may facilitate in early diagnosis of COVID-19 pneumonia.

KEYWORDS:
COVID-19; Malaysia; chest radiograph; computed tomography

INTRODUCTION

Since it was declared as a global public health crisis in late January, the coronavirus disease 2019 (COVID-19) pandemic has expanded at an alarming rate, currently affecting over 2.8 million people globally and resulting in close 200 000 deaths (as of April 26,2020).[1] As we still strive to formulate an effective treatment and vaccine, the containment strategies are primarily focused on the rapid and accurate diagnosis of those infected, aiming to halt the further spread of this disease.

Although reverse transcriptase polymerase chain reaction (RT-PCR) assay remains a gold standard for diagnosing the infection, the emerging role of imaging as an adjunct in early detection of the infection has been emphasized in several reports.[2,3] As the disease primarily affects the respiratory system, computed tomography (CT) of chest had been used on a greater scale in China, the epicenter of the disease.[4] Characteristic patterns of lung changes of COVID-19 and its evolution over time has been laid out by many authors[5-8], hoping to accelerate the identification of the disease among the suspected individuals thus speeding the isolation process. Owing to inherent high sensitivity and fast turnover time, the radiological investigations have been focused on the use of CT.[2,9]

However, as the disease has spread outside China, the use of CT scan as a screening tool has been widely discouraged by most leading radiology organizations, mainly due to the risk of cross-infection.[10,11] Portable chest radiography has been suggested to be used as a triage tool instead of CT, to assess the severity of disease, for treatment planning and to monitor the progression of the disease.[10]

With only a handful of reports on radiographic patterns of COVID-19 infection across the literature,[12-14] we aim to familiarize radiologists and clinicians alike with the radiographic features of patients with COVID-19 infection in Malaysia. The main objectives of our study were to describe the radiographic characteristics of COVID-19 infection in general and among demographic subgroups in Tawau.

MATERIALS AND METHODS

The study was approved by the Medical Research Ethics Committee (MREC), Ministry of Health Malaysia (NMRR-20-698-54570). Informed consent was waived due to the retrospective nature of this study.

Study design and Participants

This was a cohort study carried out between 9th March and 13th April 2020 from secondary data of COVID-19 positive

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patients in Hospital Tawau (HT). All patients tested positive for COVID-19 infection by reverse transcription polymerase chain reaction (RT-PCR) assay in HT, Sabah, Malaysia were enrolled. The demographic data, clinical findings and laboratory findings of patients were obtained from the hospital records and radiology imaging request forms. The chest radiographs (CXR) and CT images were retrieved from the electronic database and all information were keyed into a standard data collection form for the purpose of this study. Clinical outcomes were monitored up to April 18th 2020 the final date of follow-up.

Two radiologists (AA, general radiologist with two years of experience; SH, general radiologist with two years of experience) jointly reviewed all images to identify the key findings of the images. All findings were recorded based on the consensus of both radiologists. Should there be any discrepancy, disagreement or inability to reach a consensus, then a third independent radiologist (NSHNL, general radiologist with four years of experience) was consulted to determine the imaging findings.

Image Acquisition

Both baseline and follow up (CXR) were acquired in the posteroanterior projection (PA) using a portable chest radiograph device (Mobile X-ray Shimadzu, MobileArt Plus MUX-100H, Kyoto Japan). Volumetric (CT) studies were acquired without contrast medium using 16-multidetector CT scanner (Optima CT540, GE Healthcare Milwaukee, WI, USA) and reconstructed to 1.25mm thin slices in accordance to the local institutional protocol.

Image Analysis

Lung changes and lesions on CXR and CT images were reported based on the pattern of opacity, location and distribution following local guidelines by the Ministry of Health Malaysia Thoracic Special Interest Group, as adapted from the guideline by Radiological Society of North America (RSNA); Radiological Society of North America (RSNA) Consensus Statement on Reporting Chest CT Findings released in March 2020.15

Baseline and Follow up Radiographs

Pattern of lung opacities were classified into ground glass change, consolidation, interstitial (linear or reticular opacities) or nodular opacities. The distribution of the lung changes was categorized into (i) focal or (ii) multifocal; (i) peripheral, central or diffuse; (ii) right, left, or bilateral lung involvement; and (iii) upper zone, middle zone, lower zone or no zonal predominance. Peripheral and central demarcation was defined as halfway between lateral margin of the lung and hilum, while each lung is divided into three equal zones for the zonal distribution. Presence of pleural effusion, cavitation, pneumothorax, cardiomegaly and lymphadenopathy were also recorded. Overall, the radiographs were concluded as either normal, probable COVID-19, indeterminate or non COVID-19.

