ORIGINAL RESEARCH ARTICLE

Role of Artificial Intelligence in Quantification of Covid 19 Pneumonia

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ABSTRACT

Introduction: The novel coronavirus disease 2019 (COVID-19) is a rising international chance to public health. While chest computed tomography (CT) plays an indispensable role in its diagnosis, it is not possible to evaluate the exact location and quantify the lesions manually.We used Artificial intelligence based software to facilitate the detection, location and quantification of COVID-19 pneumonia. Asymptomatic patients may also have lung lesions on imaging. CT Pneumonia analysis software tool has been employed to facilitate CT diagnosis in our study. The study was aimed to measure the severity of lung/lobe involvement, quantify both the extent of COVID-19 infection and presence of high opacities by using the CT pneumonia analysis software.

Material and methods: A prospective study of 100 RT-PCR tested SARS-CoV-2-positive patients was done at Department of Radiodiagnosis in KRHospital attached to Mysore Medical College and Research Institute, Mysore, India for duration of 3 months from 1st July 2020 to 30stSeptember 2020. Each patient was subjected to High Resolution CT (HRCT) and CT Pneumonia analysis software tool (AI) designed by Siemens Healthineers was employed to evaluate the results. The results were tabulated and evaluated descriptively by Microsoft Excel 2016 and presented in figures, tables, frequency graphs and pie charts.

Results: Among the CT scan of 100 patients, 90 patients (90%) showed multiple lesions of which 1(1%) patient had left lung infection and 2 (2%) patients hadright lung infection (> 50% of each affected lung's volume), while 20 (20%) patients had total lung infection (> 50% of the totalvolume of both lungs). Among the 100 patients, 12(12%), 32 (32%) and 53 (53%) patients had pure ground glass opacities (GGOs), GGOs with sub-solid lesions and GGOs with both sub-solid and solid lesions, respectively. However, 94 (94%) and 3 (3%) patients had primarily presented with GGOs and sub-solid lesions, respectively. Elderly patients (≥ 60 years) were more likely to show solid and sub-solid lesions than the younger patients. The superior segment of lower lobe of right lung was the preferred site of COVID-19 pneumonia. Among the 100 patients in our study, 61 (61%) patients had mild CT severity score which was obtained from the percentage of opacity in each lobe provided by the CT pneumonia analysis software tool.

Conclusion: Chest CT combined with CT pneumonia analysis software can precisely assess pneumonia in COVID-19 patients. CT has high demonstrative sensitivity in identifying lesions, but not particular for Covid-19 and other infectious viral diseases, hence it is required to have an artificial intelligence software that provides objective assessments of the percentage of ventilated lung parenchyma compared to the affected one.

Keywords: 2019 Novel Coronavirus, Viral Pneumonia, CT Pneumonia Analysis, Artificial Intelligence (AI), High Resolution Computed Tomography (HRCT), Ground Glass Opacity (GGO)

INTRODUCTION

On December 30, 2019, a report showing a group of patients with pneumonia of unknown etiology in Wuhan City, Hubei Province, China had been published on ProMED-mail.[1] It was conceivably related to contact with a local fish and wild animal market (Huanan Seafood Wholesale Market), where there was also sale of live animals. In depth sequencing analysis from lower respiratory tract samples indicated a novel coronavirus, which was named 2019 Novel coronavirus (2019-nCoV) by world health organisation.[2] In the absence of specific therapeutic drugs or vaccines for coronavirus disease 2019 (COVID-19), it is fundamental to identify the disease early and quickly isolate the infected individual from the healthy population.

Unenhanced chest CT may be considered for early diagnosis of viral disease. At present, real-time reverse-transcription–polymerasechain-reaction (real-time RT-PCR) is the standard method used to make a definitive diagnosis of SARS-CoV-2 infection.[3]

The bilateral distribution of ground glass opacities (GGO) with or without consolidation in posterior and peripheral lungs was the cardinal trademark of COVID-19.[4] However, with further analysis of increase in cases, a variety of interesting CT imaging features were found, including crazy paving pattern,

airway changes, reversed halo sign and more.[5,6]

Li et al. had reported initial experiences of artificial intelligence (AI)-based tools to diagnose COVID-19 pneumonia on radiological images.[7]

A number of solutions presented in the literature are given in references.[8-14] In a very recent development, Chagantiet. al.[14] has developed an AI based algorithm developed for the Pneumonia Analysis from CT images that provides standardized scoring system of Lung severity score (LSS). Apart from the LSS, algorithm also gives percentage of high opacity (PHO) lesions and it has been validated on significantly large scale of training/test data. This algorithm has been further incorporated into a CT Pneumonia analysis prototype and provided to Syngo.via users as CT Pneumonia Analysis Research tool by Siemens Healthineers. The utility of this tool has not been measured in hospital settings with different types of COVID-19 cases.

