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CT derived pulmonary vascular indices and severity of pneumonia in Covid-19 patients: A retrospective study

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ABSTRACT

Context: The currently on-going COVID-19 pandemic resulted in the abnormal lung parenchymal changes which can also alter pulmonary vascular hemodynamics. *Aims:* This study was aimed to assess CT derived pulmonary vascular indices in COVID 19 patients in different groups based on the extent of pneumonia using CT severity score. *Settings and design:* Retrospective study at COVID-19 care centre in central India. *Methods and material:* This study included 78 institutionalized patients who were confirmed COVID-19 positive status. All patients were assessed based on demographic data, CT severity score; CT derived pulmonary vascular indices such as main pulmonary artery diameter and the pulmonary artery to aorta ratio (PA/AO). Changes in these pulmonary vascular indices were determined in each mild, moderate and severe group of pneumonia. *Results:* Out of 78 patients, 25.6% patients belonged to mild group, 28.2% belonged to moderate group and 21.8% belonged to severe group. 70.5% of all patients were males and 29.5% were females. 11% males and 17.4% females showed increased pulmonary artery above normal limits. 4 males and 4 females with increased pulmonary artery diameter belonged to severe group of COVID 19 pneumonia while 8 out of 10 patients with increased PA/AO belonged to severe group of pneumonia extent. *Conclusions:* In this study, patients with pulmonary artery enlargement and increased PA/AO (PA/AO) were predominantly found to belong to severe group of COVID-19 pneumonia, a finding requiring further investigation which will help to predict pulmonary hypertension in COVID 19 patients which has an unfavourable outcome.

Keywords: COVID-19 (corona virus disease), Computed Tomography (CT), CT Severity Score, Reverse Transcriptase Polymerase Chain Reaction (RT-PCR), PA/AO (pulmonary artery to aorta ratio)

1. INTRODUCTION

The COVID-19 pandemic, which has been labelled a worldwide health emergency by the World Health Organization, has so far afflicted millions of individuals around the world, with over 5 million deaths. The pulmonary

parenchyma is the most affected subset in COVID 19 patients. Parenchymal features may range from ground glass opacities, consolidation, intralobular and interlobular septal thickening to acute respiratory distress syndrome (Raptis et al., 2020). Hence Chest CT is accepted widely as useful tool for evaluating lung parenchyma especially in critically ill patient (Liu et al., 2020). These extensive lung consolidations can alter pulmonary vasculature dynamics, increasing the chances of pulmonary hypertension with reports of increased cases of pulmonary artery thrombosis in COVID 19 patients (Matsushita et al., 2014). The importance of prompt diagnosis of pulmonary hypertension and thromboembolism, which may be linked to increased mortality rates in COVID-19 individuals, cannot be overstated. However, contrast pulmonary angiography has limitations in this scenario, as COVID 19 patients most commonly undergo unenhanced CT scan of the thorax.

This retrospective study was aimed to evaluate CT derived pulmonary vascular indices which includes main pulmonary artery diameter and PA/AO in COVID 19 patients and extent of pneumonia using CT severity score. Reference normal values of 29 mm and 27 mm are accepted as cut-off for main pulmonary artery diameter in males and females respectively and PA/AO of >0.9 is regarded as marker of pulmonary vasculature damage (Truong et al., 2012).

2. MATERIALS AND METHODS

Study settings and study population

This retrospective research was done at a designated COVID centre at tertiary care hospital in central India for 3 months (from August 2020 to November 2020). This included 78 institutionalized patients who were confirmed COVID-19 positive status with RT-PCR test or Rapid Antigen test. The study protocol was accepted by the local institutional committee and patients who took part in the study gave their informed and written consent. Demographic data such as sex and age were taken from case record forms.

Chest CT scan acquisition

All the chest CT scans were carried out on 16 slice multidetector CT scanner (Toshiba Activion) with routine chest protocol. Appropriate infection control measures were taken for all COVID-19 cases which included appropriate transfer measures for cases, sanitization of CT gantry post scans and protection of health care workers performing scans. The parameters used for the routine thorax scan were identical to the manufacturer's standard recommended pre-setting.

Chest CT imaging analysis

All the chest CT scan images were reviewed for parenchymal features such as ground glass opacities, consolidation and crazy paving pattern, definitions of these radiological terminology for thoracic imaging were as those put forth by the Fleischner Society.