Radiographs were concluded as normal in the absence of any lung changes. Probable COVID-19 designated when lung changes were present at the periphery and in the lower lobes. The presence of lobar pneumonia, pulmonary edema or any other findings places the radiograph in non-COVID descriptor. An indeterminate appearance was assigned to the radiographs that do not fit into probable or non COVID-19 descriptors. Follow up CXR were assessed for the evolution of lung changes and classified as either resolution of findings, improvement or progression of findings when compared to the baseline or any available prior CXR from the same patient.

Computed Tomography Images

In HT, CT examination were performed for asymptomatic patients with suspicious baseline chest radiograph and those confirmed with COVID-19 infection demonstrating clinical deterioration. No CT examination was done for the purposes of the study, and only performed if requested by the treating physician. All CT were performed following local standard operating procedure and guideline.

Reporting guideline for CT scan followed local guideline adapted from the guideline by Radiological Society of North America (RSNA); Radiological Society of North America (RSNA) Consensus Statement on Reporting Chest CT Findings released in March 2020.[15]

The presence of typical CT appearances of COVID-19 infection (ground glass opacities, consolidation) and other features (reverse halo sign, perilobular densities and crazy paving pattern) as outlined by the local guideline were noted down, if present. The overall CT findings were categorized to typical, indeterminate, atypical appearance of COVID-19 infection and negative for pneumonia.

Statistical Analysis

Statistical analysis was performed with Microsoft Excel for Mac Version 16.18 and descriptive analysis was carried out where continuous variables were reported in mean and standard deviation and categorical variables reported in frequency and percentage.

RESULTS

A total of 82 COVID-19 patients were included in this study, most were males 65 (79.3%) and 15.9% of the total patients had co-morbidities. The average age was 37 ± 15 years (range 2 to 79 years). Seven patients (8.5%) were children, aged 18 years and below. There were also 7 patients aged 60 years of age and above in our study. On admission, 34 of 82 patients were symptomatic. Fever (38.2%) and cough (55.9%) were the most reported symptoms among the symptomatic patients. The most common co-morbidities were hypertension (8 of 82 patients) and diabetes mellitus (3 of 82 patients).

Two of three patients admitted to intensive care unit (ICU) were intubated; one succumbed to the infection (1 of 82, 1.2%); one recovered and one is still hospitalized as of the time of writing.

The demographic and clinical characteristics of the patients are summarized in Table I.

Table I: Demographics and clinical characteristics

CHARACTERISTIC	Mean ± SD / Frequency (%)
Age (years)	
Mean	37 ± 15
Range	2-79
Age Group (years)	
≤ 18 (Children)	7 (8.5)
19- 59 years	68 (82.9)
≥ 60 years	7 (8.5)
Sex	
Men	65 (79.3)
Women	17 (20.7)
Comorbidity	
No comorbid	69 (84.1)
With comorbid	13 (15.9)
Hypertension	8 (61.5)
Diabetes Mellitus	3 (23.1)
Chronic Obstructive Pulmonary Disease	1 (0.1)
Chronic kidney disease	1 (0.1)
Chronic liver disease	1 (0.1)
Others	4 (0.3)
Clinical Presentation	
Asymptomatic	48 (58.5)
Symptomatic	34 (41.5)
Fever	13 (38.2)
Cough	19 (55.9)
Runny nose	7 (20.6)
Sore throat	5 (14.7)
Loose stool	4 (11.8)

Note: Number in Parentheses are Percentages

Baseline Chest Radiograph Findings

Baseline CXRs were done between one to 19 days (average 7.8 days) after onset of symptoms. Of the 82 patients, 43 (52.4%) had normal baseline CXR, meanwhile 39 patients (47.6%) presented with abnormal CXR. Of the thirty-nine abnormal CXRs, 30 (76.9%) were concluded as probable and three (7.7%) as indeterminate. There were 6 (15.4%) abnormal CXRs reported as non-COVID with alternative diagnoses, which were consistent with pulmonary tuberculosis [5 of 6] and left hilar mass [1 of 6].