In the present Study, the CT pneumoniaAnalysis software, Artificial intelligence software, was used to automatically extract and analyze regions suspected to be infected with the virus. The distribution and volume of infection in the lungs, as well as the CT features of COVID-19, were assessed and it subsequently predicts the CT severity scoring system based on the percentage provided in the automated analysis software tool.

MATERIAL AND METHODS

A prospective study was done at Department of Radio-Diagnosis in K R Hospital attached to Mysore Medical College and Research Institute, Mysore, India for duration of 3 months from 1stJuly 2020 to 30th September 2020. Institute Ethics Committee approval was obtained (EC REG: ECR/134/Inst/KA/2013/RR-19). The patients of either sex of more than 18 years age group who were RT-PCR tested SARS-CoV-2-positive were included. Pediatric patients less than 18 years were excluded since the algorithm is not optimized for pediatric patients.

Based on the inclusion and exclusion criteria, a total of 100 patients were included in the study. High resolution computed tomography of chest was performed with 128 slice single source dual energy Somatom Definition Edge Siemens MDCT (Multidetector CT) machine.

Scanning protocol: Region from both apices to adrenals was included. Patient position was supine with arms above head and following parameters were used: 20 mA, 100 kV, slice thickness 0.6mm, scan orientation: craniocaudal. The images were reconstructed to obtain 0.6mm section in sagittal and coronal planes. Quantification and assessment of COVID-19 infection by CT pneumonia analysis software was done.

CT lung analysis: CT pneumonia analysis prototype developed based on artificial intelligence (AI) and machine learning algorithms has been provided by Siemens Healthineers as a research tool. It defines the prototype for CT pneumonia analysis and automatically identifies and quantifies hyperdense areas of the lung. It performs automated pulmonary opacity analyses on axial CT data with slice thicknesses up to 5 mm, providing an MPR series containing segmentations of the high opacity abnormalities of the lungs as well as a table with various measurements, e.g. the relative ("percentage of opacities") and absolute volume of the lungs affected by opacities. The Volume Rendering (VRT) enables a quick review of the distribution of the opacities. For a good spatial resolution, it is prescribed to utilize slice thickness underneath 1.5mm. Additionally, users can compare the mean and standard deviation of HU values between lung parenchyma and the detected opacities. The intelligent software uses the HU value to classify the lesion into three types: less than −300 for GGO, − 300 to 50 for sub-solid and greater than 50 for solid. Here, we will be able to compare the mean and standard deviation of HU values between lung parenchyma and the detected opacities.

Siemens Healthineers has been providing this research-only prototype through the Digital Marketplace for syngo.viaOpenApps since April 2020. This software usages a machine learning algorithm that was trained on a database consisting of a total 9549 CT images of which about 9223 datasets were used for lung lobe segmentation and 901 for abnormality segmentation training of which 575 volumes were also used for lobe segmentation. The algorithm quantifies the commonly seen CT abnormalities (i.e. GGO and Consolidation) and categorized the data in two combined severity measures: a) lung severity score (LSS), lung high opacity score (LHOS) b) percentage of opacity (PO), percentage of high opacity (PHO) and absolute volume of the lungs affected by opacities. Based on 3D segmentations of lesions, lungs, and lobes, the algorithm measures the degree of total abnormalities and the presence of high opacity abnormalities both globally and by lobes.

Finally, we will obtain MPR series containing segments of high opacity lung abnormalities and as well as a table with various measurements, e.g. the relative ("percentage of opacities") and absolute volume of the lungs affected by opacities. We can compare the mean and standard deviation of HU values between lung parenchyma and the software detected opacities.

The Volume Rendering (VRT) permits a fast outline of the spatial distribution of the opacities.CT Pneumonia Analysis automatically evaluates and quantifies hyperdense areas of the lung.

The smart artificial intelligent software used the HU value to classify the lesion into three types: less than −300 for GGO, − 300 to 50 for sub-solid and greater than 50 for solid.

STATISTICAL ANALYSIS

The results of the study were tabulated and evaluated descriptively by Microsoft excel 2016. Also the results were presented in figures, tables, frequency graphs and pie charts. Chi square test has been used to find the significance of study parameters between two groups of patients.

RESULTS

In our study, the total number of patients was 100. Of these, 51 (51%) were males and 49 (49%) were females with male preponderance (Table/figure 1). Most common affected age group was 5th decade among both males and females.

