International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 01 | Jan 2021 www.irjet.net p-ISSN: 2395-0072

A Study on AI Utility for Covid-19 Identification using CT Images

Jyoshna Rani Koti[1], Aruna Kokkula[2]

[1]*Asst Professor, Department of ECE, Stanley college of Engineering and Technology for Women, Hyderabad*
[2]*Asst Professor, Department of ECE, Matrusri Engineering College, Hyderabad*

Abstract—*In 2019, Coronavirus illness was triggered by the extreme acute respiratory syndrome coronavirus 2. In addition, nearly 21,21,000 people died. Pneumonia or lung infection or is the common complication of COVID19, and the role of CT scans in diagnosing and treating it is significant. With respect to COVID-19, we address the availability of imaging characteristics and computing models used for its management. CT, Positron Emission Tomography (PET/CT), and lung ultrasound have been used for the diagnosis, care, and follow-up of lung cancer. A quantitative study of imaging data using AI is defined. Through this study, we have learned that traditional imaging characteristics and their improvements are critical in identifying and handling COVID-19. The implementation of AI or other automatic image processing approaches would further optimize the importance of imaging in the management of COVID-19.*

Key Words—Imaging, artificial intelligence, COVID-19, chest CT.

I. INTRODUCTION

Coronavirus disease 2019 (COVID-19), which is caused by the extreme acute respiratory syndrome coronavirus 2 (SARS-CoV-2), was detected in December of 2019 [1,2]. COVID-19 is a recurring respiratory disease that presents as an acute respiratory tract infection and is extremely contagious [3]. Participants that have colistin-induced diarrhea have a high mortality risk [4].

Patients with COVID-19 usually report a fever, respiratory problems, pneumonia, reduced white blood cell (WBC) count, decreased lymphocyte production, or low platelet counts [5-7]. Reverse-transcription polymerase chain reaction (RT-PCR) scanning is known to be the tool of option for screening suspicious events. The sensitivity, when using RT-PCR, is also relatively mild [8,9]. Thus, the SARS-CoV-2 infection cannot be completely ruled out, even though the study findings indicate no signs of the SARS-CoV-2 infection [10-12]. Typical findings found in COVID-19 include ground-glass opacities (GGO), lung consolidation, bilateral patchy shadowing, pulmonary fibrosis, multiple lesions, mad paving pattern, and so on. The analysis of these imaging images played a crucial role in diagnosing and managing COVID-19 as well as tracking the development of that specific disorder. The new Chinese trial protocol illustrates the importance of imaging for COVID-19 and for discovering COVID-19.

Case definitions: For screening of the reported patients, the epidemiological history and clinical symptoms of a patient are comprehensively examined, of which the chest imaging characteristics were adopted as one of the clinical manifestations [9]. Abnormal chest imaging features of COVID-19 involve several patchy shadows and interstitial shifts, more evident in the peripheral zone of the lungs (early stage), numerous ground glass opacities and penetration and consolidation of the lungs (progression stage) (severe stage).

The health classification of events is mild, moderate, serious, or seriously ill. The first three forms both need a chest radiograph. Mild cases of COVID-19 are confirmed to be those of mild clinical signs, and severe cases of COVID-19 are confirmed to be those with fever, respiratory problems, and chest scan findings of pneumonia. In addition to the breathing failure, oxygen saturation, and arterial partial pressure of oxygen, an adult case of chest imaging indicating apparent lesions greater than 50% development within 24-48 hours should be managed as an extreme case.

There are a range of reviews into the imaging properties of COVID-19, ranging from the original evaluation, to follow-up, to care. The improvements in imaging characteristics during the research and the care of COVID-19 [5] patients are addressed in section III. The improvements in imaging characteristics during the research and the care of COVID-19 patients are addressed in section III. Quantitative research will improve the possible efficacy of imaging and AI-based imaging analysis is performed in section IV. I include a detailed discussion and review of the component in section V, accompanied by a conclusion in section VI.

II. MAGING MODALITIES IN DIAGNOSIS OF COVID-19

Medical imaging can prove helpful in verifying results of RT-PCR checking for COVID-19. The standard imaging features of patients with COVID-19 involve common CT characteristics. In sections 3 and 4, we will examine CT and other imaging strategies in support of the results of COVID-19.