The predominant lung infiltrates were ground glass opacities (29 of 82, 35.4%) followed by consolidation (7 of 82, 8.5%). Consolidation in the CXRs generally occurred between five and eight days after onset of symptoms. Unilateral lung involvement was observed more than bilateral lung involvement (22 of 82, 26.8% vs 15 of 82, 18.3%) with a left lung predilection (19.5%). The distribution of the lung abnormalities showed a peripheral predominance (35.4%), affecting most commonly the lower zones (29.3%). Three patients showed both central involvements extending to and peripheral lung (Figure 1) and two patients had extensive lung abnormalities involving all zones of both lung fields. Pleural effusion was found in 3 (9.1%) patients. Pneumothorax and pneumomediastinum with surgical emphysema were observed in the post intubation radiographs of one patient in this study. Thoracic lymphadenopathy and cavitating lesions were not observed in our cohorts. The radiographic pattern of COVID-pneumonia summarized in Table II.

Subgroup Analysis by Sex, Symptomatic Status, Age and Comorbid

- Twenty five of 65 men (38.5%) and 8 of 17 (47.1%) women presented with abnormal radiographs that had COVID-19 radiographic features. Generally, both sexes had higher proportion of normal radiographs compared to abnormal radiographs.
- Symptomatic patients presented with greater proportion of abnormal CXRs in comparison to the asymptomatic patients (52.9% versus 32.7%).
- There were 7 patients 60 years of age and above in our study sample. Of the 7, three patients were symptomatic and 5 of 7 (71.4%) had probable findings in the baseline radiographs.
- Seven children (1-18 years) were tested positive for COVID-19 infection in our study sample and all were asymptomatic on admission. Baseline radiographs were normal in 6 patients. Bilateral perihilar interstitial lung opacities were observed in one patient (14.3%). This finding was thus concluded as indeterminate features. No follow up radiograph was performed for this patient.
- Among the 13 patients with comorbidities, 9 patients (69.2%) presented with lung abnormalities in the baseline radiograph on admission. We observed higher number of abnormal radiographs in patients with at least one comorbidity (69.2%) when compared to patients with no comorbidities (34.8%).

The distribution of COVID-19 related radiological findings among the subgroups shown in Figure 2.

Table II. Findings on Chest Radiograph and CT scan

Criteria	Findings	Frequency (%)
Baseline Chest Radiographs	Normal	45 (54.9)
	Abnormal	37 (45.1)
	Probable	30 (81.8)
	Indeterminate	3 (8.1)
	Non COVID-19	4 (10.8)
Lung Changes	Ground glass opacities	29 (35.4)
	Consolidation	7 (8.5)
	Interstitial opacities	4 (4.9)
	Nodular opacities	1 (1.2)
Distribution	Peripheral	29 (35.4)
	Central	2 (2.4)
	Diffuse	5 (6.1)
Lung Involvement	Right lung	6 (7.3)
	Left lung	16 (19.5)
	Bilateral lungs	15 (18.3)
Zonal Predominance	Upper zone	4 (4.9)
	Middle zone	3 (3.7)
	Lower zone	24 (29.3)
	No zonal predominance	6 (7.3)
Focality	Focal	17 (20.7)
	Multifocal	20 (24.4)
Other features	Pleural effusion	3 (3.7)
	Pneumothorax	1 (1.2)
	Pulmonary nodules	1 (1.2)
	Lymphadenopathy	0 (0.0)
	Other	3 (3.7)
Follow up Radiographs (n=38)	Normal baseline CXRs becoming abnormal	0 (0.0)
	Normal baseline CXRs becoming abnormal	0 (0.0)
	Complete resolution	6 (15.8)
	Improvement	9 (23.7)
	Progression	3 (7.9)
Computed Tomography (n=5)	Typical appearance of COVID-19	3 (60.0)
	Indeterminate	1 (20.0)
	Atypical	0 (0.0)
	Negative for pneumonia	1 (20.0)
	Lung Changes	
	Ground glass opacities	4 (80.0)
	Consolidation	1 (20.0)
	Special features	
	Crazy paving	1 (20.0)
	Perilobular density	1 (20.0)
	Reverse halo sign	0 (0.0)

Note: Number in Parentheses are Percentages

Follow-Up Chest Radiograph Findings

Thirty-eight patients had follow-up CXR performed with an interval of 4 to 6 days from the baseline radiographs, of which 18 were normal and 20 abnormal CXRs (16 concluded as probable, 2 as indeterminate and 2 were non-COVID) in the baseline radiograph. Only 2 intubated patients had radiographs either daily or at shorter intervals.