The various comorbidities of the patient that were included: hypertension, diabetes, coronary atherosclerotic heart disease, liver disease, nervous system disease, chronic lung disease, chronic kidney disease and tumor among which hypertension was the foremost common comorbidity (22%) (Table/figure 2).

The common symptoms of this illness were fever (73%), cough (70%), fatigue (56%), dyspnea (49%), myalgia (32%) and cough with sputum (16%) (Table/figure 3). In our study, among the 100 patients, 90 (90%)patients had recovered and 10 (10%) patients had died (Table/figure 4).

Among the 100 CT images, 90patients (90%) showed manifestations of COVID-19 pneumonia in both thelungs. Altogether, 7patients (7%) showed unilateral pulmonaryinfection with 4 (4%) in the right lung and 3(3%) in the left, while3 patients (3%) had negativechest CT scans. 1 (1%) patient had left lung infection and 2 (2%) patients had right lung infection, which indicates for more than 50% of each affected lung volume, and 20 (20%) patients had total lung infection constituting for more than 50% of the total volume of bothlungs (Table/figure 5).

In our study, infection was found in all segments of bilateral lung lobes

And the preferred site of COVID-19 pneumonia was the superior segment of lower lobe of right lung (Table/figure 6).

In terms of lung changes, CT scans of the patients obtained showed that 12(12%), 32(32%) and 53 (53%) patients had pure GGO, GGO with sub-solid lesions and all three types, respectively. There were 94 patients (94%) presenting with GGO as the main lesion and 3 patients (3%) primarily as sub solidlesions (Table/figure 5).

The distribution of CT scan signs was not altogether diverse between male or female patients (p =0.700417). However, elderly patients (≥ 60 years) had more tendencies to develop pneumonia and presented as sub-solid lesions on computed tomography scans compared to younger patients (p <0.00001) (Table/figure 7).

Among the 100 patients in our study, 61 (61%) patients

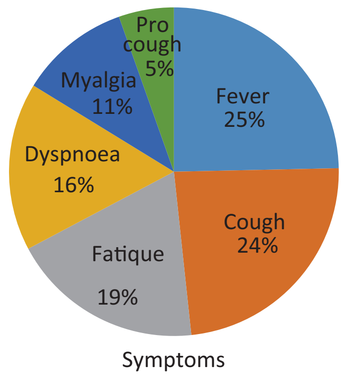
Characteristic	No. of patients	Percentage
Males(years) Range	51	51%
10-29	2	2%
30-49	12	12%
50-69	26	26%
70-100	10	10%
Females (years) Range	49	49%
10-29	2	2%
30-49	9	9%
50-69	29	29%
70-100	9	9%

Table/figure-1: Patient characteristics based on age

Characteristic	No. of patients	Percentage
Hypertension	22	22%
Diabetes	10	10%
Cardiovascular disease	4	4%
Liver disease	2	2%
Nervous system disease	2	2%
Chronic lung disease	2	2%
Chronic kidney disease	1	1%
Tumour	1	1%

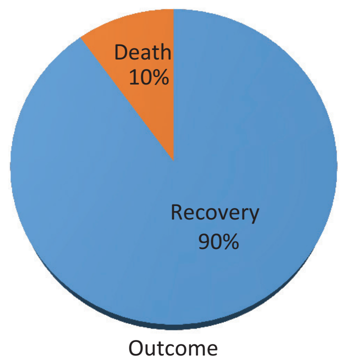
Table/Figure-2: Patient characteristics based on Comorbidities

Characteristic	No. of patients	Percentage
Fever	73	73%
Cough	70	70%
Fatigue	56	56%
Dyspnoea	49	49%
Myalgia	32	32%
Productive cough	16	16%
Diarrhoea	6	6%



Table/figure-3: Patient characteristics based on symptoms

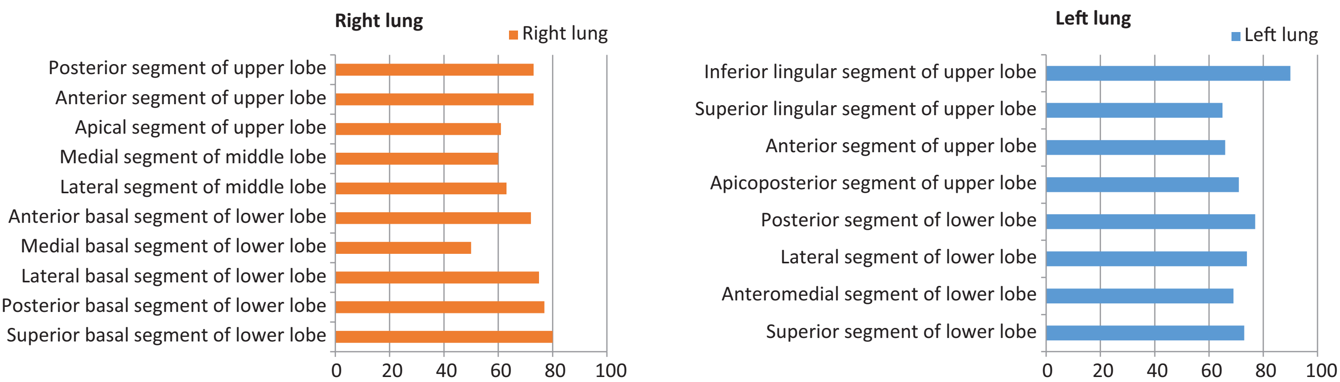
Characteristic	No. of patients	Percentage
Recovery	90	90%
Death	10	10%



