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Radiological signs and the complications of COVID-19 using different imaging modalities: A review

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The aims of this study were to determine the performance of different imaging modalities in the diagnosis of corona virus disease 2019 (COVID-19) and to familiarize radiologists with a possible chest X-ray, chest computed tomography (CT), ultrasonography (US) and magnetic resonance imaging (MRI) patterns of the disease onset and complications, which visualize in the image and to reduce the misdiagnosis rate of radiologists for COVID-19. This study was the review of the literature, which included 50 studies 35 original articles, 11 case reports and 4 literature reviews with a diagnosis of COVID-19 infection from different countries and gender. The researchers reviewed radiological signs and compared them in different imaging modalities. This study revealed that published studies of COVID-19 mostly from China; CT is most imaging modality used for evaluation and diagnosis of COVID-19, chest CT (64.71%), chest X-ray (19.2%), US (13.23%), MRI (2.94%) and chest CT had a low rate of missed diagnosis of COVID-19 (3.9%, 2/51). The most frequent findings are ground-glass opacities (GGO) 80% and patchy lung consolidation 28%. The distribution is most often bilateral, peripheral and lower zone predominant. This study concluded that radiological findings might be useful as a standard method for the rapid diagnosis of COVID-19 to optimize the management of patients. However, additional high-quality studies are needed to convince policy makers. In addition, current study present guidelines to help focus future research in this area. Furthermore, this study found that chest CT was a reliable diagnostic tool for COVID-19.

Keywords: Chest computed tomography, complications, COVID-19, ground-glass opacities, radiological signs, review of literature

INTRODUCTION

In December 2019, a lower respiratory tract febrile illness of unknown origin was reported in a cluster of patients in Wuhan city, Hubei province,

China. A novel strain of coronavirus isolated from the broncho-alveolar lavage of the patients was determined to be responsible for the outbreak. The pulmonary syndrome was later named coronavirus disease 2019 (COVID-19) by the World Health Organization (WHO). Despite the imposition of strict quarantine rules and travel restrictions, the virus transmitted rapidly out of China with a number of confirmed cases reported in Europe, the United Kingdom (UK) and the United States of America (USA). According to the recent statistics of the WHO, the disease has already involved all continents, with 4 618 821 cases confirmed cases and 311 847 deaths until 18 May 2020 (Lu, 2020).

Similar pulmonary syndromes have been recognized as being caused by other strains of the coronavirus family. The most notable examples are the severe acute respiratory syndrome (SARS) and the Middle East respiratory syndrome (MERS). The SARS outbreak has been contained, with no human infection reported since 2003; small outbreaks of MERS continue to be reported. Imaging is a critical component of the diagnostic work-up, monitoring of disease progression and follow-up in coronavirus-related pulmonary syndromes (Al-Tawfiq et al., 2014). Imaging features in the acute and chronic phases of SARS and MERS are variable and nonspecific (Ketai et al., 2006; Das et al., 2016; Das et al., 2017; Antonio et al., 2005). The first accounts of the imaging findings of COVID-19 have also reported nonspecific findings (Chung et al., 2020; Chan et al., 2020a; Liu and Tan, 2020).

Because of the primary involvement of the respiratory system, chest computed tomography (CT) is strongly recommended in suspected COVID-19 cases, for both initial evaluation and follow-up (Jun et al., 2020). Chest radiographs are of little diagnostic value in the early stages, whereas CT findings may be present even before symptom onset (Kim et al., 2020; Pan et al., 2020). In the intermediate to advanced stages of the disease, chest radiographs may show the progression of features of acute respiratory distress syndrome (ARDS). Furthermore, CT findings have proven to be diagnosed in a number of cases with an initial false-negative reverse transcription polymerase chain reaction (RT-PCR) screening test (Huang et al.,, 2020a; Xie et al.,, 2020), an assessment of 41 patients with a laboratory-confirmed COVID-19 diagnosis revealed abnormal chest CT findings in all cases (Huang et al.,. 2020b).

COVID-19 is a serious infectious disease resulting in severe respiratory illness. This pandemic represents a serious public health risk. Therefore, early and accurate diagnosis is essential to control disease progression. Radiological examinations play a crucial role in early identification and management of infected patients. The aim of this review study was to provide an overview of available published information on global research of coronavirus related to radiological modalities and clinical symptoms that available in the recently published information.

MATERIALS AND METHODS

This study was reviewed the currently available literature of imaging modalities and complications of patients whom confirmed infections by COVID-19 occurred at the time of writing on 20 March and updated on May 19, 2020. A literature search was performed using available website information, using the PubMed, Scopus, Web of Science and Google Scholar databases. Search terms included “coronavirus, radiology, COVID-19, radiological Signs”. The defined search was selected to provide an overview of available published information on global research of coronavirus related to radiological modalities, including chest X-ray, CT and ultrasonography (US), to capture the most recently published articles. Furthermore. No ethics approval was required. Seven investigators performed this research and about 50 studies were identified (35 articles, 11 case report and 4 reviews of literature) data collection sheet. Studies were excluded if they do not include radiological findings. Only studies in English Language were included. The search was limited to, articles published in 2020.

RESULTS AND DISCUSSION

From all the data collected, the authors summarized the main findings and radiological signs of the disease onset and complication in the different imaging modalities. In addition, what we put under data presentation, identifying the radiological signs at the radiographs and represent our data analysis.

A multi-centre study initiated by Chen et al., (2020a) and entitled diagnostic model for COVID-19 based on radiological semantic and clinical features, which is a cohort of 70 COVID-19 and 66 non-COVID-19 pneumonia patients. It compared 1745 lesions and 67 features in the two groups (16-69 years) mean age 42.9 years, 41 men and 29 women, for imaging manifestations, 7

patients in the COVID-19 group showed normal chest CT (10%). COVID-19 patients have a greater number of pure ground-glass opacities (GGO) and mixed GGO than non-COVID-19 patients. For pure GGO lesions, the differences are significant both in the peripheral and in central areas. The number of mixed GGO is mainly distributed at the periphery in COVID-19 patients, with no statistical difference in the central area. The consolidation lesions without GGO (Figure 1) occurred less in COVID-19 patients (10). More lesions are between 1 and 3 cm and fewer lesions are larger than half of the lung segment in COVID-19 patients. Other significant differences between the two groups include the pleural traction sign, bronchial wall thickening, interlobular septal thickening, crazy paving (Figure 2), tree-in-bud, pleural effusions, pleural thickening and the offending vessel augmentation in lesions (Jin et al., 2020).

The lung score presents no significant difference between the COVID-19 and non-COVID-19 groups. Eighteen radiological semantic features and seventeen clinical features were identified to be significantly different. Besides GGO and consolidation (Figure 1) in the lung periphery, the lesion size (1-3 cm) is also significant in the diagnosis of COVID-19. However, lung score presents no significant in difference (Chan et al., 2020a).

About 101 (45 women, 56 men) cases of COVID-19 pneumonia were retrospectively collected by Zhao et al., (2020a) for the study entitled relation between chest CT findings and clinical conditions of COVID-19 pneumonia: A multicentre, the study found that GGO or mixed GGO and consolidation vascular enlargement in the lesion and traction bronchiectasis. Lesions present on CT images were more likely to have a peripheral distribution (Figure 3) and bilateral involvement and be lower lung predominant and multifocal. Patients in the emergency group were older than those in the non-emergency group. Architectural distortion, traction bronchiectasis and CT involvement score aided in the evaluation of the severity and extent of the disease.