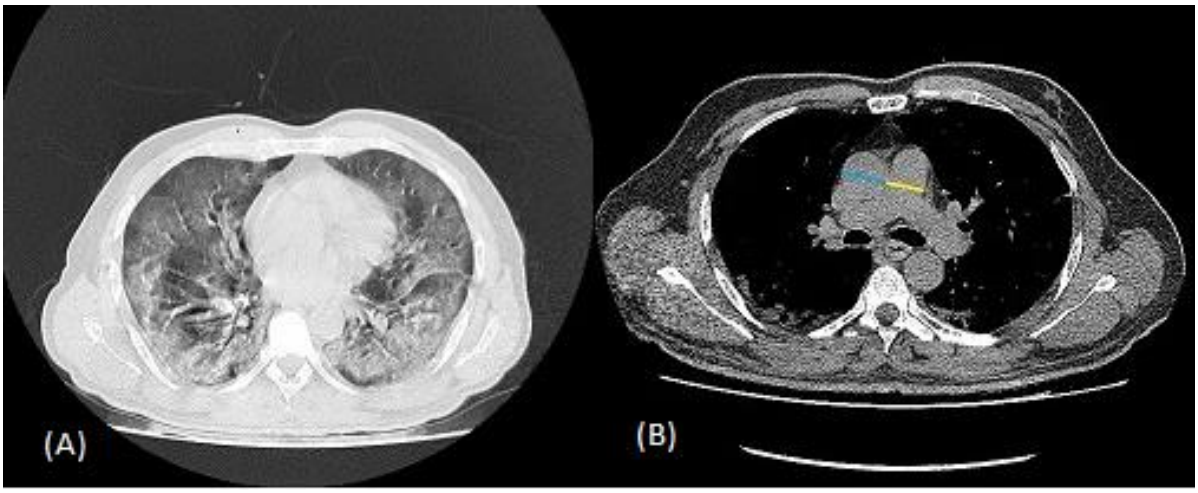

Figure 1 (A) Axial non-contrast CT chest indicating bilateral ground glass opacities with consolidatory changes. The patient had CT severity score of 21 suggesting severe category pneumonia. **(B)** Axial CT chest showing main pulmonary diameter (yellow line) and ascending aorta diameter (blue line). The ratio of main pulmonary artery diameter and the aorta diameter was calculated.

CT severity index

Quantification of pulmonary parenchymal involvement was done using semi quantitative scoring system depending on the degree of lobar involvement. Visual scoring of each of the five lobes was done on scale of 0-5 (0-no involvement, 1- <5%, 2- 5-25% involvement, 3-26-50% involvement, 4-51-75% involvement, 5- >75% involvement). The total CT severity score was taken as sum of all lobar involvement, 0 being no involvement and 25 being maximum involvement (Francone et al., 2020) (Figure 1A).

Measuring Pulmonary vascular indices

Maximum diameter of main pulmonary artery at its bifurcation and maximum diameter of the ascending aorta were assessed in a single slice on axial section. PA/AO was calculated from these values (Truong et al., 2012) (Figure 1B).

Statistical analysis

Statistical analysis was done using MS Excel and Epi info software. Categorical data was indicated as frequencies and percentages while numerical data was categorized in the form of arithmetic mean +/- SD (or median). The patients were stratified into mild (<7 score), moderate (8-18), severe (>18) based on CT severity score. P value <0.05 was considered statistically significant.

3. RESULTS

Demographic data

This retrospective study was conducted with 78 patients tested RT-PCR positive for COVID-19 infection and HRCT chest scan was performed for the same. Maximum 21 (26.9%) study subjects belonged to age group of 21-30, followed by 19 (24.4 %) in age group 51-60 years, 15(19.2%) belonged to 61-70 years. Each of the 10(12.8%) study subjects belonged to 31-40 years age group and 41-50 years and minimum 3 (3.8%) in 71-80 years (Figure 2). Out of 78 study subjects, 55 (70.5%) were males and 23 (29.5%) were females (Figure 3).

