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ORIGINAL ARTICLE

Role Of Multi-Slice CT Chest In Patients With Suspected COVID-19

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ABSTRACT

Keywords: COVID-19,Non contrast chest CT,GGO,CORADs

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Background: In mid-December 2019, corona virus disease (COVID-19) started in China with clinical symptoms including dry cough, fever, fatigue and dyspnea. Ground glass opacities (GGO) on a chest CT is a sign of COVID-19 infection. **Purpose**: Explore the role of MSCT in assessing parenchymal lung changes in patients with suspected COVID-19 as an initial diagnosis and follow up. **Patients and Methods:** A prospective study involving 260 patients with clinical suspicion of COVID-19 examined with MDCT scanner. **Results:** The most CT signs were GGO 231(88.8%) ,consolidation 156(60.0%),crazy paving appearance 56(21.5%),pleural thickening 48(18.5%),air bronchogram sign 44(16.9%),vacuolar sign 26(10.0%),subpleural lines 16(6.2%),pleural effusion 12(4.6%),halo sign 10(3.8%),reversed halo sign 8(3.1%).Eighty patients had GGOs > 4 lobes were classified as clinically severe and 92 patients had GGOs occupying >1/3 of lobe were classified as clinically severe. MSCT had 92.4% sensitivity,100% specificity. **Conclusion:** MSCT has an important role in assessing parenchymal lung changes in patients with suspected COVID 19. GGOs occupying more than 4 lobes and more than 1/3 of a lobe were classified as severe infection. MDCT can affect the plan of the treatment either at the hospital or at the home.

INTRODUCTION

On December 31, 2019 the World Health Organization (WHO) was alerted to several cases of a respiratory illness of unknown origin emerging from Wuhan City, Hubei Province of China, with clinical presentations resembling those of viral pneumonia and manifesting as fever, cough and dyspnea.. At January 30,2020, the WHO has designated this outbreak as a global health emergency.[1]

Real-time fluorescence polymerase chain reaction (RT-PCR) of respiratory specimens revealed a novel beta corona virus to be present, which has subsequently been named severe acute respiratory syndrome corona virus 2 (SARS-CoV-2) by WHO.[2]

Infection is transmitted through droplets generated during coughing and sneezing by symptomatic patients but can also occur from asymptomatic people and before onset of symptoms with incubation period varies from 2 to 14 d [median 5 d].[3,4]

Medical imaging techniques have a potentially important role to play in early diagnosis and managing the treatment of patients infected with COVID-19, chest X-ray has a useful role to play

in revealing the presence of pathology affecting the lung, however, small lesions may not be detected as CXR may be normal in early and mild disease. Findings are most extensive about 10-12 days after symptom onset, and the greater resolving power of CT is important for early diagnosis of patients with a negative CXR and high clinical suspicion of COVID-19. [5]

The typical findings of chest CT images of individuals with COVID-19 are: multifocal bilateral patchy ground glass opacities or consolidation with interlobular septal and vascular thickening, mostly in the peripheral fields of the lungs. Special classic signs including:"crazy paving" or "reverse halo" can also be seen, while cavitation, nodules, pleural effusions, and lymphadenopathy are rare. [6,7]

CO-RADS was developed to categorize the level of suspicion for COVID-19 pneumonia on a scale of 1 to 5, with CO-RADS 1 corresponding to "negative" category, CO-RADS 2 to "atypical," CO-RADS 3 and 4 corresponding to "indeterminate" with "lower" or "higher" likelihood, respectively and CO-RADS 5 equaling "typical" category.[8]

Several studies have discussed the role of MDCT in assessment of parenchymal lung changes in COVID-19 infection [5-7]. Our study is unique because according to the radiological signs at chest CT we can determine the clinical severity of the patient and will reflected in the plan direction of the treatment either at the hospital or at the home.

AIM OF THE WORK:

This study aimed to: (A) explore the role and accuracy of MDCT in assessing parenchymal lung changes in patients with suspected COVID-19, (B) identify serial CT findings in relation to clinical status with sequential follow up.

PATIENT AND METHODS

Study design:

This prospective diagnostic accuracy study was conducted at a tertiary care hospital in Upper Egypt from September 2020 to September 2021

Study population:

This study included 260 patients. Mean age of enrolled patients was 48.87 ± 16.28 years with range between 18 and 82 years.

Inclusion criteria:

- For any age and both gender.
- Patients presented with symptoms suggesting COVID-19 as fever, dry cough, fatigue, myalgia, dyspnea.
- Patients with history of contact with COVID-19 cases who have a positive result of the RT-PCR test within 14 days before symptom onset.

Exclusion criteria:

- No absolute contraindication as no contrast media was used.

Patient assessment:

1)History and clinical symptoms were taken from the patients that suggest COVID-19 pneumonia as fever, dry cough, dypnea, arthralgia and myalgia.

2) CT patient preparation included:

- Removal of all metal objects, such as jewelry, and hairpins that may obscure the field of view.
- Take off most clothes and change into a gown.