Huang et al., (2020c) described a preliminary study on the ultrasonic manifestations of peri-pulmonary lesions of non-critical novel COVID-19 20 patients (11 male and 9 female) with clinically diagnosed non-critical COVID-19 treated were retrospectively analysed, the study revealed that the lesions tended to occur in both lungs. This type of lesions are rough and discontinuous pleural line, subpleural consolidation, air bronchogram sign or air bronchiologram sign in subpleural peripleural consolidation, visible B lines, localized pleural thickening, localized pleural effusion, poor blood flow in the consolidation detected by colour Doppler US (Figure 4)

Lomoro et al., (2020) in Italy made a single-centre study and comprehensive radiologic literature review, entitled COVID-19 pneumonia manifestations at the admission on chest US, radiographs and CT. In their retrospective study, fifty-eight patients (36 men, 22 women; age range, 18-98 years were examined, they found that Lung US findings were consistent with diffuse B lines (100%) and subpleural consolidations (27.3%). Chest X-ray showed prevalent manifestations of consolidations (46.9%) and hazy increased opacities (37.5%). Typical CT features included bilateral and multilobar GGO with (59.5%) and without (35.7%) consolidations having a predominantly peripheral distribution (64.3%). Other imaging features included crazy paving pattern (57.1%), fibrous stripes (50%), subpleural lines (35.7%), architectural distortion (28.6%), air bronchogram sign (26.2%), vascular thickening (23.8%) and nodules (2.4%). In addition, enlarged lymph nodes (14.3%) and pleural effusion (7.1%) were observed (Figure 5) (Lomoro et al., 2020).

Zhou et al., (2020) studied CT features of COVID-19 pneumonia in 62 patients in Wuhan, China. In their study, multiple lesions were seen on the initial CT scan patients (83.9%). (77.4%) had predominantly peripheral distribution of lesions.). CT findings of the patients were as follows: (40.3%) had GGO, (33.9%), consolidation; (62.9%), GGO plus a reticular pattern, (54.8%), vacuolar sign, (45.2%), microvascular dilation sign, (56.5%), fibrotic streaks, (33.9%), a subpleural line and (53.2%) with a subpleural transparent line. With regard to bronchial changes seen on CT, patients (72.6%) had air bronchogram and (17.7%) had bronchus distortion. In terms of pleural changes, CT showed (48.4%) had pleural thickening, (56.5%) had a pleural retraction sign and (9.7%) had pleural effusion. Compared with early-phase disease (≤7 days after the onset of symptoms), advanced-phase disease (8-14 days after the onset of symptoms) was characterized by significantly increased frequencies of GGO plus a reticular pattern, vacuolar sign, fibrotic streaks, a subpleural line, a subpleural transparent line, air bronchogram, bronchus distortion and pleural effusion; however, GGO significantly decreased in advanced-phase disease (Figure 5) (Lomoro et al., 2020).

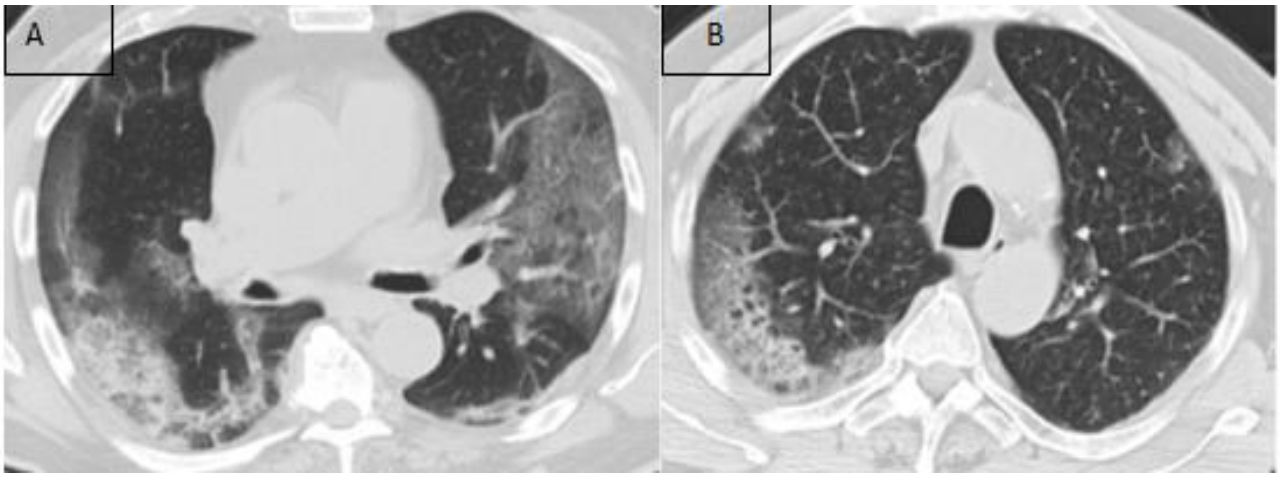

Figure 1: Chest CT images show consolidations (Chan et al., 2020a).

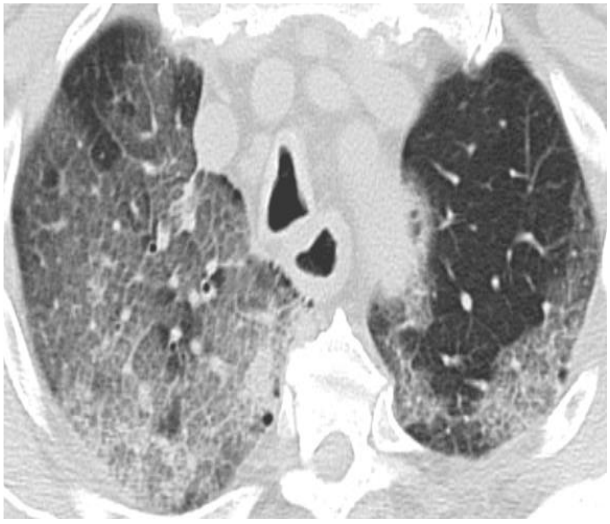

Figure 2: Chest CT images show septal thickening and GGO and crazy-paving pattern (Jin et al., 2020).

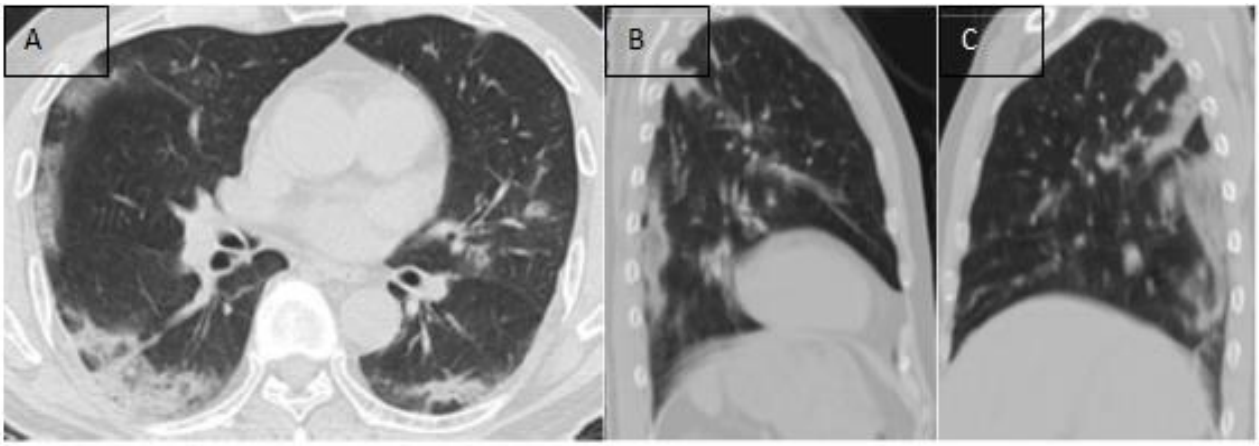

Figure 3: Chest CT images show peripheral/subpleural distribution (Zhao et al., 2020a).