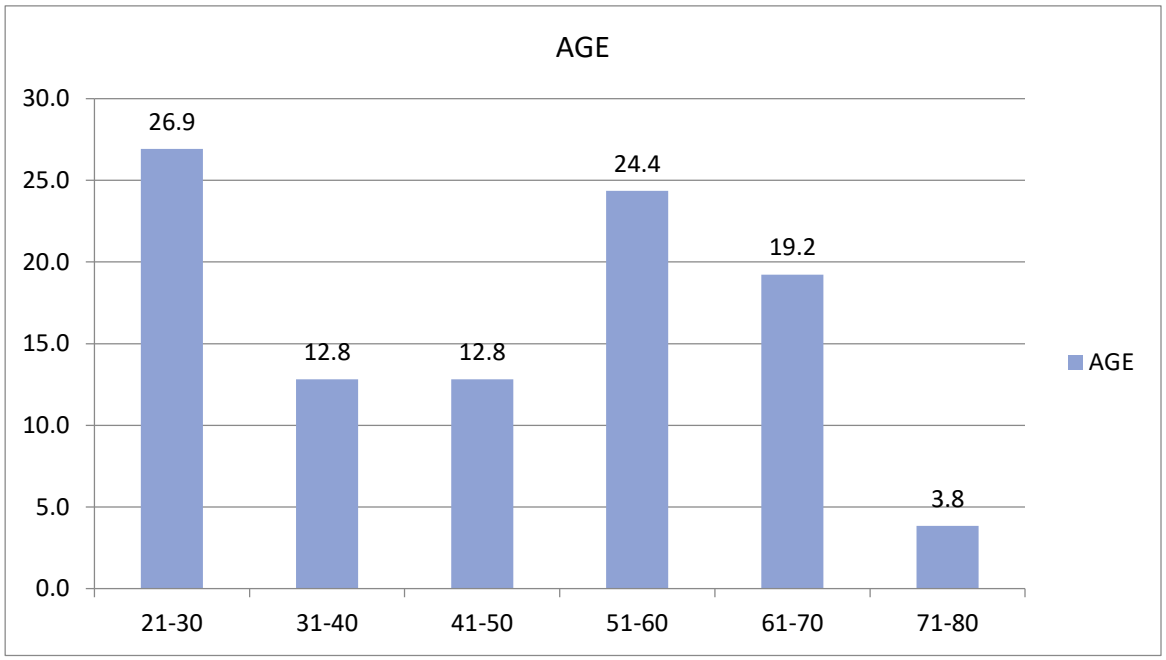

Figure 2 Age wise distribution of study subjects.

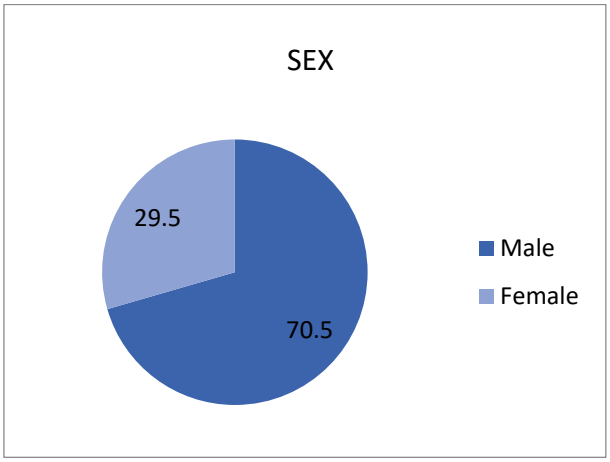

Figure 3 Gender wise distributions of study subjects.

Lung parenchyma CT findings

Lung parenchyma was assessed for CT features like ground glass opacities in the presence or absence of consolidation and divided into mild, moderate and severe group. 20(25.6%) patients belonged to mild group, 22(28.2%) belonged to moderate group and 17(21.8%) belonged to severe group, while 19(24.4%) patients did not have any parenchymal findings (Figure 4).