MSCT Technique:

- All patients had been subjected to non contrast chest MSCT exam.
- Examinations carried out with 160-slice MDCT (Aquilion Prime Model, TSX-303A CGGT-032A, Toshiba, Canon Medical Systems, Japan). Patients were scanned in the

supine position, during breath-hold on full inspiration, from the lung apices down to the lung bases. The scanning parameters were:

tube voltage:120 kV, tube current: 50 mA, rotation time: 0.5 s, slice thickness: 5 mm, matrix: 512 × 512,and breath-holding on full inspiration.

- MSCT in axial cuts with post processing reformation in coronal & sagittal planes.
- Study protocol:

  I-Initial CT had done for patients with symptoms that suggest COVID-19 infection.

  II-Follow up CT scan had done to assess prognosis of pulmonary changes.

  CT image analysis:
- All CT images were extracted from the Picture Archiving and Communication Systems (PACS) and imported into a dedicated workstation for image analysis.
- **Intra observer & inter observer agreement**(through 2 expert radiologists with 20 and 15 years experience in diagnostic Imaging reviewed all CT images after the candidate independently).
- Image analysis focused on features of the lesion in each patient included:(a) distribution characteristics, (b) number of lobes involved, (c) patterns of the lesion (e.g. ground glass opacification, consolidation, crazy paving pattern), (d) other signs in the lesion (e.g. interlobular septal thickening, air bronchogram sign) and (e) other findings (e.g., adjacent pleura thickening, pleural effusion)
- Imaging results findings had tabulated and analyzed with comment on the CO-RADS which includes five grades as follows:

CO-RADS	Probability
CO-RADS 1	No
CO-RADS 2	Low
CO-RADS 3	Indeterminate
CO-RADS 4	High
CO-RADS 5	Very high

- All patients were subjected to PCR to confirm Imaging diagnosis.

Statistical analysis:

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp). Significance of the obtained results was judged at the 5% level.

RESULTS

Out of the studied patients, 165 (63.5%) patients were males and 95 (36.5%) females. Mean age of enrolled patients was 48.87 ± 16.28 years with range between 18 and 82 years. 256 (98.5%)patients had fever followed by 198 (76.2%) had dry cough and 112 (43.1%) had dyspnea. According to clinical severity, 86 (33.1%) patients were mild, 82 (31.5%) patients were moderate and 92 (35.4%) patients were severe. Baseline data of enrolled patients are summarized in **Table 1**.

It was noticed that there were 231 of the studied patients(88.8%) had ground Glass opacity and 156 patients(60%) had consolidations. There were 176 patients (67.7%) had bilateral GGO. There were 152 patients (58.5%) had GGO at more than 4 lobes and 79 patients (30.4%) had GGO at less than 4 lobes. There were 94 patients (36.2%) had GGO area size larger than 1/3 of lobe. as shown in **Table 2.**

Of the 260 patients,there were 56 patients (21.5%) had crazy paving appearance, 48 patients (18.5%) had pleural thickening, 44 patients (16.9%) had air bronchogram sign, 26 patients (10%) had vacuolar sign, 16 patients (6.2%) had subpleural lines,12 patients (4.6%) had pleural effusion,, 10 patients (3.8%) had halo sign, and 8 patients (3.1%) had reversed halo sign, respectively (**Table 3**).

There were 5 grades of CO-RADS with 24 patients had CO-RADS 1, 4 patients had CO-RADS2, 38patients had CO-RADS 3,18 patients had CO-RADS4 and 176 patients had CO-RADS 5. Regarding PCR relative to CO-RADS, it was noticed that CO-RADS 3 or greater had positive PCR, CO-RADS 1,18patients had positive PCR and 6 patients had negative PCR. While CO-RADS 2 had negative PCR, as shown in **Table 4.**

In our study: as it was catastrophic pandemic, Follow up CT results can be obtained only for 60 Pts. 48 (18.4%) patients of them showed progressive course and 12 patients (4.6%) showed regression of the disease.(**Table 5**)

It was noticed that there was highly statistically significant difference between clinical severity of studied groups and GGO in terms of Number ofaffected lobes and Size>1/3 of lobe. The data is summarized in **Table 6**.

CT (CORADs) showed 92.4% sensitivity, 100% specificity, PPV 100%, NPV 34.5% with AUC of 0.947.(**fig. 1**)&(**Table 7**)

DISCUSSION

COVID-19 is a new disease outbreak with potentially far-reaching public health pandemic disease. MSCT is a key component of the diagnostic work-up for patients with suspected infection. Numerous researches have established the important contribution of MSCT chest in diagnosing COVID-19 pneumonia. In the majority of PCR-positive patients, CT scan yields a typical pattern with 97% sensitivity in certain studies**.**[9]

In a patient with a history of close contact with a COVID-19 infected patient, early manifestation of bilateral, multifocal, and peripheral ground glass opacities on a chest CT scan might be a sign of a COVID-19 infection. Thus, chest CT is suggested as an important tool for COVID-19 infection diagnosis. MSCT can detect lung abnormalities with high sensitivity, which is quite helpful for early diagnosis of the disease that can trigger early treatment, which facilitates the containment of this emergency disease.[10]

In the current study we found that there were 63.5% (n=165)of the studied cases were males and 36.5%(n=95) were females, findings are in agreement with **Ahmed et al.**[11] reported that there were 106 females representing 53.5% of total cases and 92 males representing 46.5%.