Of the 18 patients who had normal baseline radiographs, none developed abnormalities on follow-up radiographs. Among the 20 abnormal baseline CXRs, 2 exhibited chronic pulmonary tuberculosis changes and were designated as non-COVID, which remained unchanged during the follow up. While in the remaining 18 abnormal CXRs with probable or indeterminate COVID-19 pneumonia descriptors, radiological resolution was observed in 15 patients (83.0%) (Figure 3) on follow up CXR; 6 showed complete resolution and 9 with radiological improvement. Three patients showed progressive worsening of lung consolidation.

Chest Radiograph correlation with CT

Five asymptomatic patients in our study cohort with lung changes on baseline CXR underwent CT examination. CT scans revealed a greater extent of the lung involvement than what was depicted from the baseline radiograph. Typical imaging features of COVID-19 pneumonia of were observed in 4 patients who underwent CT examination, while one patient had no abnormality depicted on the CT examination. Bilateral peripheral ground glass opacity with a predilection for the lower lobes were observed in 3 patients. Intralobular reticulation were present in one of the patients, giving rise to the crazy paving appearance. Diffuse consolidation with atypical features (bilateral pleural effusion, pericardial thickening, pneumomediastinum and surgical emphysema) were depicted in one patient. CT findings of COVID-19 pneumonia summarized in Table II.

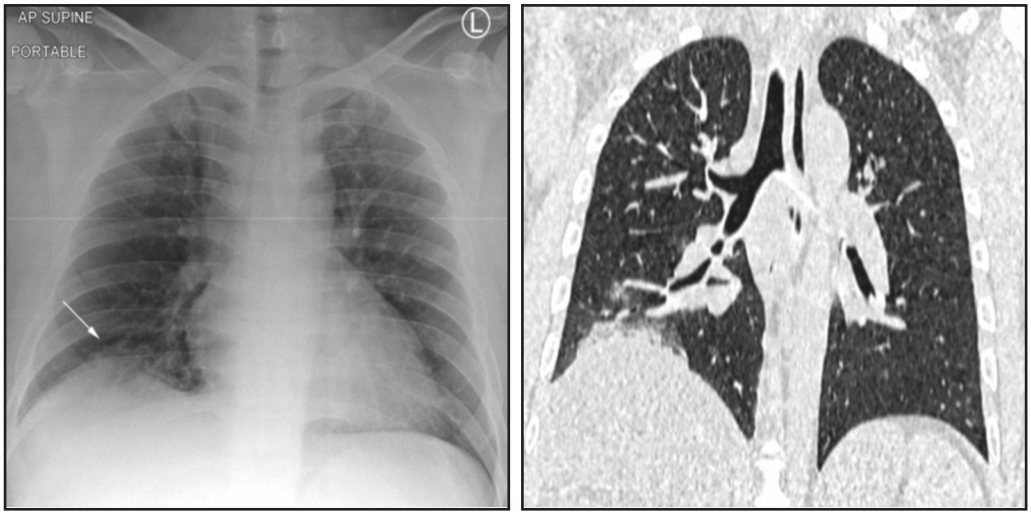

FIGURE 1A FIGURE 1A

Fig. 1: (A) Chest radiograph shows ground glass opacity at right lower zone. (B) Coronal CT image shows ground glass opacity at right lower zone corresponds to the finding on radiograph.