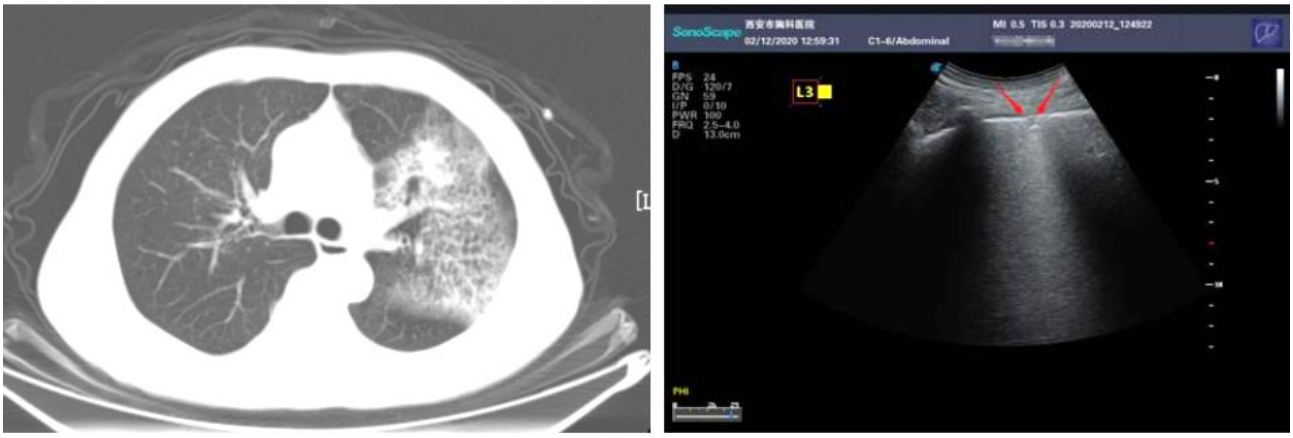

Figure 4: Chest high-resolution computed tomography (HRCT) (left) showed GGO and reticular shadows under the pleura in the field of the left lung. The convex array probe (right) revealed B lines in the left posterior lower area and a line disappeared. Small patchy lesions were observed and the pleural line was discontinuous (red arrow) (Huang et al., 2020c).

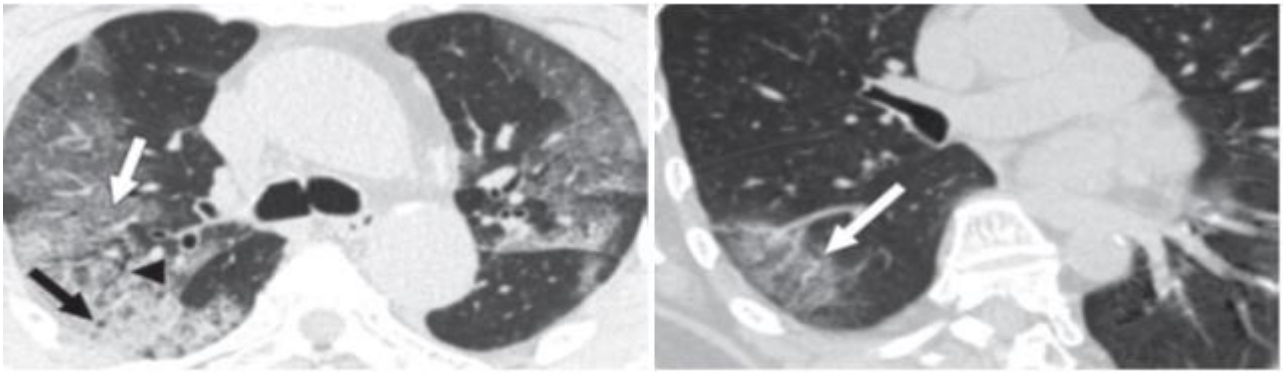

Figure 5: A 77-year-old woman with COVID-19. Transverse CT scan shows multiple GGO and consolidation with thickened intralobular and interlobular septum (white arrow). Air bronchogram sign (arrowhead) and air trapping (black arrow) are present (Lomoro et al., 2020).

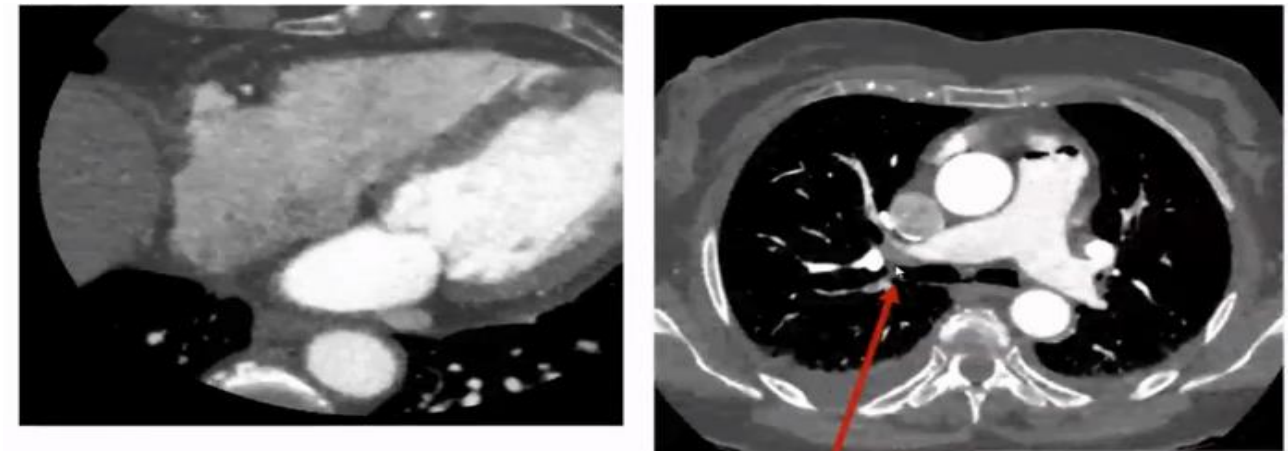

Figure 6: Chest CT images with contrast; computed tomography angiography (CTA) show pulmonary embolism (red arrow) (Grillet et al. 2020).

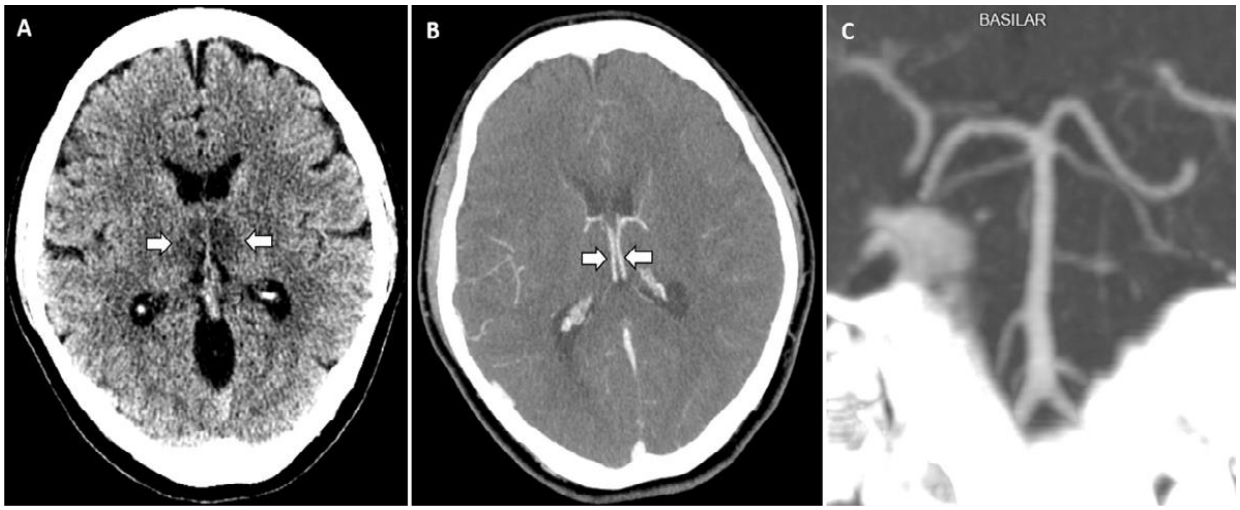

Figure 7: (A), Image from non-enhanced brain CT demonstrates symmetric hypo attenuation within the bilateral medial thalami (arrows). (B), Axial CT venogram demonstrates patency of the cerebral venous vasculature, including the internal cerebral veins (arrows). (C), Coronal reformat of a CT angiogram demonstrates the normal appearance of the basilar artery and proximal posterior cerebral arteries (Poyiadji et al., 2020).