Table/Figure-4: Patient characteristics based on outcome

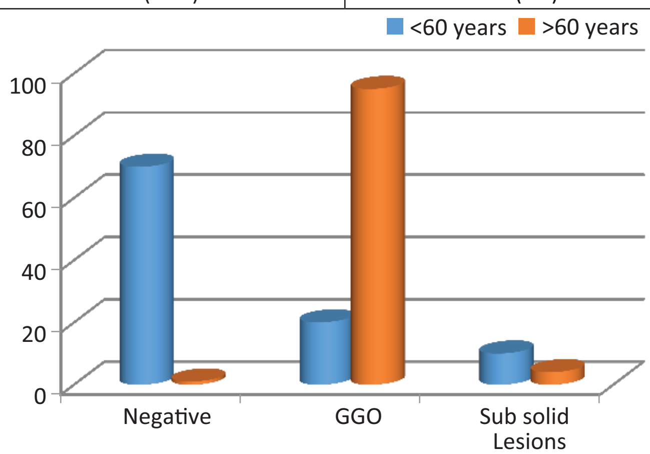
CT feature		No. of patients	(%) of patients
Lesion presentation on scan	Negative	3	**3%**
	Unilateral infection	**7**	**7%**
	Only right lung	4	4%
	Only left lung	3	3%
	Bilateral infection	90	90%
	Left lung infection volume greater than 50%	1	1%
	Right lung infection volume greater than 50%	2	2%
	Total lung infection volume greater than 50%	20	20%
CT signs	Pure GGO	12	12%
	GGO + sub-solid	32	32%
	GGO + sub-solid + solid	53	53%
	GGO as the main lesion	94	94%
	Sub-solid as the main lesion	3	3%

Table/figure-5: Chest CT features of patients with COVID-19



Table/figure-6: Anatomic distribution of infected bronchopulmonary segments in patients with COVID-19

Category	CT signs			
	Negative	Primarily presenting with GGO	Primarily presenting with sub-solid lesions	P Value
Sex				
Male	3 (3%)	94(94%)	3(3%)	The p-value is .700417 Not significant at p < .05.
Female	4(4%)	93(93%)	3(3%)	
Age				
<60 Years	70(70%)	20(20%)	10(10%)	The p-value is <0.00001. Significant at p < .05.
>60 Years	1(1%)	95(95%)	4(4%)	



Table/figure-7: Distribution of CT signs in relation to age and sex

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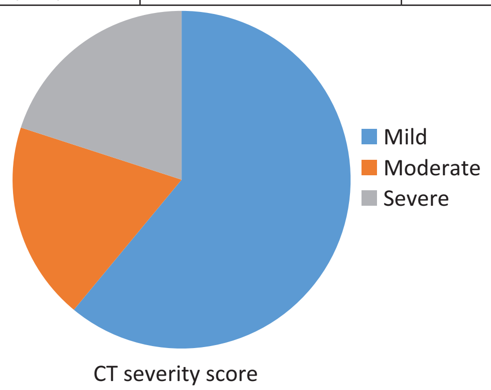
had mild CT severity score which was obtained from the percentage of opacity in each lobe provided by the CT pneumonia analysis software tool (AI).