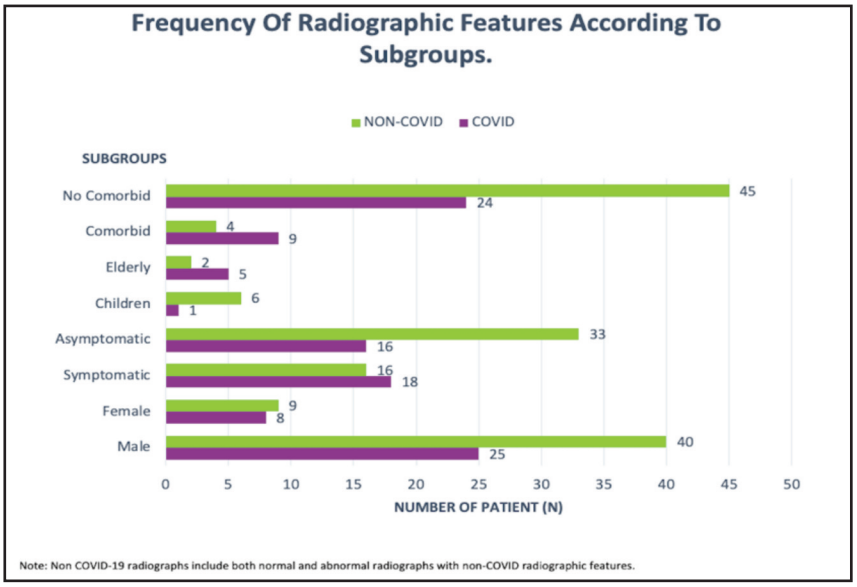

Fig. 2: Distribution of radiographs with COVID-19 and non-COVID-19 features among the various subgroups.

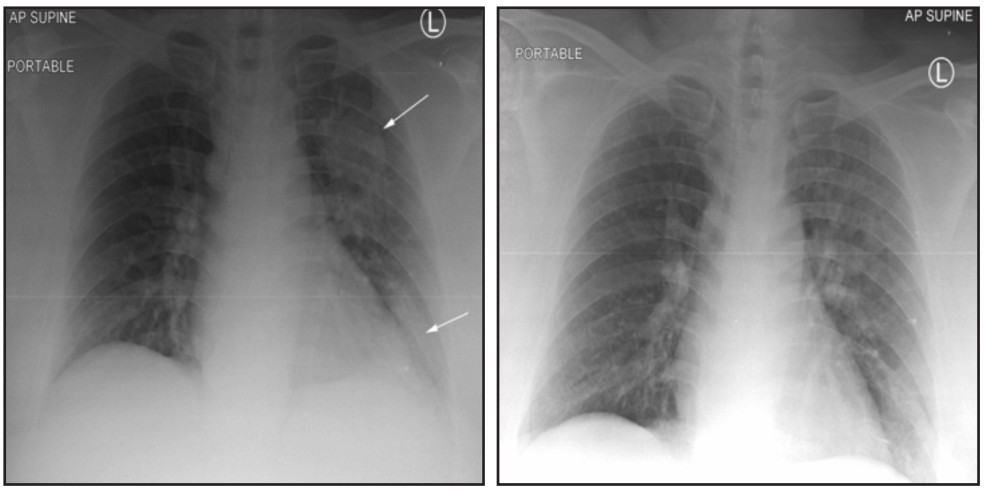

FIGURE 1A FIGURE 1B

Fig. 3: (A) Asymptomatic COVID-19 patient with consolidation at the left upper zone (arrow) and ground glass opacities at the left lower zone in the baseline radiograph. (B) Resolution of the lung abnormalities on day 5 of admission.

DISCUSSION

To the best of our knowledge, imaging profile of COVID-19 infection in Malaysia has not been published as yet. Patients of all ages were affected by the disease with predilection for males (79.3%). Greater proportion (54.9%) of the study sample presented with normal chest radiographs. Ground glass opacities (35.4%) and unilateral lung involvement (26.8%) were the predominant features in the abnormal radiographs, contrary to a few published studies which reported consolidation and bilateral lung involvement.[3,4] The lung changes were predominantly multifocal and peripheral in distribution more commonly affecting the lower zones, consistent with previous studies.[3-4,14,16,17] Patient who were sixty years of age and above, were symptomatic or had comorbidities were more common to have abnormal radiograph at admission, similar to the trend observed by other researchers.[14,18] Children aged 18 years and below, were all asymptomatic with 85.7% presented with no pneumonic changes in the radiograph. Radiological recovery observed in 83% of our study sample with one patient succumbing to the infection.

