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MEDICAL IMAGING—ORIGINAL ARTICLE

Chest imaging findings in COVID-19-positive patients in an Australian tertiary hospital

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Abstract

Introduction: Coronavirus disease 2019 (COVID-19) has infected over 215 million individuals worldwide. Chest radiographs (CXR) and computed tomography (CT) have assisted with diagnosis and assessment of COVID-19. Previous reports have described peripheral and lower zone predominant opacities on chest radiographs. Whilst the most common patterns on CT are bilateral, peripheral basal predominant ground glass opacities (Wong *et al*., *Radiology*, 296, 2020, E72; Karimian and Azami, *Pol J Radiol*, 86, 2021, e31). This study describes the imaging findings in an Australian tertiary hospital population.

Methods: COVID-PCR-positive patients who had chest imaging (CXR, CT and ventilation perfusion (V/Q) scans) from January 2020 to August 2020 were included. Distribution, location and pattern of involvement was recorded. Evaluation of the assessors was performed using Fleiss Kappa calculations for review of radiographic findings and qualitative analysis of CT findings.

Results: A total of 681 studies (616 CXRs, 59 CTs, 6 V/Q) from 181 patients were reviewed. The most common chest radiograph finding was bilateral lower lobe predominant diffuse opacification and most common CT pattern being ground glass opacities. Of the CT imaging, 33 were CT Pulmonary Angiograms of which five demonstrated acute pulmonary emboli. There was good inter-rater agreement between radiologists in assessment of imaging appearances on CXR (kappa 0.29–0.73) and CT studies.

Conclusion: A review of imaging in an Australian tertiary hospital demonstrates similar patterns of COVID-19 infection on chest X-ray and CT imaging when compared to the international population.

Key words: chest CT; chest imaging; chest radiograph; COVID-19; VQ.

Introduction

Coronavirus disease 2019 (COVID-19) was first described in late 2019 where the first cluster of cases was reported in Wuhan, Hubei Province, China.[1] COVID-19 has since spread globally and on 11 March, 2020 the World Health Organisation (WHO) officially characterised COVID-19 as a pandemic. As of 3rd October 2021, over 215 million individuals have been infected worldwide resulting in significant mortality and morbidity. The first case of COVID-19 in Australia was confirmed on the 25th January 2020, and by 3rd October 2021 Australia has had more than 110,000 cases which have resulted in over 1000 deaths.

Chest radiographs (CXR) and computed tomography (CT) have frequently been utilised in assistance with diagnosis and assessment of progression of disease. A multinational consensus statement from the Fleischner society describes the role of chest imaging in the management of COVID-19, recommending that imaging is not indicated in patients suspected of having COVID-19 with mild clinical features, but is recommended for patients at risk for disease progression and in those with worsening respiratory status.[2] Imaging of patients with

COVID-19 infection has raised challenges in ensuring that studies are performed appropriately whilst ensuring the safety of health personnel.

Whilst the CXR is low in sensitivity, it can be highly suggestive of COVID-19 in the correct clinical setting when the radiographs exhibit characteristic COVID-19 findings.[3] Typical findings include a peripheral mid to lower zone lung distribution of opacification.[3,4]

CT imaging is not recommended for screening or as a first line test to diagnose COVID-19 and should be used sparingly, for hospitalised, symptomatic patients with specific clinical indications.[5,6] The Royal Australian and New Zealand College of Radiologists (RANZCR) recommendation for CT technique in the setting of COVID-19 is a volumetric CT of the entire chest at end inspiration, with reconstruction of contiguous high-resolution (HR) images at 0.625–1.5 mm for assessment of the lungs. Studies have demonstrated that COVID-19 can cause microvascular injuries resulting in a procoagulant state.[5] The role of computed tomography pulmonary angiography (CTPA) is reserved for the detection of pulmonary emboli in individuals who have clinical deterioration.[7] Characteristic CT findings include bilateral, peripheral and basal predominant ground glass opacities and consolidation.[8] Consolidation superimposed on ground glass opacity is found in a small number of cases, predominantly in the elderly.[7]

This study describes the imaging findings of 180 patients who presented to The Royal Melbourne Hospital (an Australian tertiary hospital), evaluating the patterns demonstrated on CXR, CT and ventilation perfusion (V/Q) scans.