DISCUSSION

COVID-19 disease is a highly contagious illness that has shown a rapid spread throughout the world. Early diagnosis of the disease is mandatory for disease containment strategies and for the patient management.[15,16] Chest CT shows higher sensitivity in detecting milder forms of pulmonary manifestations in early disease stages. That is why, chest CT has ended up being a foremost diagnostic tool during the pandemic of COVID 19.[10]

Li et al. had reported that AI software could accurately detect and differentiate COVID-19 pneumonia from community-acquired pneumonia and other lungdiseases.[7] In our study, we analysed the CT scans of 100 COVID-19 patients using the CT pneumonia analysis software. This software can accurately segment different anatomical structures of the lung to detect infection regions and measure the percentage of infection in both lungs, along with its lobes and segments. It has been reported that patients affected by COVID-19 pneumonia show bilateral and multilobar involvement in CT scans, with lesions being more frequent in the lower lobes.[4,11] Consistent with these studies, our study also showed that COVID-19 pneumonia manifested in both lungs in 90 of 100 patients. Furthermore, the study found that the favouredsite of COVID-19 pneumonia is the superior segment of the right lower lobe. This may be because of the innate anatomic features of the lobar bronchus. Since the bronchus of the right lower lobe of the lung is straighter and steeper than other bronchial branches, and the angle between the right lower lobe and the long axis of the trachea is smaller, the right lower lobar bronchus is more likely to be infected.

CT severity score	No. of patients (n=100)	Percentage
Mild (<8)	61	61%
Moderate (9-15)	19	19%
Severe (>15)	20	20%



Table/figure-8: Distribution of patients according to CT severity scoring system

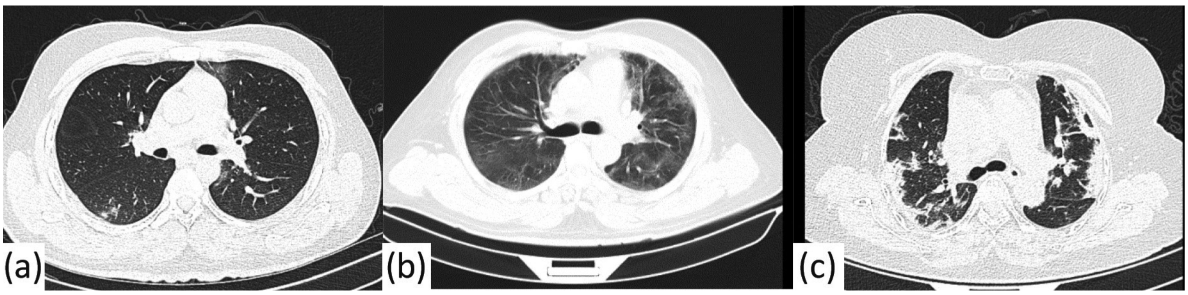
The presence of multifocal GGOs is the foremost common CT highlight of COVID-19 pneumonia is.[12,13] In this study, lesions were automatically classified by the CT pneumonia analysis software into GGOs, sub-solid lesions and solid lesions. Results showed that 94 patients (94%) presented primarily with GGO. This may be explained by the pathogenesis of the virus, with different stages of infection manifesting as a progression of abnormalities seen in the chest CT scans. As the disease progresses, alveolar septal capillaries dilate and become congested and alveolar exudates and lobular interstitial edema appear. The CT scan would show patchy ground glass shadows. However, with an increase in alveolar exudate, expansion of intravascular interstitial blood vessels and aggravation of the alveolar and interstitial edema, CT scans would progress to show a consolidation likened to ground glass. A gradual increase in the density of lesions may also be seen. Theground glass shadow then decreases in density or even completely disappears during the absorption period. Thus, even in the presence of changing lesion appearances, GGOs were present throughout all CT scans.

Our study found that sub-solid lesions were more likely to be found in the CT scans of elderly patients compared to those of younger patients ($p < 0.00001$). This may be linked to the general observation of COVID-19 pneumonia being more severe in the elderly.[14]