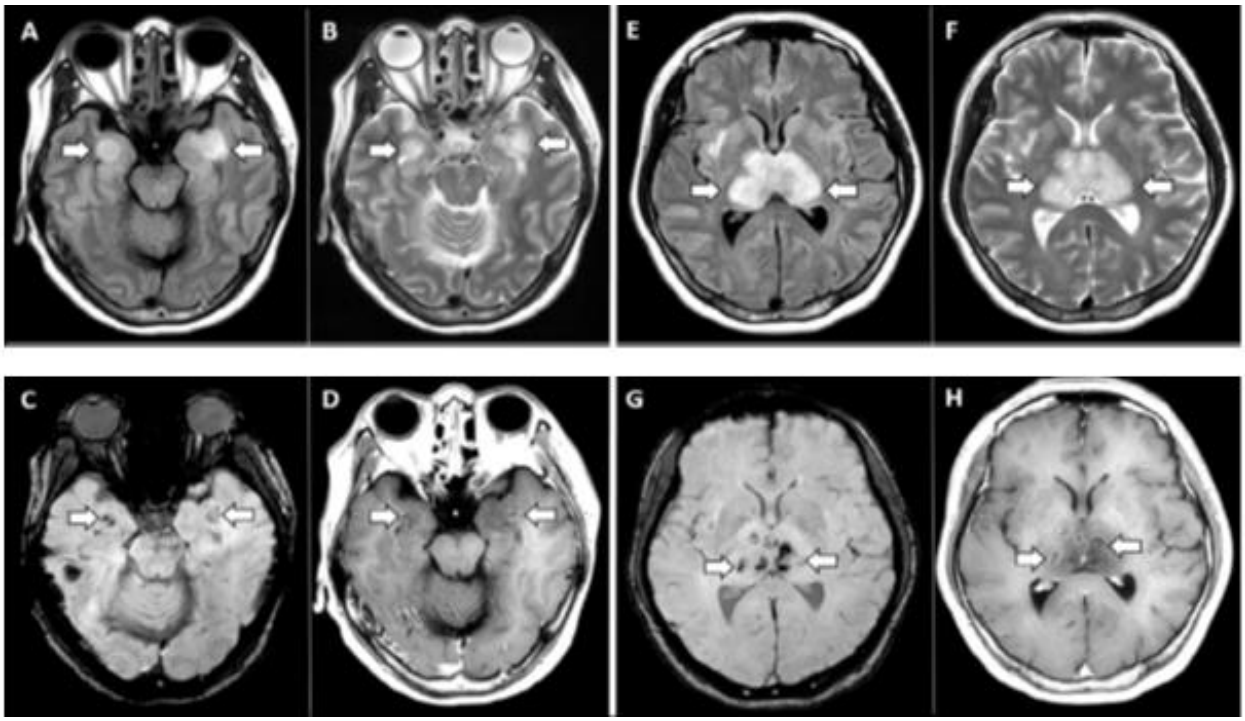

Figure 8: Magnetic resonance imaging (MRI) images demonstrate T_2 Fluid attenuation inversion recovery (FLAIR) hyper intensity within the bilateral medial temporal lobes and thalami (A, B, E, F) with evidence of hemorrhage indicated by hypo intense signal intensity on susceptibility-weighted images (C, G) and rim enhancement on post contrast images (D, H) (Poyiadji et al., 2020).

According to Muniz et al.,, (2020), there were two patient's case reports for a 65-year-old male patient and his wife of 67 years age entitled: Covid-19 CT findings. Chest radiographs were normal. Chest CT showed bilateral multifocal GGO
in both patients, some associated with areas of consolidation. There was no pleural effusion or lymph node enlargement.

In Italy, Inciardi et al., (2020) studied cardiac involvement in a patient with COVID-19. Findings on chest radiography were normal. There was no evidence of obstructive coronary disease on coronary angiography. Cardiac magnetic resonance imaging (CMRI) showed increased wall thickness with diffuse biventricular hypokinesis, especially in the apical segments and severe left ventricular dysfunction (left ventricular ejection fraction of 35%). Short tau inversion recovery and T_2 mapping sequences showed marked biventricular myocardial interstitial edema and there was diffuse late gadolinium enhancement involving the entire biventricular wall. A circumferential pericardial effusion was most notable around the right cardiac chambers.

In France, Grillet et al., (2020) did a retrospective study of 2003 patients diagnosed with COVID-19. They found that, 23 (23%); (95% CI, 15-33%) patients had an acute pulmonary embolism. Patients with pulmonary embolus were more frequently in the critical care unit than those without pulmonary embolus (17 (74%) versus 22 (29%) patients, P<0.001), required mechanical ventilation more often 15 (65%) versus 19 (25%) patients, P<0.001) and had longer delay from symptom onset to CT diagnosis of pulmonary embolus (12±6 versus 8±5 days, P<0.001), respectively (Figure 6).

From China, Long et al., (2020), discussed diagnosis of the COVID-19: Real-time reverse-transcriptase-polymerase chain reaction (rRT-PCR) or CT in 36 patients diagnosed with COVID-19 pneumonia. Thirty-five patients had abnormal CT findings at presentation, whereas one patient had a normal CT. Using rRT-PCR, 30 patients were tested positive, with 6 cases initially missed. Amongst these 6 patients, 3 became positive in the second rRT-PCR assay (after 2 days, 2 days and 3 days respectively) and the other 3 became positive only in the third round of rRT-PCR tests (after 5 days, 6 days and 8 days respectively). Thus, CT sensitivity was therefore 97.2%, whereas the sensitivity of initial rRT-PCR was only 83.3%.

An analysis of the radiographic and clinical features as a case report was done by Poyiadji et al. (2020), entitled COVID-19 – associated acute haemorrhagic necrotizing encephalopathy: CT and MRI. They found that in non-contrast head CT images demonstrated symmetric hypoattenuation within the bilateral medial thalami with a normal CT angiogram and CT venogram. Images from brain MRI demonstrated haemorrhagic rim enhancing lesions within the bilateral thalami, medial temporal lobes and subinsular regions (Figure 7 and Figure 8).