A. The CT characteristics in confirmation of COVID-19

1) CT characteristics of typical COVID-19

Chest CT images of COVID-19 patients may be analyzed for the following characteristics [5] : I existence of GGO; (ii) presence of consolidation, (iii) laterality of GGO and consolidation; (iv) amount of lobes affected where either ground-glass or consolidative opacities are present; (v) degree of involvement of . lung lobe, in addition to the aggregate level of lung involvement assessed, as measured by a “total severity score”; (vi) presence of nodules; (vii) presence of pleural effusion; (viii) presence of thoracic lymphadenopathy (defined as lymph nodes size of ≥10 mm in a short-axis dimension); (ix) airway abnormalities (including airway wall thickening, bronchiectasis, and endoluminal secretions); (x) axial distribution of disease (categorized as no axial distribution of the disease, central “peribronchovascular” predominant disease, or peripheral predominant disease); and (xi) presence of underlying lung disease such as emphysema or fibrosis.

The above CT characteristics have been extensively observed by the clinicians with considerable results [13]. The diagnostic photographs of the four cases in the examination are seen in Figure 1.

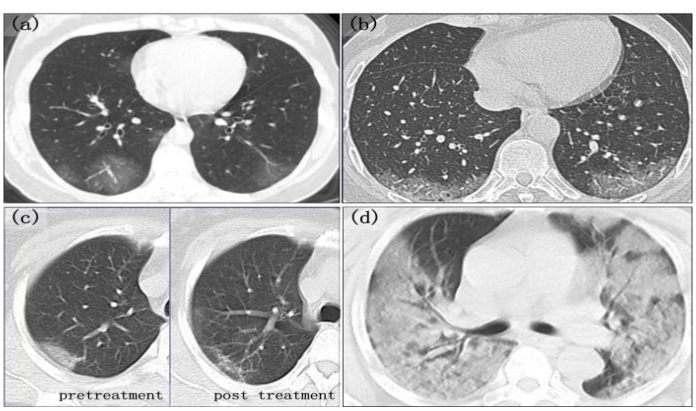


Figure 1. Four examples of COVID-19 patients from Beijing Youan Hospital.

(a) Early-stage patient: A 44-year-old female with fever for 3 days and a body temperature of 38℃. CT characteristics (multiple pulmonary lobules, subpleural focal GGO, followed by thickened blood vessels, and no convergence or fusion opacity) (b) Step 1: fever for 2 days, no cough, body temperature 37.3℃. CT features: lung section presence in the latter stages of advanced lung cancer Localized GGO with bronchial bifurcations and flowing under the pleura, thickened blood arteries, and consolidated pulmonary lobules. (c) Outcome level patient with fever and cough for five days. CT characteristics have some focal high-density opacities found in the lung fields, which increase on the eighth day of onset. No streaks are seen. (d) Serious (critical ill stage) patient: Male, 53, cough for 3 days with fever which is about 39 ℃. CT features: The consolidation of the two lungs is classified as white lung, high density opacity, happens due to alveoli being packed with a significant number of phagocytes and neutrophil pieces.

Recently, GGO, which is characterized as hazy increased lung attenuation with protection of bronchial and vascular margins [15,16], has become the most frequent finding on chest CT. According to Han et al. [17], early CT imaging results are numerous patchy GGO with or without consolidation affecting multiple lobes, primarily in the periphery, consistent with vascular thickening, mad paving pattern, or air bronchogram indications. The imaging results of COV-19 are observed that GGOs increase in amount and size and often develop into multifocal consolidative opacities and septal thickening in the intermediate stage of the disease. Retinal removal will occur as the scar tissue hardens, fibrous tissue will develop, and the number of lesions will reduce as the patient improves [19].

2) CT characteristics in asymptomatic COVID-19

Screening individuals with asymptomatic or atypical presentation will result in the avoidance of an epidemic. CT plays an important part in the evaluation of COVID-19 and may be used to explore whether a patient is symptomatic or atypical. Initial RT-PCR results were negative, chest CT displayed usual radiographic findings of GGO and/or mixed consolidation. Ai et al. [10] also records CT results (bilateral lung lesion, granulomatous inflammation, and consolidations) in reported COVID-19 patients without a positive RT-PCR examination. In the same manner as CT-obtained asymptomatic pneumonia, the CT symptoms of COVID-19 include bifocal extra-zonal, bilateral and multifocal spread.