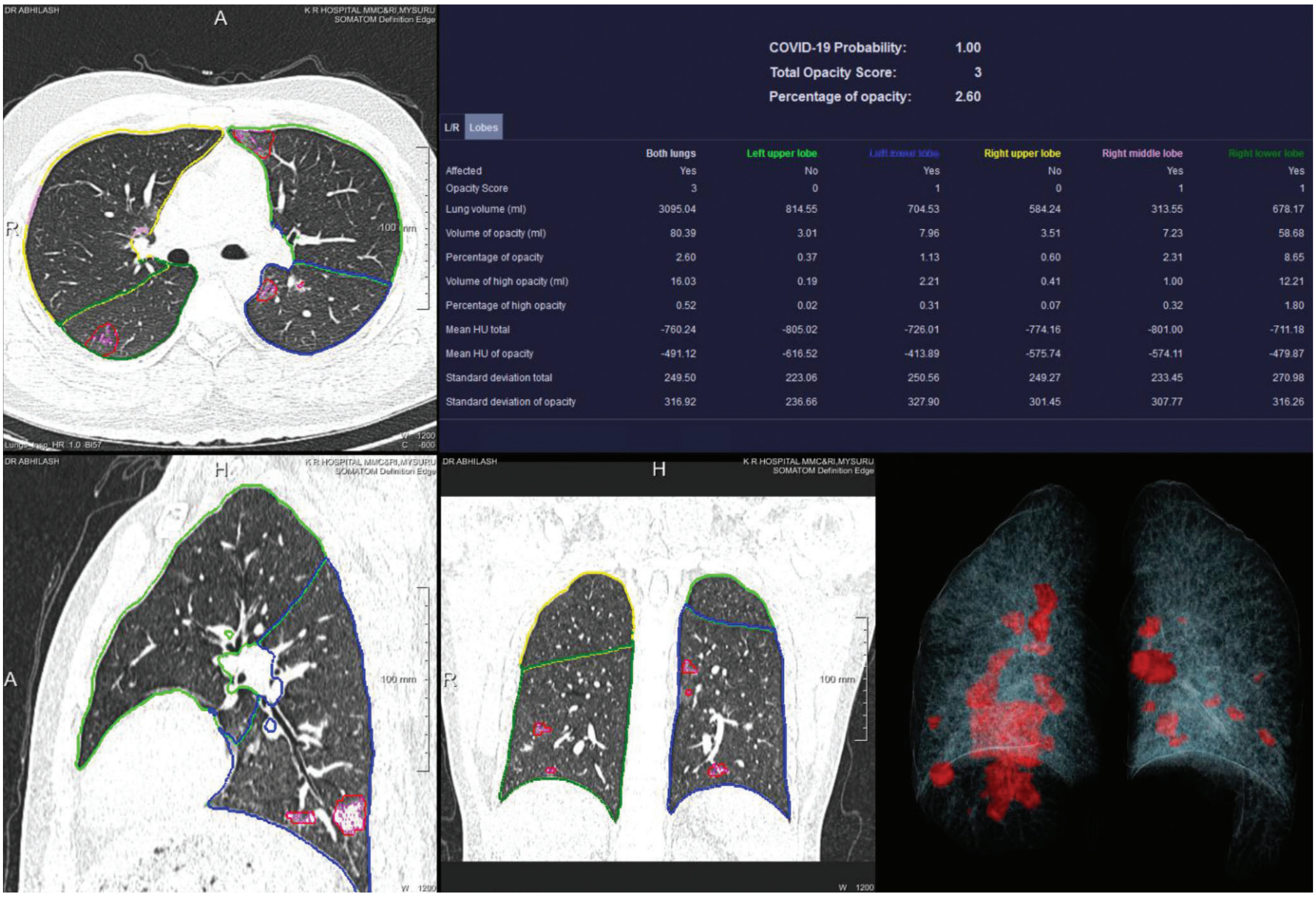
In addition, AI can improve work efficiency by accurate delineation of infections in CT images, facilitating subsequent quantification.[15] Moreover, assessing the disease by AI-based software is of great importance that could help decision making in treatment planning based on the CT severity score as represented in (Table/figure 9 -12).

CT severity score prediction

Each of the 3 lobes on the right lung and 2 lobes on the left lung were individually assessed and percentage of the lobe involved was provided by the CT pneumonia analysis software.