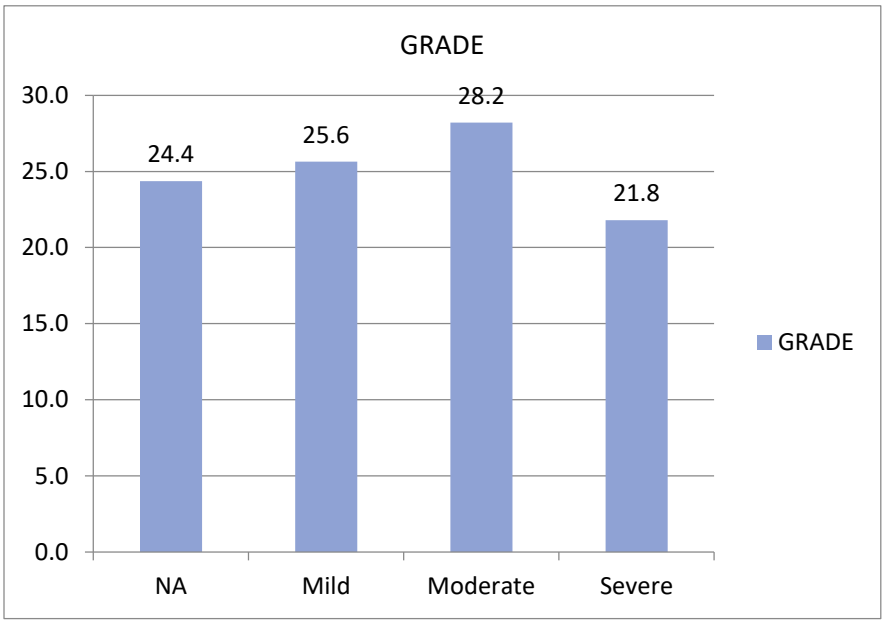

Figure 4 Distribution of study subjects according to severity of disease

Table 1 Mean and SD of pulmonary artery according to their gender

	Mean and SD of pulmonary artery according to their gender			P value
Gender	Mild	Moderate	Severe	
Male	26.11 ± 2.44	26.49 ± 2.42	27.88 ± 2.59	0.0685996
Female	24.66 ± 2.52	25.07 ± 2.48	28.54 ± 2.86	0.00606592

Pulmonary artery diameter

Mean value for main pulmonary artery diameter was highest in severe group 27.88 for males while it was lowest in mild group 26.11. Since the p value > 0.05 so there is no significant relationship between gender and pulmonary artery for males. Similarly, mean value was highest in severe group 28.54 while it as lowest in mild group 24.66 for females. Since the p value < 0.05 so there is

a significant relation between gender and pulmonary artery for females (Table 1). Also, the p value < 0.05 so there is a significant relationship between pulmonary artery and age (Table 2). It was found that mean value for pulmonary artery diameter was 26.117, range value was 11.4 and IQR value was 3.5 (Table 3).

Table 2 Mean and SD of pulmonary artery according to their age

	Mean and SD of pulmonary artery according to their age	P value
Age	Mean ± S.D.	
21-30	24.72 ± 2.48	
31-40	25.58 ± 2.44	
41-50	25.91 ± 2.45	0.0272965 df:5
51-60	26.90 ± 2.46	
61-70	27.42 ± 2.56	
71-80	26.8 ± 2.33	

Table 3 Mean, SD, range and IQR of pulmonary artery diameter

PULMONARY ARTERY DIAMETER	
Mean	26.117
Std. Deviation	2.4057
Range	11.4
1ST Quartile	24.450
2nd Quartile	26.200
3rd Quartile	27.900
Interquartile Range	3.5

6 (11%) males had pulmonary artery diameter greater than 29mm and 49(89%) males had pulmonary artery diameter less than or equal to 29mm. Similarly, 4(17.4%) females had pulmonary artery diameter greater than 27mm whereas 19(82.6%) had pulmonary diameter less than or equal to 27mm (Figure 5).