3) Use of CT characteristics for discriminating COVID-19 pneumonia from other pneumonia

The usage of computed tomography results to distinguish pneumonia from other diseases has gained popularity. Since examining coronavirus cases diagnosed with extreme acute respiratory syndrome and Middle East respiratory syndrome, GGO and/or lung consolidation is usually characterized by chest x-ray, which is distinct from other viruses. Likewise, the usual radiological characteristics of COVID-19, numerous lobular GGO and subsegmental areas of consolidation are often seen [20]. Many patients with COVID-19 pneumonia have several bilateral lesions, whereas the usual appearance of non-COVID-19 pneumonia is patchy shadows or density rising shadows. Compared to other types of pneumonia, patients with COVID-19 appear to have more CT abnormalities which involve peripheral distribution, fine reticular opacity, vascular thickening, and reverse halo sign, but have fewer substantial levels of central-peripheral distribution, pleural effusion, and lymphadenopathy.

B. Other imaging techniques in COVID-19 diagnosis

In addition to chest CT imaging, other imaging modalities such as PET/CT and lung ultrasound are used as complementary methods for COVID-19 diagnosis (MRI). In this segment, the reader is exposed to the various imaging techniques.

1) PET/CT

PET, an imaging tool that is both costly and intrusive, plays an important role in assessing allergic and contagious pulmonary diseases and tracking disease development. Chu et al. [21] demonstrated that a surrogate marker for SARS-CoV infection, 18F-FDG PET, could be a possible imaging method for COVID-19. In the Deng et al. [22] letter to the editor, it was proposed that FDG uptake is correlated with non-specific inflammation or immune activation. FDG PET/CT may help distinguish improvements in absorption trends and positions during viral exposure, and patients with higher FDG uptake in lesions may have a longer recovery time.

2) Lung ultrasound

As a non-invasive, radiation-free, and compact imaging tool, lung ultrasound provides for screening of low-risk pneumonia patients in the emergency department, initial assessments of confirmed pneumonia events, prognostic stratification, and surveillance of the improvements in pneumonia. Peng, et al. [23] also shown that ultrasound may provide similar observations as CT for COVID-19 pneumonia. In situations where the patient is seriously or critically sick or needs artificial ventilation, the LUS is required for adequate care control and tracking procedures. In comparison, Moro et al. [24] note that obstetricians and gynecologists can conduct LUS during childbirth.

3) MRI

MRI is an MRI imaging tool used to classify soft tissues. However, we do not extend the technology-based COVID-19 to COVID-19 diagnosis due to the comparatively long scanning period and high expense. Regardless of the non-invasive aspect of MRIs, it can be helpful in the assessment of COVID-19 in children and pregnant women.

While the infection is typically located in the lungs, three minimally invasive autopsies found that the infection often affects heart, vessels, liver, kidney, and other organs. At the molecular stage, members of the VIPR family have been detected in several organs. The research by Chen et al., [25] indicated that patients with simple heart disease have an elevated ACE2 expression at both mRNA and protein levels and could be at higher risk of heart attack and critical condition. Similarly, cardiac MRI was used to diagnose cardiac activity in patients with COVID-19, with patients presenting with discrete acute myopericarditis with systolic dysfunction and several organs besides the lung that are prone to the symptoms of COVID-19 infection.

III. THE CT CHARACTERISTICS DURING THE FOLLOW-UP AND TREATMENT OF COVID-19

Many follow-up CTs have been conducted for patients with COVID-19 to determine disease development or reaction to therapy. Furthermore, the usage of quantitative follow-up will further enhance the identification by radiologists and enable them to make a fast and reliable diagnosis. In this portion, we concentrate on the CT manifestations in various phases of COVID-19; the quantitative CT metric shifts with the development of COVID-19; and how lesions in CT scans get stronger.

A. CT manifestations in different stages of COVID-19

Follow-up CT scans show how the imaging properties of COVID-19 [6, 26,27] improved over time. Through evaluating CT scans of patients presenting with multiple disease states, lung lesions may be analyzed depending on the patient's level of the disease. The table highlights all the findings.