A case study conducted by Lin et al., (2020a), for a 66-year-old woman was transferred to their hospital in Lanzhou, China. Where HRCT image obtained on the second day of admission, showed GGO distributed in multiple lobes and segments of both lungs. CT images revealed little change in the lesion. After treatment, patient's bilateral pulmonary lesions improved and a little fibrous stripe was evident. Shi et al., (2020a) studied radiological findings from 81 patients with COVID-19 pneumonia and they found that the predominant pattern of abnormality observed was bilateral 79% patient, peripheral 54%, ill-defined 81% and GGO 65%, mainly involving the right lower lobes 27% of 849 affected segments in group number one (n=15), the predominant pattern was unilateral 9 (60%), multifocal 8 (53%) and GGO 14 (93%). Lesions quickly evolved to bilateral 19 (90%), diffuse 11 (52%) and GGO opacity predominance 17 (81%) in group number two (n=21). Thereafter, the prevalence of GGO continued to decrease 17 (57%) of 30 patients in group number three and 5 (33%) of 15 in group number four and consolidation and mixed patterns became more frequent 12 (40%) in group number three and 8 (53%) in group number four.

The imaging profile of the COVID-19 infection: Radiologic findings and literature review was a retrospective study of 21 COVID-19 cases done by Ng et al., (2020). In their study CT thorax examinations were performed at a median of 3 days from onset of symptoms (interquartile range 1-7 days). Of the 21 cases, two patients had a normal chest CT. The CT lesions and distribution across the 21 reported cases were listed briefly, the predominant feature were GGO followed by consolidation. Eleven cases had predominantly GGO, four had mixed appearances and four had predominantly consolidative changes. The ground glass and consolidative opacities were peripheral in all patients with lung findings (n=18), apart from one patient who had perihilar ground glass changes. Eight patients showed lower zone predominance, eight patients showed an equal

distribution between the upper and lower zones and three patients showed upper zone predominant changes. Subpleural sparing, pleural effusions, pericardial effusion, cavitation, mediastinal and hilar lymph node enlargement were not seen in any of the patient. Four of twenty-one patients had a follow-up CT. Three patients had follow-up CT performed four days after the initial CT, while one patient had follow-up CT three days after the initial CT. In one patient, there was a reduction in the consolidation and the second patient had a normal CT thorax examination at presentation. On subsequent CT, the CT remained normal with no new lung changes. The third patient's CT showed progression of the lung changes with new ground-glass nodules in other lobes. The preceding GGO increased in size, with some peripheral consolidation. The fourth patient showed the previously observed GGO becoming smaller areas of consolidation.

A review of literature initiated by Yang et al., (2020), entitled the role of imaging in COVID-19, they found that chest radiography could detect multiple patchy opacities throughout the lungs. These opacities eventually become confluent and severe cases may appear as a "whited out lung". In more advanced opacity and consolidation, even pleural fluid (in a severe case) in addition to GGO. In early stages, no obvious abnormalities on the chest radiograph during the early stages after the onset of symptoms. However, on day nine of the illness, an increased area left basilar opacity was visible on chest radiography. Then, stable streaky opacities in the lung bases were visible and the opacities have steadily increased over time. Finding on CT imaging includes multiple, patchy, GGO, crazy paving pattern and consolidation shadows, mainly distributed in the peripheral and subpleural areas of both lungs, which are very helpful for the frontline clinicians. Imaging examination has become the indispensable means not only in the early detection and in diagnosis.

A retrospective study of 121 patients demonstrated by Bernheim et al., (2020), entitled chest CT findings in COVID-19: Relationship to duration of infection, they found that, of the 121 patients, 27 (22%) had no GGO and no consolidation on chest CT. Of the 94 patients with GGO, consolidation, or both, 41 (34%) had only GGO (with no consolidation) and two patients (2%) had consolidation in the absence of GGO. Eighteen patients (15%) had opacities in one lobe, 14 patients (12%) had two affected lobes, 11 patients (9%) had three affected lobes, 18 patients (15%) had four affected lobes and 33 patients (27%) had disease affecting all five lobes. The frequency of GGO and consolidation was far less in the early group as compared with the intermediate and late groups 20 of 36 early patients (56%, 95%CI 47-65%) had no lung opacities as compared with three of 33 intermediate patients (9%) and 1 of 25 (4%) late patients. Bilateral lung involvement was observed in 10 of 36 early patients (28%), 25 of 33 intermediate patients (76%) and 22 of 25 late patients (88%), a "crazy-paving" pattern and a "reverse halo" sign were all absent in the early group, but were present in the late group 20%, 20% and 4% of the time, respectively. In terms of distribution of disease in the axial plane, peripheral distribution was found in 8 of 36 early patients (22%), 21 of 33 intermediate patients (64%) and 18 of 25 of late patients (72%).

Duan and Qin (2020) describe pre- and post-treatment chest CT findings: 2019 novel coronavirus pneumonia as case report of a 46-year-old woman, they found that by CT scan obtained on the first day after admission shows multiple GGO in both lungs. GGO were seen in the superior segment of both lower lobes. Follow-up CT scans obtained on day seven after admission and after taking treatment show GGO were completely resolved in the superior segment of right lower lobe and partly resolved in the superior segment of left lower lobe. Follow-up CT scans obtained at day thirteen after admission show GGO were completely resolved in the superior segment of right lower lobe and partly resolved in the superior segment of left lower lobe.

Song et al., (2020) studied fifty-one patients with emerging COVID-19 pneumonia. Chest CT images showed pure GGO (77%) patients and GGO with reticular and/or interlobular septal thickening in (75%) patients. GGO with consolidation was present in (59%) of the patients and pure consolidation was present in (55%) of them. About 86% patients had bilateral lung involvement, while (80%) involved the posterior part of the lungs and 44 of 51 (86%) were peripheral. There were more consolidated lung lesions in patients 5 days or more from disease onset to CT scan versus 4 days or fewer (431 of 712 lesions versus 129 of 612 lesions; $P<0.001$). Patients older than 50 years had more consolidated lung lesions than did those aged 50 years or younger (212 of 470 versus 198 of 854; $P<0.001$). Follow-up CT in 13 patients showed

improvement in 7 (54%) patients and progression in 4 (31%) patients.

Shi et al., (2020b), from China studied evolution of CT manifestations in a patient recovered from 2019 novel coronavirus pneumonia in Wuhan, China. The chest radiograph obtained on day seven after the onset of symptoms shows opacities in the left lower and right upper lobes. Chest CT scans obtained on day nine show multifocal bilateral GGO. Chest CT scans obtained on day fifteen, show evolution to a mixed pattern of GGO and consolidation while scans obtained on day 19 show healing of the consolidations and GGO. Finally scans obtained on day 31 show complete resolution.

About 1014 patients in Wuhan, China who underwent both chest CT and RT-PCR tests were included, a report done by Ai et al., (2020), entitled: Correlation of chest CT and RT-PCR testing in COVID-19 in China, of 1014 patients, 59% (601/1014) had positive RT-PCR results and 88% (888/1014) had a positive chest CT scan. The sensitivity of chest CT in suggesting COVID-19 was 97% (95%CI, 95-98%, 580/601 patients) based on positive RT-PCR results. In patients with negative RT-PCR results, 75% (308/413) had positive chest CT findings; of 308, 48% were considered as highly likely cases, with 33% as probable cases. By analysis of serial RT-PCR assays and CT scans, the mean interval time between the initial negative to positive RT-PCR results were 5.1±1.5 days; the initial positive to subsequent negative RT-PCR result was 6.9±2.3 days). 60% to 93% of cases had an initial positive CT consistent with COVID-19 prior (or parallel) to the initial positive RT-PCR results. About 42% (24/57) cases showed improvement in follow-up chest CT scans before the RT-PCR results, turning negative.