Methods

The retrospective review was approved by the ethics committee through the quality assurance pathway. COVID-PCR-positive patients who had chest imaging (CXR, CT and V/Q scans) from January 2020 to August 2020 were included. The imaging was evaluated by a senior radiology registrar and four subspecialty chest radiologists including one dual trained radiologist and nuclear medicine specialist. Imaging performed within 5 days prior to the COVID-PCR-positive test was also included to account for the potential lag time between onset of infection and a COVID-PCR-positive test.

A set of descriptors were developed for the purposes of labelling based on descriptors in the current literature.

Chest radiograph descriptors

Chest radiograph descriptors were divided into zone involvement, distribution and findings. The chest radiograph was divided into six zones, right upper, right middle, right lower, left upper, left middle and left lower (Fig. 1). This method of dividing the lungs into thirds is commonly used in reporting and has been proposed for the reporting of COVID-19 chest radiographs.[9]

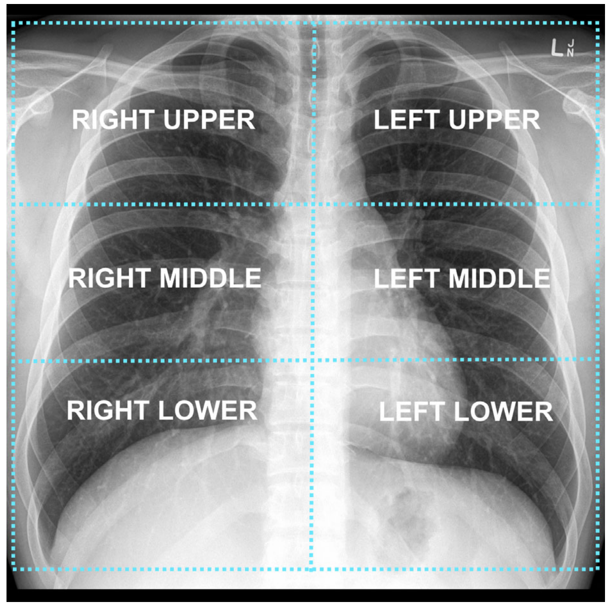

Fig. 1. The chest X-rays were distributed into six zones as illustrated.

The distribution of the lung changes were also classified into three categories: peripheral, central and diffuse (Fig. 2). Peripheral distribution was selected when only peripheral opacities were present. Central distribution was selected when only central opacities were present. A diffuse distribution was selected if there were opacities that either crossed both regions or were both peripheral

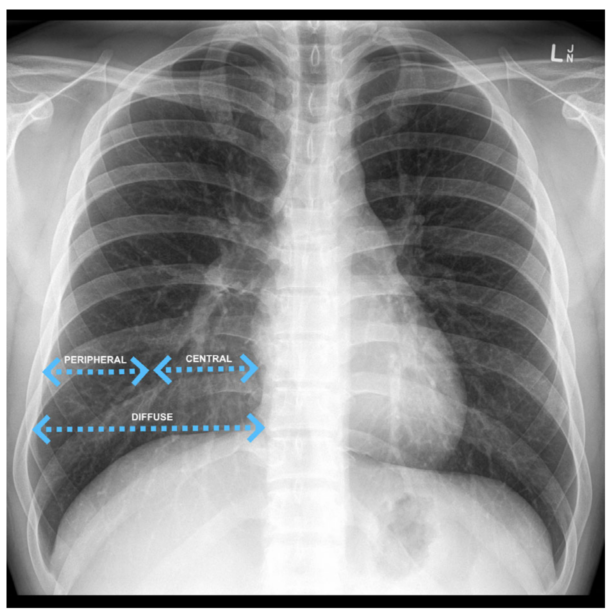

Fig. 2. Descriptors for the distribution of opacity.

and central. Figure 3 demonstrates a chest radiograph with a peripheral distribution.