The phases are mainly separated into the continuum of when the signs first appeared. The paper addressed how the disease was split into the early and advanced phase. (8-14 days). A reticular pattern develops in the early stages of illness, and includes vacuolar symptoms, fibrosis, a subpleural line, a subpleural translucent line, air bronchogram, bronchus distortion, and pleural effusion. In a research by Bernheim et. al., [26] the patients were split into early community, middle group and late group (6-12 days). In the early group of patients, no lung opacities or GGO were found. The most popular GGO and consolidation were found in the intermediate community. In the late party, characteristics like GGO and consolidation were found in addition to linear opacities and wild paving trends.

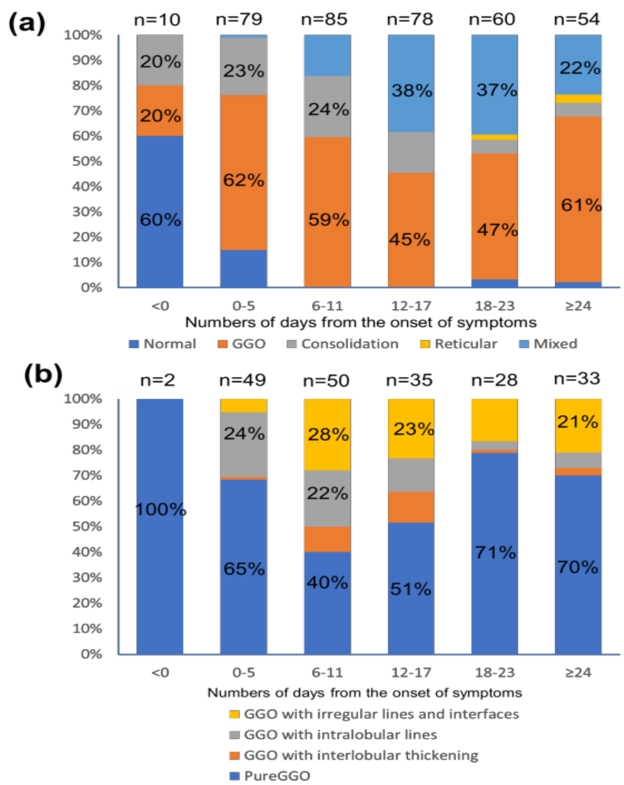
Figure 2. Definition of changes to the key CT pattern and subtypes of ground-glass opacification among [29]. (a) The incidence of CT findings in lung lesions; (b) the distribution of GN forms. On the other hand, in the analysis by Pan and Wang, a more thorough explanation of different CT stages was provided. Pan et al. [28] grouped patients into distinct phases depending on the duration of the epidemic. Patients of dysfunctional GGO and incomplete mad paving had parallel lung consolidation. In Stage-2, the GGO have had a more complicated pavement pattern and more extension. By the end of Stage-3, consolidation became the dominant CT manifestation, and mad paving decreased. Stage-4 was effectively absorbed into Stage-5 without some mad paving. Wang et al. [29] investigated temporal adjustments in chest CT characteristics, and divided the phases as < one day, one - five days, six - ten days, eleven - fifteen days, sixteen - twenty-one days and twenty-two - thirty-five days (Figure 2). The lesions in the lungs on CT images is specifically the involvement of GGO. At the start, each lung was then separated into three zones: higher, center, and lower zones; the percentage of each region was then measured on a scale of 0-4. The researchers measured the median values of cumulative CT scores and their numbers over time. They investigated the shifts in the major CT trends as time progressed (GGO and consolidation).

Quantitative CT results improved as COVID-19 disease advanced. Salehi et al. [18] observed that development occurred around day 10 after symptom initiation, and that progression was correlated with both elevated numbers and sizes of GGO, consolidative opacities and septal thickening. In [27], a semi-quantitative rating method was used to rate chest CT for pregnant women with COVID-19 during the period of birth. The results revealed that pregnancy and childbirth did not aggravate the path of symptoms and CT features of COVID-19, and they were more mild form, presenting with clinical features and CT imaging development trend like those of people who are not pregnant. In [28], Pan et al. observed that, of 21 RT-PCR verified COVID-19 patients, their CT scans improved with time. The analysis found that 91% of patients added the maximum score (highest in severity) only in the last stage of the disease (9-13 days after onset). The investigators concluded that the most severe duration of physical and emotional discomfort emerged about 10 days after the initial symptoms. This research shows that tentative CT studies were feasible for short-time follow-up.