A report of three cases titled clinical features and multidisciplinary treatment outcome of COVID-19 pneumonia, discussed by Liu et al., (2020a). Where chest CT scans of a 32-year-old male reveals diffuse multiple patchy exudates, which are more marked in both lower lungs, suggesting infectious lesions. Second chest CT scans shows diffuse bilateral GGO and partial exudation, which are markedly improved compared with admission CT scan findings. Chest CT scans of a 48-year old male patient with fever and cough for nine days who had confirmed COVID-19 pneumonia on February 6 diffuse multiple patchy exudates with partial interlobar septation, suggesting viral pneumonia. Second CT scans on reveals multiple bilateral patchy shadows, partial exudation and fibrotic changes, which are markedly improved versus changes at admission. Chest CT scan of an 82-year old female patient referred with a confirmed diagnosis of COVID-19 for 5 days shows multiple bilateral GGO and mainly peripheral exudative changes. The second chest CT scan reveals multiple bilateral GGO and scant cord-like shadows, which are mainly peripheral.

Wang et al., (2020a) studied the clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China. All of the 138 enrolled patients showed bilateral involvement of chest CT scan. Cao et al., (2020) studied 31 articles and 46959 patients, including 10 English articles and 21 Chinese articles studied to compare imaging and clinical features of patients with 2019 novel coronavirus SARS-CoV-2. A systematic review and meta-analysis showed that in CT examinations, the pneumonia compromise was predominantly bilateral in 75.5% (0.639-0.871) and unilateral 20.4% (0.106-0.302). The most common patterns on chest CT were GGO (69.9%, 0.602-0.796), followed by an irregular or halo sign (54.4%, 0.255-0.833), air bronchogram (51.3%, 0.326-0.701), bronchovascular bundle thickening (39.5%, 0.082-0.708), grid-form shadow (24.4%, 0.116-0.371) and hydrothorax. Lee et al., (2020) studied a case of COVID-19 and pneumonia returning from Macau in Taiwan: Clinical course and anti-SARS-CoV-2 IgG dynamic for a 46-year-old woman chest radiograph showed patchy densities in the left upper and middle lung fields. On day one, there was increased pulmonary infiltration, especially in the left lung field while in hospital day fourteen resolutions of pulmonary infiltrates detected in the left lung field. COVID-19 pneumonia in a haemodialysis patient was studied by Tang et al., (2020) where they found that bilateral multiple GGO prominent on the left and bilateral pleural effusion. Repeated CT scans show decreases in the size of GGO in the lungs.

Sohrabi et al., (2020) review for WHO declares global emergency a review of the 2019 novel coronavirus. Where out of 90,870 cases of COVID-19 have been confirmed, 80,304 of which were confined to China. Of the Chinese cases, 67,217 were confirmed in the Hubei Province with the remainder being reported in 34 provinces, regions and cities in China using CT chest found that mean sign bilateral lung infiltrates on imaging. In Italy, Lupia et al., (2020) studied 2019-novel coronavirus outbreak: A new challenge and they found that multiple bilateral lobular and

subsegmental areas of consolidation or bilateral GGO were the main reported radiological features of COVID-19. In the 41 patients' case series reported by Huang et al., (2020d), all had a plain chest X-ray or CT findings of pneumonia. Although CT is the best method to define extension and a typology of lung parenchyma involvement, a chest X-ray was mostly employed as a first investigation, probably because the associated need to comply with infection control procedures. Huang et al., (2020d), in their study of 41 admitted hospital patients had been identified as having laboratory-confirmed COVID-19 infection. Most of the infected patients were men 30 of 41 (73%); less than half had underlying diseases 13 (32%), including diabetes 8 (20%), hypertension 6 (15%) and cardiovascular disease 6 (15%). The typical findings of chest CT images of intensive care unit (ICU) patients on admission were bilateral multiple lobular and subsegmental areas of consolidation. The representative chest CT findings of non-ICU patients showed bilateral GGO and subsegmental areas of consolidation. Later chest CT images showed bilateral GGO, whereas the consolidation had been resolved.

Chest CT showed mild ground glass changes in the both lungs in the study done by Li et al., (2020) entitled transmission of COVID-19 in the terminal stage of incubation period: A familial cluster. Six family members studied by Chan et al., (2020b) for their research titled a familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to-person transmission: A study of a family cluster. Their results were multifocal patchy GGO, especially around the peripheral parts of the lungs on CT scans, which were compatible with changes seen in viral pneumonia. Using chest CT a comparative study on the clinical features of COVID-19 pneumonia to other pneumonias demonstrated by Zhao et al., (2020b) that fifteen (78.95%) non-COVID-19 but 4 (26.67%) of the non-COVID-19 patients had bilateral involvement while 17 (89.47%) non-COVID-19 but 1 (6.67%) non-COVID-19 patients had multiple mottling and GGO of chest CT images. A case report and potential application for a 52 years-old-man was evaluated in their emergency department (ED) because of fever, cough, asthenia, headache, myalgia and photophobia since one week (Buonsenso et al., 2020). Where chest X-ray showed a doubtful left peri-hylar hypodiafania while lung US showed, on the anterior and posterior hemi-thorax bilaterally, an irregular pleural line with small subpleural consolidations, areas of white lung and thick, confluents and irregular vertical artifacts (B lines and spared areas were present bilaterally, mixed with pathological areas while in lung US a normal pleural line with A lines regularly reverberating and only one, regular vertical artifacts (B line) noted in a single area compare to control 38 years-old-man US case.

A longitudinal study entitled temporal changes of CT findings in 90 patients with COVID-19 pneumonia done by Wang et al., (2020b), found that the predominant pattern of abnormalities after symptom onset was GGO 35/78 (45%) to 49/79 (62%) in different periods. The percentage of mixed pattern peaked 30/78 (38%) on illness days 12-17 and became the second most predominant pattern thereafter. Pure GGO was the most prevalent sub-type of GGO after symptom onset 20/50 (40%) to 20/28 (71%). The percentage of GGO with irregular linear opacity peaked on illness days 6-11 was 14/50 (28%)) and became the second most prevalent subtype thereafter. The distribution of lesions was predominantly bilateral and subpleural. 66/70 (94%) patients discharged had residual disease on final CT scans (median CT scores and zones involved four and four cases presents with GGO 42/70 (60%) and pure GGO 31/42 (74%) the most common pattern and subtype.

Chest X-ray showed multiple patchy shadows in both lungs as a result from the study entitled pathological findings of COVID-19 associated with ARDS made in China by Xu et al., (2020), using chest X-ray. Finding of COVID-19 from chest X-rays using deep learning on a small dataset for 135 chest X-rays of COVID-19 and 320 chest X-rays of viral and bacterial pneumonia in San Francisco by Hall et al., (2004). Their results were an overall accuracy of 90.7% with a COVID-19 true positive rate of 0.83 and an area under curve (AUC) of 0.987, pre-trained ResNet 50 (is one of the early adopters of batch normalisation) and VGG16 plus (is a built-in neural network in Keras) and their small CNN image classifiers were tuned or trained on a balanced set of COVID-19 and pneumonia chest X-rays. An ensemble of the three types of CNN classifiers was applied to a test set of 33 unseen COVID-19 and 208 pneumonia cases. The overall accuracy was 94.4% with the true positive rate for COVID-19 of 0.969 with 6% false positive for a true negative rate of 0.94 and AUC of 0.99. This preliminary study has flaws, most critically a lack of information about where in the disease process the COVID-19 cases were and the small data set

size. More COVID-19 case images at good resolution will enable a better answer to the question of how useful chest X-rays can be for diagnosing COVID-19.