Other findings recorded included the presence of pleural effusions or interstitial change.

CT descriptors

CT characteristics were classified according to pattern, distribution, lobe involvement and other findings. The CT descriptors were used for all chest CT imaging including pre- and post-contrast CT chests such as pulmonary angiograms.

CT patterns reviewed were based on patterns described in the literature.[10] Patterns that were included were ground glass opacities, consolidation, ground glass with consolidation, crazy paving pattern, reverse halo, interlobular septal thickening and air bronchograms.

Distribution on CT was divided into peripheral, central, peribronchovascular or diffuse. Similar to the chest radiograph distribution, if more than one pattern was involved the diffuse descriptor for distribution was selected. Lobar involvement was also recorded based on the normal anatomical division of the right and left lung lobes (right upper, middle and lower and left upper and lower). Each lobe involved in the CT was selected.

Other findings that were recorded included pleural effusions, lymphadenopathy, pulmonary nodules, scarring and presence of pulmonary embolism on CT pulmonary angiograms.

V/Q scan descriptors

V/Q scans were analysed as either with findings or without findings. The V/Q scans recorded in this study were either performed just prior to a positive COVID swab or after the acute episode of COVID as follow-up imaging.

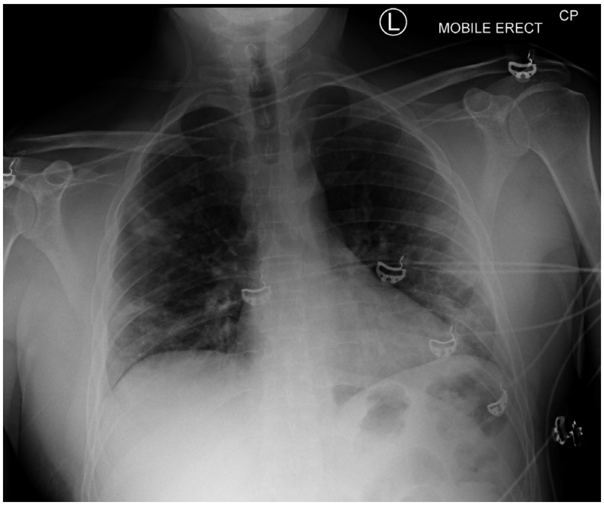

Fig. 3. Chest radiograph with a peripheral distribution.

Evaluation of readers

Between the five assessors, the senior radiology registrar reviewed all 661 studies. The consultant radiologists each reviewed 20 studies, 20 of which were also reviewed by the radiology registrar and 10 reviewed by another consultant radiologist. Fleiss kappa values were calculated to assess inter-rater variability between all five assessors for chest radiograph distribution (peripheral, central and diffuse) as well as for each of the six lung zones. A qualitative assessment of the responses of the five assessors was performed with all discrepancies reviewed.

Results

A total of 681 studies (616 Chest X-Rays, 59 CTs, six V/Q scans) from 181 patients were reviewed. Of the 181 patients, there were 92 females and 89 males with a mean age of 61.99 (range 16–101).

Chest radiograph findings

A total of 103 (17%) of radiographs performed were normal with no findings. Three chest radiographs were considered not suitable for evaluation as they did not have the entire chest in view for evaluation. The most commonly involved zones were the left lower zone ($n = 441$, 72%) and right lower zone ($n = 433$, 70%). The least involved zone was the left upper zone ($n = 112$, 18%). The distribution in each lung zone is shown in Table 1. Findings in both lungs ($n = 417$, 67%) were demonstrated more often than unilateral findings ($n = 239$, 39%). The most common pattern of distribution was a diffuse pattern ($n = 351$, 57%) followed by a peripheral pattern ($n = 146$, 24%) with the least common pattern of distribution being central ($n = 13$, 2%). In the other findings evaluated, 3% had pleural effusions and 3% had interstitial change.