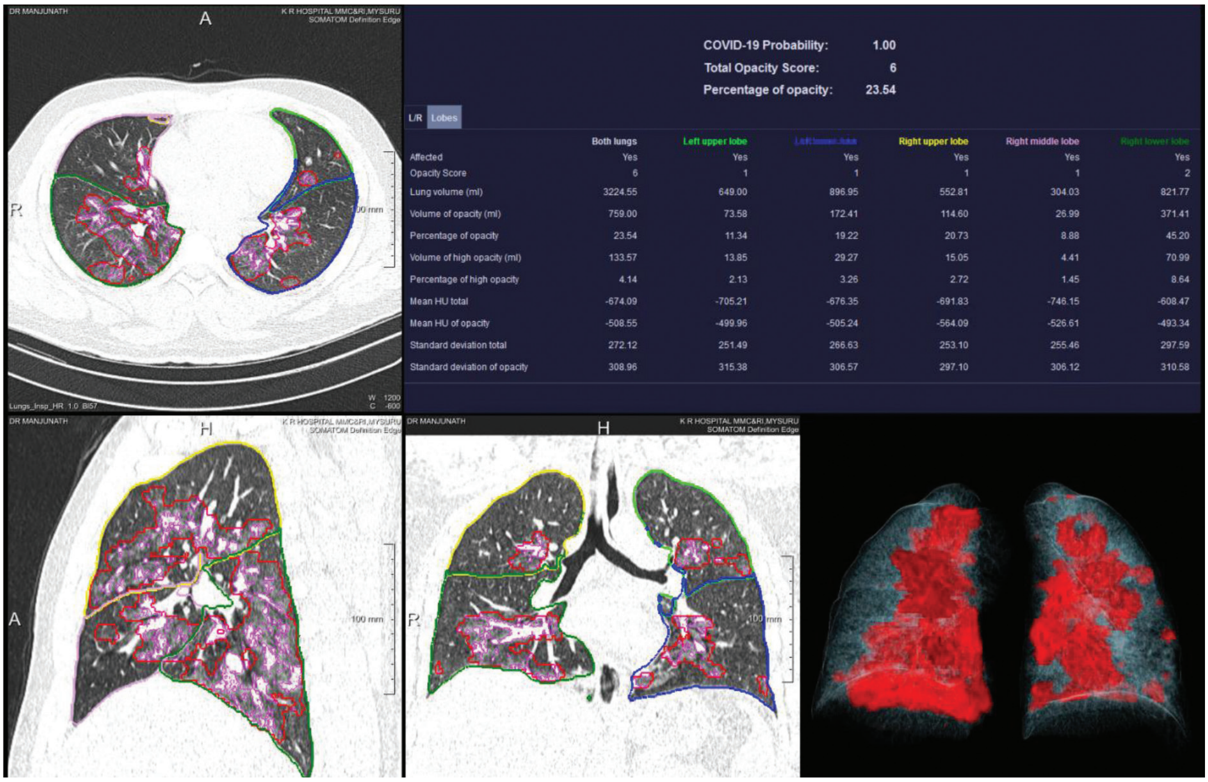


Table/figure-9: (a) Axial HRCT image shows few patchy ground glass opacities involving visualised lung fields, (b) Axial HRCT image shows ground glass opacities mixed with sub solid lesions (45HU) in the visualised bilateral lung fields and (c) Axial HRCT image shows solid lesions of more than 50 HU in peripheral distribution in bilateral visualised lung fields



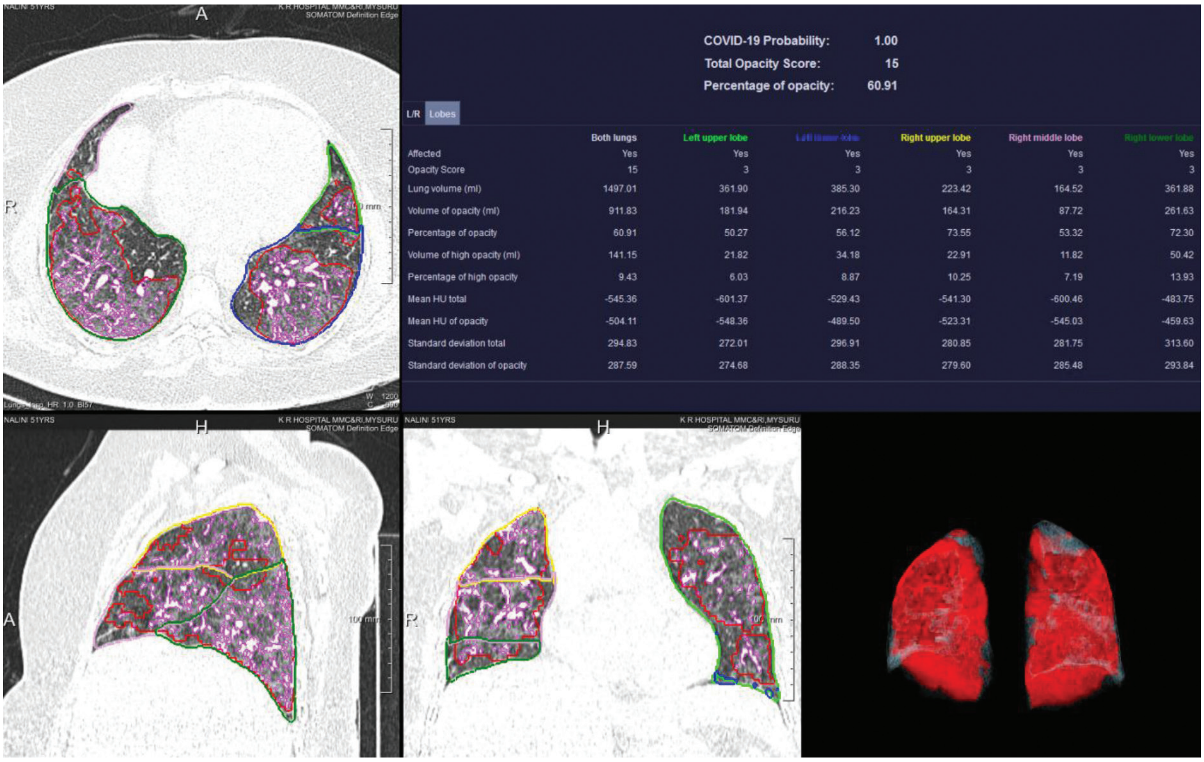
	Both lungs	Left upper lobe	Left lower lobe	Right upper lobe	Right middle lobe	Right lower lobe
Affected	Yes	No	Yes	No	Yes	Yes
Opacity Score	3	0	1	0	1	1
Lung volume (ml)	3095.04	814.55	704.53	584.24	313.55	678.17
Volume of opacity (ml)	80.39	3.01	7.96	3.51	7.23	58.68
Percentage of opacity	2.60	0.37	1.13	0.60	2.31	8.65
Volume of high opacity (ml)	16.03	0.19	2.21	0.41	1.00	12.21
Percentage of high opacity	0.52	0.02	0.31	0.07	0.32	1.80
Mean HU total	-760.24	-805.02	-726.01	-774.16	-801.00	-711.18
Mean HU of opacity	-491.12	-616.52	-413.89	-575.74	-574.11	-479.87
Standard deviation total	249.50	223.06	250.56	249.27	233.45	270.98
Standard deviation of opacity	316.92	236.66	327.90	301.45	307.77	316.26