Review of literature of chest CT findings of the 2019 novel coronavirus infections from Wuhan, China, done by Kanne (2020) determines key points for the radiologist, found that at chest CT GGO 86%, consolidation 29%, crazy paving 19%, linear 14%, bilateral distribution 76% and peripheral distribution 33%. Inui et al., (2020), studied chest CT findings in cases from the Cruise Ship "Diamond Princess" with COVID-19. They found that 41 of which had lung opacities on CT. Another 28 cases were symptomatic, 22 of which had abnormal CT findings. Symptomatic cases showed lung opacities and airway abnormalities on CT more frequently than asymptomatic cases (lung opacity; 22 versus 41, airway abnormalities; 14 versus 15). Asymptomatic cases showed more GGO over consolidation, while symptomatic cases more frequently showed consolidation over GGO. The CT severity score was higher in symptomatic cases than asymptomatic cases, particularly in the lower lobes between symptomatic versus asymptomatic cases; right lower lobe: left lower lobe: abnormal lung opacities (GGO and/or consolidation) and airway abnormalities (bronchiectasis and/or bronchial wall thickening) were present in 63 and 29 of the whole cohort, respectively. Lung opacities on CT were found in 41 of 76 asymptomatic. Twenty-two of 28 symptomatic cases had abnormal CT findings consistent with viral pneumonia. Comparing the two groups, symptomatic cases showed lung parenchymal and airway abnormalities on CT more frequently than did asymptomatic cases (symptomatic versus asymptomatic), lung opacity, airway lesion: asymptomatic cases with lung opacities on CT, 17 cases had pure GGO, 7 GGO with intra- and interlobular septal thickening without consolidation and 17 GGO with consolidation. Of 22 symptomatic cases who had lung opacities on CT, 5 cases had pure GGO, 4 GGO with intra- and interlobular septal thickening and without consolidation and 13 GGO with consolidation. In terms of the predominance of the lung parenchymal findings, asymptomatic cases showed GGO predominance over consolidation, while symptomatic cases were more likely to show a consolidation predominance over GGO (asymptomatic versus symptomatic cases; GGO predominance: 34 versus 13; consolidation predominance: 7 versus 9. In terms of the number of lesions, asymptomatic cases had a single lesion in 9 and more than 2 in 32 (78%) cases, compared to symptomatic cases, who had a single lesion in 4 and more than 2 in 18 cases. In terms of the axial distribution, more than half of the cases in each group showed a peripheral dominant distribution (24 asymptomatic versus 11 symptomatic cases). On the other hand, only asymptomatic cases (4 cases) showed a central dominant distribution with single or multiple rounded GGO in one or multiple lobes. Symptomatic cases were more likely to show a mixed distribution (coexisting peripheral and central distribution) than asymptomatic cases (11 symptomatic versus 13 asymptomatic cases).

In a study of four patients conducted in China by Xue et al., (2020), entitled lung US in the diagnosis and management of novel coronavirus pneumonia: Pearls and pitfalls, mention CT and US finding for each patient, multifocal, discrete, or confluent B lines, which were multiple vertical echogenic reverberation artifacts extending from the lung surface without attenuation. This was caused by the reverberation of the US beam between the slightly decreased alveolar air and increased interstitial fluids. Multiple focal B lines (≥3) usually appear in the early stage or mild type patients. Diffuse confluent B lines (waterfall sing) thickened pleural line. Similar to CT feature, this sign indicates pulmonary fibrosis. Small patchy of consolidation, occasionally with air bronchograms. This visualized on US as tissue-like hypoechoic region, which reflects the pathological process of highly reduced air and increased inflammatory cellular exudate. Pleural effusion. This is uncommonly seen in COVID-19 pneumonia. Chest CT shows multiple patchy GGO in the left peripheral lung. Lung US in the corresponding location reveals suspected B lines; Chest CT shows small patchy opacities in the right subpleural area deep to the rib. Lung US in the corresponding location reveals normal pleural line. Lesion might be obscured by coastal rib. Chest CT shows multiple subpleural consolidation and interlobular septal thickening in the bilateral peripheral lung. Lung US using a high frequency linear probe in the corresponding location shows tissue-like hypoechoic region representing a focal consolidation.

Fang et al., (2020), studied the sensitivity of chest CT for COVID-19: Compared to RT-PCR for 51 patients with chest CT and RT-PCR assay performed within 3 days they found that 50/51 patients had evidence of abnormal CT compatible with viral pneumonia at baseline while one patient had a normal CT. Of 50 patients with abnormal

CT, 36 had typical CT manifestations and 14 had a typical CT manifestations in this patient sample, the study concluded that the sensitivity of CT for COVID-19 infection was 98% compared to RT-PCR sensitivity of 71% (P<0.001).

Differences in clinical and imaging presentation of pediatric patients with COVID-19 in comparison with adults studied by Chen et al., (2020b). They found that pediatric patients had a lower rate of positive CT findings and a milder clinical grade (P=0.004, P=0.001), respectively. On chest CT, the number of the pulmonary lobes involved was reduced in pediatric patients when compared to adults (P=0.012). Subpleural distribution of lung opacities was a dominant feature in both groups, whereas bronchial distribution was more common in the pediatric group (P=0.048). Among the CT features in adults, GGO were the most common finding, followed by GGO by consolidation. In pediatric patients, GGO, bronchial wall thickening and GGO with consolidations and nodular opacities respectively. However, these CT features did not differ in two groups, except for bronchial wall thickening, which was more commonly found in pediatric patients. Additionally, the semi-quantitative scores of lung involvement were higher in adults than in pediatric patients. Compared with adults, pediatric patients had a lower rate of positive CT findings and milder clinical grade respectively. CT features did not differ in two groups, except for bronchial wall thickening, which was more common in pediatric patients.

Letter to the editor written by Poggiali et al., (2020a), asking can lung US help critical care clinicians in the early diagnosis of COVID-19 pneumonia? The answer after examining twelve patients (9 male and 3 female, mean age 63±13 years) using chest CT and US was a diffuse B-pattern with spare areas. Only three patients had posterior subpleural consolidations. A chest CT scan was performed in all twelve patients and showed a strong correlation with US, where bilateral lung involvement with GGO; five of twelve patients had a crazy-paving pattern was seen. Organizing pneumonia was confirmed in four patients as well as detected by lung US. Lin et al., (2020), for nine patients; 5 males (55.56%) and 4 females (44.44%), aged 9-57 years, with an average age of (34±17.85) studied the application value of lung US in asymptomatic patients with confirmed COVID-19 they found that two had abnormal findings in their lungs on US. One of these two showed localized pulmonary consolidation under the pleura in zone 6 of the left lung, just like “fragment” in this case, the sonographers applied for remote consultation during the US examination and obtained the final diagnosis through consultation. Another case showed a fusion B 3 line in zone 5 of the right lung (R5) The remaining seven cases (77.78%) showed no obvious abnormality, but only clear pleural sliding sign and A line in chest CT of an abnormal male patient. One showed GGO with thickened interlobular septal in the left lower lobe, involving the pleura, the other two (22.22%) showed a flocculent high-density shadow at the base of both lungs, especially in the right lung. Remaining six cases showed no abnormal manifestations on CT. The results of this study indicated that the sensitivity, specificity, positive predictive value, negative predictive value and Kappa value of the lung US in the diagnosis of asymptomatic patients with COVID-19 pneumonia, taking chest CT as the gold standard.

Abdominal pain: A real challenge in novel COVID-19 infection was a study done by Poggiali et al., (2020b), they found that all patients were investigated by bedside US, which showed a diffuse B-pattern, due to a severe loss of aeration, with spared areas with no pleural effusion; in six patients subpleural consolidation in the lower lobes was detected. Chest CT confirmed COVID-19 pneumonia with typical imaging signs of GGO, patchy consolidation and crazy-paving pattern, which were detected by lung US. An X-ray of the abdomen was performed in only one patient and was normal. US of the abdomen did not reveal an abnormal stomach and bowel distension, except in one female patient who had bowel inflammatory signs as confirmed by a CT scan of the abdomen. This patient completely recovered after antiviral treatment and was discharged home with no signs of bowel disease in the US of the abdomen.