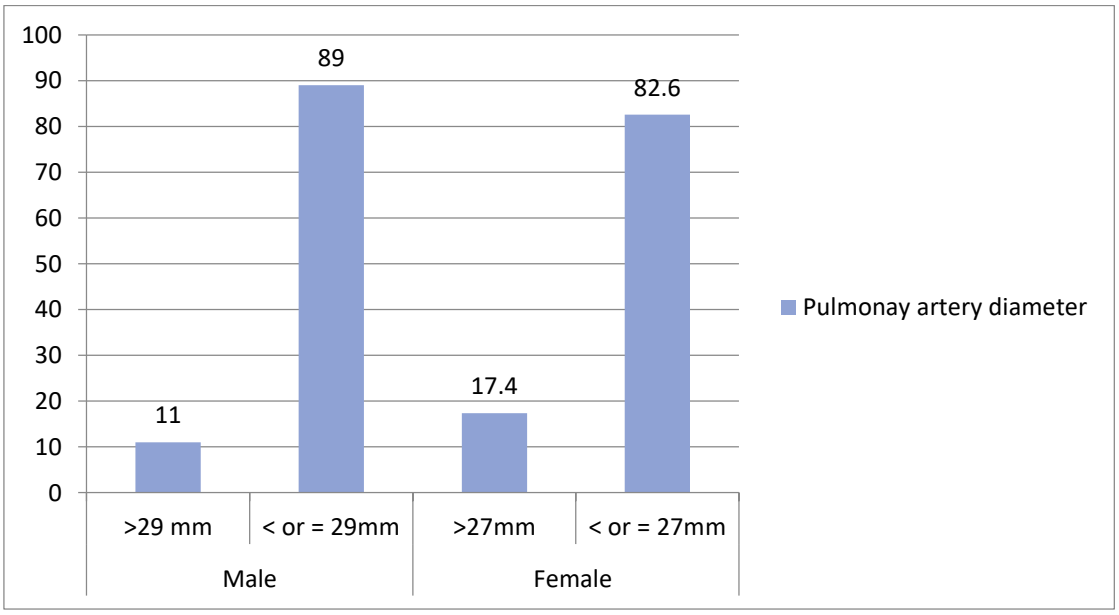

Figure 5 Gender wise distributions of study subjects according to normal and abnormal pulmonary artery diameter values

4 (7.3%) males with pulmonary artery diameter greater than 29mm belonged to severe group. Each 1 male belonged to mild and moderate group whereas 17(31%) males with pulmonary artery diameter less than or equal to 29mm belonged to moderate group, followed by 14(25.5%) in mild, 10(18.2%) in NA and 8(14.4%) in severe group (Table 4). 4 (17.4%) females with pulmonary artery diameter greater than 27mm belonged to severe group whereas 5 (27.78%) females with pulmonary artery diameter less than or equal to 27mm belonged to mild group, followed by 4(22.2%) in moderate and 1(5.56%) in severe group (Table 4).

Table 4 Gender wise distribution of pulmonary artery diameter according to the severity of pneumonia

Gender	Frequency	Percent
Male > 29mm		
NA	0	0
Mild	1	1.8
Moderate	1	1.8
Severe	4	7.3
Male< or = 29mm		
NA	10	18.2
Mild	14	25.5
Moderate	17	31
Severe	8	14.4
Female>27mm		
NA	0	0
Mild	0	0
Moderate	0	0
Severe	4	17.4
Female< or =27mm		
NA	8	44.44
Mild	5	27.78
Moderate	4	22.22
Severe	1	5.56

Pulmonary artery to aorta ratio

Mean value of PA/AO was 0.83 whereas IQR was 0.08. There is no significant relation between PA/AO and age as the p value > 0.05. Mean value for PA/AO was highest in severe group 0.88 and it was lowest in moderate group 0.82 for males whereas mean value was highest in severe group 0.9 and it was lowest in moderate group 0.82 for females. Since the p value < 0.05 so there is a significant relationship between gender and PA/AO for males as well as females (Table 5). 10(12.8%) study subjects had PA/AO $\geq$ 0.9 while 68(87.2%) study subjects had PA/AO < 0.9 (Figure 6). 8(80%) study subjects with PA/AO > 0.9 belonged to severe group, followed by 2(20%) in moderate and 0 (0%) in mild group (Table 6).

Table 5 Mean and SD of PA/AO according to the severity of pneumonia

	Mean and SD of PA/AO according to the severity of pneumonia			P value
Gender	Mild	Moderate	Severe	
Male	0.84 ± 0.05	0.82± 0.06	0.88 ± 0.05	0.00158546
Female	0.84 ± 0.05	0.82 ± 0.04	0.9 ± 0.06	0.00575628