CT findings

Of the 59 CTs, nine were performed as follow-up after the acute episode. Ten (17%) CTs performed were normal. Of these normal CT studies, two were in follow-up CT scans. Thirty-three of the scans were CT pulmonary angiograms, with five positive for pulmonary embolism. The most common patterns demonstrated on CT imaging

Table 1. Distribution of changes in each zone on chest radiograph

Zone	Number	Percent
Right upper	239	39
Right middle	337	55
Right lower	433	70
Left upper	112	18
Left middle	266	43
Left lower	441	72

were ground glass opacity (n = 20, 45%) and ground glass with consolidation (n = 20, 34%). The most common distribution demonstrated on CT was peripheral (n = 29, 49%) and peribronchovascular (n = 16, 27%). The most commonly involved lobe was the right lower lobe (n = 42, 71%) followed by the left lower lobe (n = 41, 69%). Bilateral involvement (n = 45, 76%) was more common than unilateral involvement (n = 3, 6%). In the other findings evaluated, four demonstrated pleural effusion (n = 4, 7%), two cases demonstrated lymphadenopathy and five cases demonstrated pulmonary nodules. Scarring was observed in three cases, two of which were in follow-up CT scans. An example CT demonstrating peripheral regions of consolidation, ground glass and air bronchograms is shown in Figure 4.

Fig. 4. CT chest performed on a COVID-19-positive patient with regions of peripheral consolidation, ground glass opacity and air bronchograms which are lower lobe predominant.

V/Q scan findings

Of the six V/Q scans performed, two (33%) demonstrated findings and four (67%) were normal. One V/Q scan was performed 7 days prior to the positive COVID test and 4 days prior to the onset of symptoms to investigate a 6 month history of chest pain. The V/Q scan was negative for pulmonary embolism with bronchopulmonary changes seen in the left apex on both ventilation and perfusion images (Fig. 5). Although CT chest two days later demonstrated no correlative changes, bilateral regions of opacification were subsequently demonstrated on CXR 7 days after the V/Q scan. The other positive V/Q scan was requested for follow-up of pulmonary emboli demonstrated on CT pulmonary angiogram on admission. This V/Q scan demonstrated mild heterogeneous tracer uptake in both lungs.

Evaluation of readers

Moderate agreement was demonstrated between the readers for assessment of distribution on the chest radiograph (peripheral, central, diffuse) with a Fleiss Kappa value of 0.42 (P-value < 0.05). The Fleiss Kappa values of the inter-rater agreement for the distribution of the opacities in zones ranged from fair to substantial agreement with Fleiss kappa values ranging from 0.29 to 0.73 (P-value < 0.05).

A qualitative assessment performed on the CTs read by all consultant radiologists demonstrated consistency in labelling of the lobe involvement. There was a general consensus for the presence of ground glass opacity, air bronchograms and ground glass with consolidation.