The mode of transmission suspected for the majority of our patients, more than 60% were directly linked to a religious event, thus explaining the young age and male predominance in our study sample. Females and children were predominantly the secondary contacts of these cases. Although we observed higher percentage (8.5%) of children contracting the disease than reported in the previous studies[19], all remained asymptomatic throughout the disease course. Milder form of the disease among children than their adult counterparts has been well reported in many studies.[19,20] More than half (48 of 82, 58.5%) of our patients were asymptomatic at presentation. This result is contrary to a large case series by the Chinese Center for Disease Control and Prevention which reported 1% of the study population were asymptomatic.[21] Patients presenting with pneumonic changes on radiograph at admission varies across the literature and were reported between as high as 60-80% in few earlier studies in China and Hong Kong.[3,4] Contrarily, we observed lower (45.1%) proportion of abnormal radiographs in our study group similar to the report from a case series in Korea and a study in ambulatory care setting in New York.[14,16] Among the abnormal CXRs, single lung involvement was more common (59.5%) and has been described lately, contrary to the more commonly reported bilateral lung involvement in earlier studies.[6,14,22] We attribute this finding to lower sensitivity of radiograph in detecting subtle lung changes in the early course of disease, in agreement with Wong et al.[3] Pleural effusion, notably were uncommon and observed only among patient above 40 years of age consistent with previous observations.[3,8,14,17-18] Although it has been described in only a few case reports, pneumothorax and pneumomediastinum with diffuse chest wall subcutaneous emphysema, are exceedingly rare findings, and were only present in our intubated patients, highly suggestive of complication of mechanical ventilation.[23,24] In HT, computed tomography was reserved only for asymptomatic patients with suspicious baseline chest radiograph and those confirmed COVID-19 demonstrating clinical deterioration. The predominant CT features as seen in the other previous studies were multilobar, bilateral lung ground glass opacities with peripheral distribution, and affection for the lower zones.[3,4,8] Consolidation was found in our patient admitted to ICU, consistent with a previous report by Huang et al.[6] As in previous reports, crazy paving was less frequent than ground glass opacities alone and consolidations, observed in a single patient with disease progression in our study.[25] In all these patients, the subtle abnormalities and single lung involvement on chest radiograph appeared more extensive on CT with bilateral lung involvement suggestive of the higher sensitivity of CT in detecting abnormalities.9 Follow up CXRs were used for clinical monitoring of COVID-19 infection during hospitalization in HT. We observed higher radiographic recovery in our study sample at 83%, as opposed to Ai et al., who observed 42% radiological recovery on CT prior to RT-PCR becoming negative.9 However, we should mention that we didn't obtain the virologic recovery data to make a valid comparison. Resolving lesions are subtle and may go unrecognized on CXR in comparison to CT.

Taking into account our study was a retrospective and observational study, there are several inherent limitations. Firstly, the study sample was small, as the study was limited to a single institution. The interval between RT-PCR result and baseline chest radiographs were not uniform (range of 1 to 20 days), largely due to the remote testing location of the COVID-19 designated laboratories, hence, baseline radiographs were obtained at various phases of illness, which may contribute to missed early COVID-19 pulmonary changes. Secondly, the radiologists interpreting the images were not blinded to the RT-PCR assay result and clinical manifestation of the patients, thus we cannot exclude some degree of reporting bias. Subtle radiographic features in the poor inspiratory supine radiographs may be also be under or overestimated. We had also described the pattern and frequency of lung findings among all COVID patients, rather than among patients with abnormal CXRs only, as to guide radiologists and clinicians on the most common findings and the frequency one would expect to find these changes when they review all COVID-19 patient CXRs.

CONCLUSION

Although a greater proportion of our patients presented with normal baseline radiographs, generally speaking, the abnormal group demonstrated specific patterns of COVID-19 complementing the radiographic and CT findings in the literature. Familiarization with the radiographic appearance of the disease may help in the early detection of the disease, especially this is pertinent in remote and economically challenged regions where access to reliable RT-PCR testing is limited or delayed and portable chest radiographs are more readily available instead. We may also reasonably conclude that chest radiograph is a useful adjunct screening tool for early isolation and mitigation of suspected patients specifically the symptomatic, 60 years of age and above and those with comorbidities while waiting for the RT-PCR result.

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