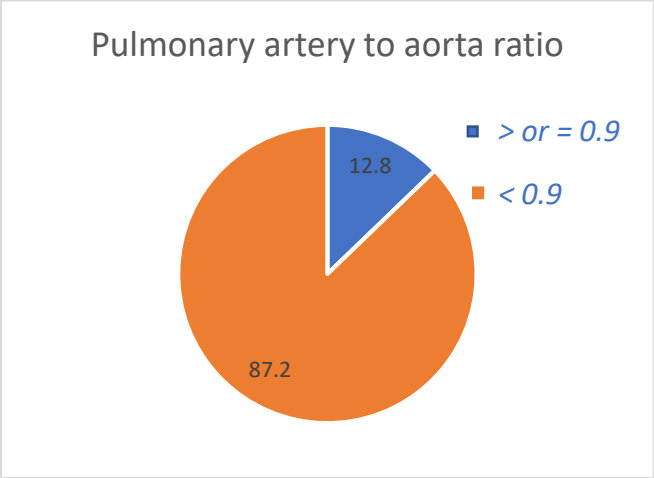

Figure 6 Distribution of study subjects according to normal and abnormal Pulmonary artery to aorta ratio

Table 6 Distribution of study subjects according to pulmonary artery to aorta ratio according to severity of pneumonia

PA/AO ratio	Frequency	Percentage
> 0.9		
NA	0	0
Mild	0	0
Moderate	2	20
Severe	8	80
< or =0.9		
NA	19	27.9
Mild	20	29.4
Moderate	20	29.4
Severe	9	13.3

4. DISCUSSION

COVID-19 pneumonia can alter pulmonary vasculature dynamics following inflammatory changes due to consolidation. These parenchymal alterations can significantly increase the risk of pulmonary thromboembolism and pulmonary hypertension (Xiong et al., 2020). Pulmonary hypertension could be diagnosed with invasive techniques such as ventricular catheterization or contrast pulmonary angiography. However, these techniques have limitations for using in COVID 19 patients. Few studies have been reported which assessed unenhanced CT derived indices such as pulmonary artery diameter and PA/AO as a tool for prediction of pulmonary artery hypertension (Shen et al., 2014). Patients with COVID 19 infection frequently undergo unenhanced CT scan examinations; these indices might have prognostic importance.

In our study, 25.6% patients belonged to mild group, 28.2% belonged to moderate group, and 21.8% belonged to severe group, while 24.4% patients did not have any parenchymal findings. Out of those, 70.5% were males and 29.5% were females. 11% males had pulmonary artery diameter greater than 29mm and 17.4% females had pulmonary artery diameter greater than 27mm. Out of total, each of 4 males and 4 females who had pulmonary artery diameter greater than 29mm and 27 mm respectively belonged to severe group of COVID 19 pneumonia. 10 study subjects had PA/AO greater than 0.9 out of which 8 patients belonged to severe group of pneumonia extent. These vascular changes could be attributable to changes in hemodynamics according to severity of pneumonia as maximum patients with abnormal vascular indices belonged to severe group.

In one study conducted by Troung et al., (2018) in non-COVID circumstances, an increased pulmonary artery diameter on CT scan was linked to pulmonary hypertension and was thought to reflect disease severity. Another study with sample size of 44 patients revealed that the main pulmonary artery diameter enlargement as compared to previous CT examination in non survivors could be probably due to increased vascular resistance in endothelial injury associated with COVID-19 (Spagnolo et al., 2020).

The major limitation of our study has been number of study subjects included. Increasing the study population size is needed to assess correlation the between these parameters. Another limitation of this study is measurement of these indices and visual scoring

system for pneumonia severity which are completely operator dependent. However, the evaluation of these pulmonary vascular indices is easily measurable, fast and does not need any dedicated software. Moreover, these indices may have impact on management of patient and treatment strategies.

5. CONCLUSION

To conclude, in this present study, patients with pulmonary artery enlargement and increased PA/AO predominantly belonged to severe group of COVID-19 pneumonia. The extent of these lung parenchymal changes might have led to the increase in the pulmonary vascular indices. More of similar data is needed to stratify risk of pulmonary hemodynamics according to involvement of lung parenchyma which might help in further management of patient.

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Author Contributions

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; gave final approval of the version to be published; and agree to be accountable for all aspects of the work.

Ethical considerations

Ethics approval for the study was obtained from the institutional ethics committee after ethical approval code (NKPSIMS & RC and LMH/ IEC-RADIOLOGY/01/2020). Data were kept anonymous and confidential during all stages of the study.

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Conflicts of interest

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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