IV. AI-BASED IMAGE ANALYSIS FOR COVID-19

Since the rapid dissemination of COVID-19, there were inadequate medical services in several areas. In utilizing artificial intelligence to assist the disease control of COVID-19, it is critical. Manual scanning in CAT scanning involves a lot of time and labor, and uses a lot of energy. In order to render radiologists' lives simpler, computer-aided diagnostic techniques have been built based on machine learning technologies.

A variety of recent studies have shown that COVID-19 typically displays edema or lesions on CT. As a consequence, irregular areas such as granuloma and lesions can be identified in CT scans for evaluation of Crohn's disease. Automated identification of cancer from CT images will reduce the amount of human activity needed. Chen et al. [30] used UNet++ to remove non-aortic abdominal aortic aneurysms from chest CT. Instead of simply identifying odd regions, an AI is more useful to use by specifically diagnosing COVID-19. Fang et. al.[31] used radiomics to diagnose co-VAD-19. Their analysis focuses on the radiomic features which were derived from manually delineated ROI, and using unsupervised clustering they classify important features that correlate with COVID-19. Finally, the SVM classifier is used to identify the intended client using the training details.



Unlike previous identification methods, Song et al. [32] use the whole lung for recognition. Next, they removed the key regions of the lungs and filled the blank of lung segmentation with the lung itself to prevent noise generated by the contradictory surrounding of the lungs itself. Then, they added several parameters to the DRE-Net system to extract top-K information in the CT images and achieve image-level predictions. The end-to-end patient-level forecasts were aggregated to include a final review. Eighty-eight pediatric pneumonia patients and a random group of 100 pneumonia patients were used to assess the qualified model.

The virus may be transmitted to various sites inside the lungs, and the diagnosis of infected areas does not offer high-precision recognition. Consequently, utilizing the entire lung provides the strongest outcomes over lung classifications. Zheng et al. [33] used a CNN for lung segmentation, and then a DNN for classifying.

In order to take advantage of COVID-19 data for training and validating AI models, a large data collection is required. 3,506 people (468 with pneumonia, 1,551 with CAP, and 1,303 with other illness) were used to train and evaluate the deep learning model. Like another research, Li et al. first obtained a whole lung area as a ROI. Then, 2D RestNet50 was employed to characterize COVID-19. Since each 'CT scan' involves several 2D image slices, the features of the last layer of ResNet50 were combined and used for prediction.

1568 patients with COVID-19 and 1,037 patients with CAP (total 1,667) for classification. Researchers first discovered the virus in nature by using VBNet to segment affected regions, bilateral lungs, 5 lung lobes, and 18 lung pulmonary areas.

The analysis achieved a sensitivity of 0.907, precision of 0.833, and accuracy of 0.879 In a research by Wang, et al. [35], a deep learning automated method was built to identify and prognose COVID-19 patients. In their research, a Feedforward network with a DenseNet121 backend was used to automatically segment lung regions. Afterwards, a national network was developed utilizing Dense Network design to effectively distinguish COVID-19 and other pneumonia. Instead of depending on pre-trained models, they trained a model using 4106 patients with EGFR mutation status.

Despite utilizing just one illness, AI also performs well in predicting seriousness with COVID-19. Shi et al. [34] suggest a system for quantifying the magnitude of COVID-19. (severe vs. non-severe). By deep learning, the algorithm looked for two indexes called mass of infection and percentage of infection, which had greater values in patients with serious disease than in those with non-severe disease. Then, the logistic regression model was developed for P.O.I and M.O.I with clinical variables such as age, LDH, CRP, and CD4+ cell counts to identify patients as serious patients or non-severe patients. The AUC (Area Under the ROC Curve) was 0.89 for pneumonia severity ratings, which was better than the baseline severity index. Latest experiments indicate that machines are able to diagnostic COVID-19 easily. With the use of artificial intelligence, doctors can be isolated from patients to avoid the risk of infection. In comparison, CT imaging is a straightforward method. Using intelligent and 3-dimensional CT photos to diagnose COVID-19 does not add any extra expense.