Table/figure-10: Representative CT pneumonia analysis output of a 28-year-old man with COVID-19 CT images showing bilateral lesions with percentage of opacity of 2.6%.CT severity score of 6/25 (Mild severity) calculated by adding up the scores based on percentage in each lobe.



	Both lungs	Left upper lobe	Left lower lobe	Right upper lobe	Right middle lobe	Right lower lobe
Affected	Yes	Yes	Yes	Yes	Yes	Yes
Opacity Score	6	1	1	1	1	2
Lung volume (ml)	3224.55	649.00	896.95	552.81	304.03	821.77
Volume of opacity (ml)	759.00	73.58	172.41	114.60	26.99	371.41
Percentage of opacity	23.54	11.34	19.22	20.73	8.88	45.20
Volume of high opacity (ml)	133.57	13.85	29.27	15.05	4.41	70.99
Percentage of high opacity	4.14	2.13	3.26	2.72	1.45	8.64
Mean HU total	-674.09	-705.21	-676.35	-691.83	-746.15	-608.47
Mean HU of opacity	-508.55	-499.96	-505.24	-564.09	-526.61	-493.34
Standard deviation total	272.12	251.49	266.63	253.10	255.46	297.59
Standard deviation of opacity	308.96	315.38	306.57	297.10	306.12	310.58

Table/figure-11: Representative CT pneumonia analysis output of a 56 year-old man with COVID-19 CT images showing bilateral lesions with percentage of opacity of 23.5%. CT severity score of 11/25 (Moderate severity) calculated by adding up the scores based on percentage in each lobe.



Table/figure-12: Representative CT pneumonia analysis output of a 51 year-old female with COVID-19 CT images showing bilateral lesions with percentage of opacity of 60.9%. CT severity score of 20/25 (severe severity) calculated by adding up the scores based on percentage in each lobe.

Visual CT chest severity scoring was graded as Score-1 (<5% area involved), Score-2 (5-25% area involved), Score-3 (25-50% area involved), Score-4 (50-75% area involved), Score-5 (>75% area involved), making a total score of 25. A CT Severity Score was calculated out of 25 based on the percentage of area affected in each of the 5 lobes.[16] A score of <8 indicates mild CT severity, 9 to 15 indicates moderate CT severity and > 15 indicates severe CT severity. In our study, the percentage involvement of each lobe was provided by the (AI) CT pneumonia analysis software without the need for visual assessment.

In conclusion, classical CT features of COVID-19 pneumonia include multifocal

Bilateral GGOs, with the foremost common location of infection being the

superior segment of lower lobe of right lung. The ability of the (AI) CT pneumonia Analysis software to quickly and accurately localize and quantify infection regions from CT scans will not only aid in the diagnosis of COVID-19, but also aid in assessing the disease severity based on CT severity scoring system to help guide physicians in their treatment plans.

CONCLUSION

The use of chest CT combined with subsequent CT pneumonia analysis software can accurately evaluate the pneumonia in COVID-19 patients.

Classical CT features of COVID-19 pneumonia are multifocal bilateral GGOs, with the most common location of infection being the superior segment of the right lower lobe. The ability of the AI Analysis to quickly and accurately localize and quantify infection regions from CT scans will not only aid in the diagnosis of COVID-19, but also aid in assessing the disease to help guide physicians in their treatment plans.

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