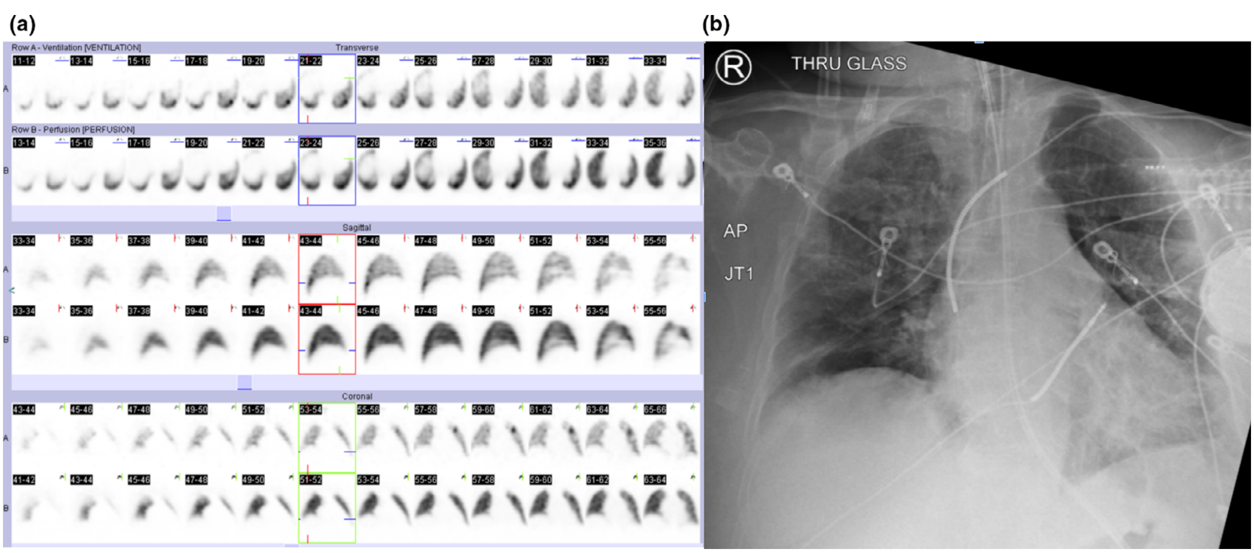

Fig. 5. V/Q scan (a) in a patient who subsequently became COVID-19 positive with bilateral regions of opacification on CXR performed 7 days after the V/Q scan (b).

Discussion

A review of imaging in an Australian tertiary hospital demonstrates similar trends on chest radiographs with those described in the literature of international populations with predominantly bilateral mid to lower zone regions of opacification.[3,11] The population had approximately 17% normal chest radiographs which is slightly lower than what has been reported in other populations but comparable to those reported in hospitalised patients.[4,12] Another factor that would have contributed to a higher percentage of radiographs with findings in this population would be that individuals who were hospitalised received a greater number of radiographs when compared to those managed in the emergency department and discharged for community treatment. Furthermore, this cohort demonstrated a greater number of radiographs with a diffuse distribution of findings instead of a peripheral only distribution which likely reflects the acuity of the patient population who present to hospital.

Litmanovich *et al*.[9] proposed a suggested reporting language for the review of chest radiograph findings of COVID-19 pneumonia. The authors proposed a reporting language for grading the severity of lung disease using a modified version of a scoring system used in quantifying the severity of acute respiratory distress syndrome. The authors base their grading on the number of lung zones involved, dividing the lung into six zones, similar to what was performed in this study. Mild with involvement of 1–2 lung zones, moderate with opacities in 3–4 lung zones and severe > 4 lung zones. This standardisation in reporting is thought to be helpful in assessing progression over multiple radiographs in a patient with COVID-19. Our study demonstrates that there is a fair to substantial inter-rater agreement in the evaluation of opacities in zones which may indicate that such a proposed reporting system may be useful in this clinical setting.

CT imaging findings described in this population were similar to the characteristics described on CT of a systematic review performed on 919 patients with coronavirus disease with predominantly bilateral and peripheral involvement demonstrated. A large proportion of CTs in this study also demonstrated multilobar involvement, similar to that in the literature, reflecting the severity of symptoms in patients who receive cross sectional imaging.

COVID-19 can cause microvascular injury and is associated with a procoagulant state increasing the risk of thromboembolic disease.[8,13] Greater than half of the CT chest scans performed on COVID-19-positive patients were CT pulmonary angiograms with five positive for pulmonary emboli demonstrating that the symptoms of PE may mimic or overlap with those of COVID-19 infection.

Although V/Q imaging does play a role in the diagnosis of thromboembolic disease especially in those with impaired renal function, the use of ventilation images in COVID-19-positive patients is discouraged due to its potential risk of spread of infection.[14] All V/Q imaging included in this study was either performed after a negative COVID-19 swab during an acute episode, or prior to a subsequent positive COVID-19 swab, without clinical suspicion of the diagnosis at time of study.

In conclusion, a review of imaging in an Australian tertiary hospital demonstrates similar trends on chest X-ray and CT imaging when compared to the international population. A propensity for a number of radiographs with diffuse findings may reflect the acuity of the patients who present to hospital.

Data availability statement

Research data are not shared.

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