Weinstock et al., (2020) analyzed chest X-ray findings in 636 ambulatory patients with COVID-19 presenting to an urgent care centre: A normal chest X-ray is no guarantee. Chest X-rays were reviewed among patients with confirmed COVID-19, 363 were male (57.1%) and 273 were female (42.9%). Patient ages ranged from 18 to 90 years of age, with most 493 (77.5%) patients being 30–70 years old. 265 abnormal cases (41.7%), 195 demonstrated mild disease, 65 demonstrated moderate disease and five demonstrated severe diseases. Interstitial changes and GGO were the predominant descriptive findings in 151 (23.7%) and 120 (18.9%) of the total, respectively. Location of the abnormalities were in the lower

lobe in 215 (33.8%), bilateral in 133 (20.9%) and multifocal in 154 (24.2%). Effusions and lymphadenopathy were uncommon. The vast majority of patients (566/636) had either normal or only mildly abnormal chest X-rays (89%), despite being symptomatic enough to warrant imaging as determined by the treating UC provider "interstitial changes and GGO were the predominant descriptive findings in 23.7% and 18.9% of the total, respectively. Location of the abnormalities were in the lower lobe in 33.8% of patients, bilateral in 20.9% and multifocal in 24.2%. Effusions and lymphadenopathy were uncommon.

Multicentre cohort study demonstrates more consolidation in the upper lungs on initial CT increases the risk of adverse clinical outcome in a COVID-19 patient's was done by Yu et al., (2020). In their study, the median age was 48 years and the male proportion was 53% (224/421). CT chest done during the follow-up period, 64 (15%) patients had a composite endpoint. There was an association of older age (odds ratio (OR), 1.04; 95% confidence interval (CI): 1.01-1.06; P=0.003), larger consolidation lesions in the upper lung (right: OR, 1.13; 95% CI: 1.03-1.25, P=0.01; Left: OR, 1.15; 95% CI: 1.01–1.32; P=0.04) with increased odds of adverse endpoints. There was an association of older age and larger consolidation in the upper lungs on admission with higher odds of poor outcomes in patients with COVID-19.

Liu et al., (2020b), focus on pregnant women and children by studding clinical and CT imaging features of the COVID-19 pneumonia. Totally 614 lesions were detected with predominantly peripheral and bilateral distributions in 54 (98%) and 37 (67%) patients, respectively. Pure GGO was the predominant presence in 94/131 (72%) lesions for the non-pregnant adults. Mixed consolidation and complete consolidation were more common in the laboratory-confirmed 70/161 (43%) and clinically diagnosed 153/322 (48%) pregnant groups than 37/131 (28%) in the non-pregnant adults (P=0.007, P<0.001). GGO with reticulation was less common in 9/161 (6%) and 16/322 (5%) lesions for the two pregnant groups than 24/131 (18%) for the non-pregnant adults (P=0.001, P<0.001). The pulmonary involvement in children with COVID-19 was mild with a focal GGO or consolidation. Twenty-three patients underwent follow-up CT, revealing progression in 9/13 (69%) at three days, whereas improvement in 8/10 (80%) at 6-9 days after initial CT scans.

A descriptive investigation study was done by Ma et al., (2020) and examined 76 children by using chest CT. On 7 (14%) of the 50 had no radiologic evidence of disease on chest CT. For the 43 patients who had abnormal CT findings, in addition to previously reported patterns of GGO (67%), local patchy shadowing (37%), local bilateral patchy shadowing (21%) and lesion location of lower lobes (65%). Other CT features include that an overwhelming number of pediatric patients had lesions in the subpleural area (95%) and 22 of the 28 lower lobe lesions were in the posterior segment (78%). Lesions in most of the 15 patients (67%) who received chest CT at discharge were not completely absorbed and 26% of these pediatric patients had CT lesions that were either unchanged or worse.

Li and Xia (2020) studied COVID-19 role of chest CT in diagnosis and management, in 51 patients with a diagnosis of COVID-19 infection confirmed by nucleic acid testing. The results of COVID-19 were misdiagnosed as a common infection in the initial CT study in two inpatients with underlying disease and COVID-19. Viral pneumonia was correctly diagnosed at the initial CT study in the remaining 49 patients with COVID-19 and 2 patients with adenovirus. These patients were isolated and obtained treatment. GGO and consolidation with or without vascular enlargement, interlobular septal thickening and air bronchogram sign are common CT features of COVID-19. The "reversed halo" sign and pulmonary nodules with a halo sign are uncommon CT features. The CT findings of COVID-19 overlap with the CT findings of adenovirus infection. There are differences as well as similarities in the CT features of COVID-19 compared with those of the severe acute respiratory syndrome. They concluded that chest CT had a low rate of missed diagnosis of COVID-19 (3.9%, 2/51) and may be useful as a standard method for the rapid diagnosis of COVID-19 to optimize the management of patients. However, CT is still limited in identifying specific viruses and distinguishing between viruses.

A single centre study in Shanghai, China, initiated by Cheng et al., (2020), identifies the clinical features and chest CT manifestations of COVID-19, their results mention the frequency of opacification in patients with positive results and patients with negative results, respectively, was as follows: GGO, 100% versus 90.9%; mixed GGO, 63.6% versus 72.7%; and consolidation, 54.5% versus 77.3%. In patients with positive RT-PCR results, GGO were the most commonly observed opacification (seen in 100.0% of patients) and were predominantly located in the

peripheral zone (100% of patients), compared with patients with negative results (31.8%) (P=0.05). The median number of affected lung lobes and segments was higher in patients with positive RT-PCR results than in those with negative RT-PCR results (5 versus 3.5 affected lobes and 15 versus 9 affected segments; P<0.05). Although the air bronchogram reticular pattern was more frequently seen in patients with positive results, centrilobular nodules were less frequently seen in patients with positive results.

Chen et al., (2020c), studied can chest CT features distinguish patients with negative from those with positive initial RT-PCR results for COVID-19? They found that most of the COVID-19 lesions were located in multiple lobes (67%) in both lungs (72%). The main CT features were GGO (95%) and consolidation (72%) with a subpleural distribution (100%). Otherwise, 33% of patients had other lesions around the Broncho vascular bundle. The other CT features included air bronchogram (57%), vascular enlargement (67%), interlobular septal thickening (62%) and pleural effusions (19%). Compared with that in the group with positive initial RT-PCR results, CT of the group with negative initial RT-PCR results were less likely to show pulmonary consolidation (P<0.05). The less pulmonary consolidation found at CT, the greater is the possibility of negative initial RT-PCR results. Chest CT is important in the screening of patients in whom disease was clinically suspected, especially those who have negative initial RT-PCR results.

Yin et al., (2020) investigated a mild type of childhood COVID-19 case report 9 years' childhood from China, chest CT on the first day after admission showed there was a cord shadow in the middle lobe of the right lung and no obvious abnormality was found in the remaining part of the lung. Chest CT images on the third and fifth days after admission showed no obvious changes in the bilateral lung.

CONCLUSION

This study concluded that radiological findings might be useful as a standard method for the rapid diagnosis of COVID-19 to optimize the management of patients. However, additional high-quality studies are needed to convince policy makers. In addition, it presents guidelines to help focus future research in this area. The most common signs in the chest CT when infected with COVID-19, are multifocal and GGO with consolidation. The distribution of the lesion has been always bilateral, peripheral and predominant affects lower lobes of the lungs, quickly spread to the centre and includes all the lungs. It was found that the middle lobe of the right lung is less injured than other lobes. Much more, the current review provides insight into the initial and follow-up imaging findings for the disease.

CONFLICT OF INTEREST

The authors have declared that the present study was performed in the absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

The authors contributed equally in all parts of the paper.

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