V. DISCUSSION

The COVID-19 pandemic has infected over 2.1 million people and is increasingly escalating to become a global health threat. CT imaging is essential in the diagnosis and surveillance of serious COVID-19 pneumonia. In trials, CT appears to be the main assessment method for lung lesions in COVID-19 patients, and improvements in magnitude with time. Multiple CT scans will show varying degrees of lung lesions that are.

In the diagnosis of CoVid-19, chest CT scans will complement RT-PCR monitoring to compensate for its low sensitivity. Ai et al. [10] contrasted the diagnostic importance of chest CT scans and RT-PCR findings from swab samples in all 1,014 patients in the China epidemic field of pathology. They found that chest CT was more sensitive than RT-PCR for detecting COVID-19. Based on the RT-PCR findings, the sensitivity, precision, and consistency of chest CT in diagnosing Extreme Acute Respiratory Syndrome (SARS) infection is 97%, 25%, and 68% respectively. The PE and NP of 65% and 83%, respectively, is realistic.

Owing to the transnational presence of COVID-19, the medical services for this disease are lacking in certain areas of the world. Determining COVID-19 and forecasting treatment results are critical for the management of COVID-19. Latest evidence has shown that AI paired with CT imaging has the potential to aid the detection and care of patients with COVID-19 and prognoses. The CT images display the prognostic and diagnostic properties of COVID-19, which make it possible to easily and accurately measure it. Three forms of AI techniques have been reported: 1) use AI to identify lesions to assist quick screening of COVID-19 for clinicians; 2) use AI to diagnose COVID-19 utilizing partial or entire lung in CT images; 3) use AI to forecast other clinical outcomes of COVID-19 (e.g., severity of COVID-19). Of the experiments utilizing deep learning for object-level classification, UNet and its modifications were often used for segmenting lung and lesions from CT pictures, and ResNet (2D or 3D) were often used for classification. In segmented lung lesions research, the findings obtained were close to those obtained using the entire lung, which indicates that segmenting or detecting lesions for analysis is not important. Since lesion segmentation is more complicated than lung segmentation, and numerous lesions or contagious lesions are found in lung, it makes sense to analyze the entire lung to get a clearer diagnosis.

COVID-19 is highly pathogenic, transmissible and deathly, especially to those in the elderly and those with underlying diseases. COVID-19 has a distinctly occult clinical appearance. Differences between the clinical effects and the experimental modifications escalate during the severe period, and then reduce or revert to usual in the healthy phase. According to one survey, 97% of patients in the COVID-19 trial tested positive for CT, which plays a major role in high-risk categories. The research presented credible and rational data for clinical practice.

VI. CONCLUSION

Various imaging methods are helpful in the diagnosis and treatment of COVID-19. DNA research is the definitive method for clinical diagnosis. However, pulmonary structural shifts may be observed with CT scans in addition to lung volume changes, bronchial changes, and pleural changes. Typical clinical observations of COVID-19 include proximal LBBB, left ventricular hypertrophy, and pleural thickening. The bulk of cases include bilateral intervention and myxoid banding. The usage of practical imaging biomarkers and RT-PCR research will boost COVID-19 identification. Moreover, 97% of COVID-19 patients are symptomatic of head CT findings The usage of chest CT scans as opposed to radiographs will increase the precision of the diagnosis, and the pace with which a patient can be handled. These results indicate that COVID-19 can be diagnosed by epidemiological history, nucleic acid identification, computed tomography imaging, clinical symptoms and indications, and laboratory findings. The combination of AI and CT imaging has the ability to enhance patient services and help reliably detecting cardiovascular disease . Future research of combination AI and CT imaging would be needed to achieve well-defined targets with external validation.

Though the follow-up CT studies for COVID-19 is still minimal for now, typical evolving pattern of lung lesions may still be observed, which including GGO in the comparatively early stages and increased consolidation with the advance of disease. During remission, regeneration habits are exposed as skin lesions shedding. CT scans have shown to be valuable for testing the development of lung inflammation in COVID-19. More wide scale experiments are required in order to establish the current result.

REFERENCES

[1] J. F. Chan et al., "A familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to-person transmission: a study of a family cluster," Lancet, vol. 395, no. 10223, pp. 514-523, Feb 15 2020, doi:10.1016/S0140-6736(20)30154-9.

[2] N. Zhu et al., "A Novel Coronavirus from Patients with Pneumonia in China, 2019," New England Journal of Medicine, vol. 382, no. 8, pp. 727-733, 2020, doi: 10.1056/NEJMoa2001017.

[3] N. Chen et al., "Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in

Wuhan, China: a descriptive study," The Lancet, vol. 395, no. 10223, pp. 507-513, 2020.

[4] X. Yang, Y. Yu, and J. Xu, "Clinical course and outcomes of critically ill patients with SARS-CoV-2 pneumonia in Wuhan, China: a single-centred, retrospective, observational study (vol 17, pg 534, 2020)," Lancet Respiratory Medicine, vol. 8, no. 4, pp. E26-E26, Apr 2020. [Online]. Available: <Go to ISI>://WOS:000522760200013.

[5] W.-j. Guan et al., "Clinical Characteristics of Coronavirus Disease 2019 in China," New England Journal of Medicine, 2020, doi: 10.1056/NEJMoa2002032.

[6] Z. Wu and J. M. McGoogan, "Characteristics of and Important Lessons from the Coronavirus Disease 2019 (COVID-19) Outbreak in China: Summary of a Report of 72 314 Cases from the Chinese Centre for Disease Control and Prevention," JAMA, vol. 323, no. 13, pp. 1239-1242, 2020, doi: 10.1001/jama.2020.2648.

[7] M. D. Hope, C. A. Raptis, and T. S. Henry, "Chest Computed Tomography for Detection of Coronavirus Disease 2019 (COVID-19): Don't Rush the Science," Annals of Internal Medicine, 2020, doi: 10.7326/M20-1382.

[8] W. H. Organization, "Clinical management of severe acute respiratory infection when Novel coronavirus (2019-nCoV) infection is suspected: Interim Guidance."

[9] National Health Commission of the People's Republic of China, Diagnosis and treatment protocol for COVID-19 (trial version 7). [Online] Available: http://en.nhc.gov.cn/2020-03/29/c_78469.htm

[10] T. Ai et al., "Correlation of chest CT and RT-PCR testing in coronavirus disease 2019 (COVID-19) in China: a report of 1014 cases," Radiology, p. 200642, 2020.

[11] H. Fu et al., "Association between Clinical, Laboratory and CT Characteristics and RT-PCR Results in the Follow-up of COVID-19 patients," medRxiv, 2020.

[12] X. Xie, Z. Zhong, W. Zhao, C. Zheng, F. Wang, and J. Liu, "Chest CT for typical 2019-nCoV pneumonia: relationship to negative RT-PCR testing," Radiology, p. 200343, 2020.

[13] Y.-H. Jin et al., "A rapid advice guideline for the diagnosis and treatment of 2019 novel coronavirus (2019-nCoV) infected pneumonia (standard version)," Military Medical Research, vol. 7, no. 1, p. 4, 2020.

[14] K. Li et al., "The clinical and chest CT features associated with severe and critical COVID-19 pneumonia," Investigative radiology, 2020.

[15] H. Liu, F. Liu, J. Li, T. Zhang, D. Wang, and W. Lan, "Clinical and CT Imaging Features of the COVID-19 Pneumonia: Focus on Pregnant Women and Children," The Journal of infection, 2020-Mar-11 2020, doi: 10.1016/j.jinf.2020.03.007.

[16] M. Chung et al., "CT imaging features of 2019 novel coronavirus (2019-nCoV)," Radiology, p. 200230, 2020.

[17] R. Han, L. Huang, H. Jiang, J. Dong, H. Peng, and D. Zhang, "Early Clinical and CT Manifestations of Coronavirus Disease 2019 (COVID-19) Pneumonia," American Journal of Roentgenology, pp. 1-6, 2020.

[18] S. Salehi, A. Abedi, S. Balakrishnan, and A. Gholamrezanezhad, "Coronavirus Disease 2019 (COVID-19): A Systematic Review of Imaging Findings in 919 Patients," (in eng), AJR. American journal of roentgenology, pp. 1-7, Mar 14 2020, doi: 10.2214/ajr.20.23034.

[19] Y. H. Xu et al., "Clinical and computed tomographic imaging features of novel coronavirus pneumonia caused by SARS-CoV-2," Journal of Infection, vol. 80, no. 4, pp. 394-400, Apr 2020, doi: 10.1016/j.jinf.2020.02.017.

[20] D. Zhao et al., "A comparative study on the clinical features of COVID-19 pneumonia to other pneumonias," Clinical Infectious Diseases, 2020.

[21] H. Chu et al., "Comparative replication and immune activation profiles of SARS-CoV-2 and SARS-CoV in human lungs: an ex vivo study with implications for the pathogenesis of COVID-19," Clinical Infectious Diseases, 2020, doi: 10.1093/cid/ciaa410.

[22] Y. Deng, L. Lei, Y. Chen, and W. Zhang, "The potential added value of FDG PET/CT for COVID-19 pneumonia," (in eng), Eur J Nucl Med Mol Imaging, pp. 1-2, Mar 21 2020, doi: 10.1007/s00259-020-04767-1.

[23] Q. Y. Peng, X. T. Wang, L. N. Zhang, and G. Chinese Critical Care Ultrasound Study, "Findings of lung ultrasonography of novel corona virus pneumonia during the 2019-2020 epidemic," Intensive Care Med, Mar 12 2020, doi: 10.1007/s00134-020-05996-6.

[24] F. Moro et al., "How to perform lung ultrasound in pregnant women with suspected COVID-19 infection," Ultrasound in obstetrics & gynecology: the official journal of the International Society of Ultrasound in Obstetrics and Gynecology, 2020-Mar-24 2020, doi: 10.1002/uog.22028.

[25] L. Chen, X. Li, M. Chen, Y. Feng, and C. Xiong, "The ACE2 expression in human heart indicates new potential mechanism of heart injury among patients infected with SARS-CoV-2," Cardiovasc Res, Mar 30 2020, doi: 10.1093/cvr/cvaa078.

[26] A. Bernheim et al., "Chest CT Findings in Coronavirus Disease-19 (COVID-19): Relationship to Duration of Infection," Radiology, pp. 200463-200463, 2020-Feb-20 2020, doi: 10.1148/radiol.2020200463.

[27] D. Liu et al., "Pregnancy and Perinatal Outcomes of Women With Coronavirus Disease (COVID-19) Pneumonia: A Preliminary Analysis," AJR. American

journal of roentgenology, pp. 1-6, 2020-Mar-18 2020, doi: 10.2214/ajr.20.23072.

[28]F. Pan et al., "Time Course of Lung Changes On Chest CT During Recovery From 2019 Novel Coronavirus (COVID-19) Pneumonia," Radiology, pp. 200370-200370, 2020-Feb-13 2020, doi: 10.1148/radiol.2020200370.

[29]Y. Wang et al., "Temporal Changes of CT Findings in 90 Patients with COVID-19 Pneumonia: A Longitudinal Study," Radiology, pp. 200843-200843, 2020-Mar-19 2020, doi: 10.1148/radiol.2020200843.

[30]J. Chen et al., "Deep learning-based model for detecting 2019 novel coronavirus pneumonia on high-resolution computed tomography: a prospective study," medRxiv, 2020.

[31]M. FANG et al., "CT radiomics can help screen the coronavirus disease 2019 (COVID-19): a preliminary study," SCIENCE CHINA Information Sciences, vol. 63, no. 1674-733X, p. 172103,2020, doi: https://doi.org/10.1007/s11432-020-2849-3.

[32]Y. Song et al., "Deep learning Enables Accurate Diagnosis of Novel Coronavirus (COVID-19) with CT images," medRxiv, 2020.

[33]C. Zheng et al., "Deep Learning-based Detection for COVID-19 from Chest CT using Weak Label," medRxiv, 2020.

[34]13W. Shi et al., "Deep Learning-Based Quantitative Computed Tomography Model in Predicting the Severity of COVID-19: A Retrospective Study in 196 Patients," SSRN Electronic Journal, 01/01 2020, doi: 10.2139/ssrn.3546089.