In our study, we found that there were 98.5% of the studied cases had fever as clinical symptom, 76.2% had dry cough and 43.1% had dyspnea. This is in agreement with A study performed by **Hafez** [12] who found that fever and lower respiratory symptoms are the most common presenting symptoms in 69.5% and 66% of the patients, respectively.

Regarding the presence of GGO and its bilaterality: we found that there were 88.8% had GGO. There were 67.7% had it bilateral. 58.5% had GGO at <4 lobes and 30.4% had GGO at >4 lobes. There were 36.2% had GGO occupying >1/3 of lobe. This is in agreement with **Bao et al.**[13] who Found that GGO is the most common abnormality 40%–83% detected in this disease. **Salehi et al.**[14] reported bilateral involvement in 87.5% of their patients.

Bao et al.[13] reported that consolidation is the second most common presentation of the disease 22%–43%. Another study done by **Chung et al.**[1] they found consolidation in 29% (n=6) among 21 patients. In our study, it was noticed that there were 60.0% had consolidation.

In our study, we found that there were 21.5% of the studied cases had crazy paving appearance. A study performed by **Ye et al.**[15] who stated that crazy paving pattern has been found in 10%–15% of COVID-19 pneumonia patients in recent studies. Another study done by **Bernheim et al.**[16] who reported that the crazy paving pattern was reported in 5-36% of COVID-19 patients.

Zhou et al.[17] reported that results were found in a meta analysis study with 4121 patients, in which pleural thickening 27.1% was found to be more prevalent than pleural effusion 5.3%. Also concluded that sub pleural lines have been reported in 2%–33%.In our study, we found that there were 18.5% had pleural thickening, 4.6% had pleural effusion and 6.2% of the studied cases had sub pleural lines.

Regarding the presence of halo sign, reversed halo sign and vacuolar sign **Caruso et al.**[18] reported that halo sign had been reported in 12%–17.6% of COVID-19 pneumonia cases. **Zuo**[19] mentioned that reversed halo sign had been reported in around 4% of COVID-19 pneumonia patients. In our study, we found that there were 3.8% had halo sign, 3.1% had reversed halo sign and 10.0% had vacuolar sign.

In our study, it was noticed that there was highly statistically significant correlation between clinical severity of thestudied groups and radiological signs in terms of number of GGOs at lobes and their size>1/3 of lobe as we found that 80 patients had GGOs occupying > 4 lobes were classified as severe and 92 patients had GGOs occupying >1/3 of lobe were classified as severe who admitted to the intensive care unit to take COVID-19 treatment protocol, while moderate cases isolated at hospital room and mild cases isolated at the home. This is in agreement with **Yu et al**.[20] who reported that severe form patients were more likely to have opacities involving nine or more segments. Individual opacities also tended to involve a larger extension of the lung parenchyma in the severe form of disease. All patients with severe symptoms were admitted to the intensive care unit, and the length of hospital stay was longer than that of patients with mild disease.

De Smet K et al.[21] reported that CT with CO-RADS had good diagnostic performance in symptomatic individuals as groups with CO-RADS 3 or greater showed positive PCR. This is in agreement with our results, we found that CO-RADS 3 or greater had positive PCR while CO-RADS 2 had negative PCR and finally CO-RADS 1 (n=24),18 patients had positive PCR and 6 patients had negative PCR.

Regarding the follow up results, **Xu et al.**[10] found that 52 patients out of 90 patients repeated a chest CT examination after 1–6 days. Among them, 10 patients (19%) had no changes, 4 patients (8%) had disease resolution, and 38 patients (73%) had disease progression. Our current follow up CT results, CT scan had repeated for 60 patients revealed that there were 4.6% (n=12) exhibited regression coarse, 18.4% (n=48) had progression.

Ourresults, it was noticed that MSCT had 92.4% sensitivity, 100% specificity**,** this is in agreement with **Kim et al.**[22] who reported that the sensitivity of chest CT for diagnosis of COVID-19 pneumonia is reported at 90%–94%.

Limitations of the study:

This study had some limitations as it's a single centre study with limited number of Follow up CT which might help in more judgment of the infection course.

Conclusion

MSCT is sensitive to assess the parenchymal lung changes in patients with suspected COVID -19; and the determining the lesion and its grading. GGOs with or without consolidation in a bilateral predominant distribution were the most common findings in COVID-19 pneumonia. According to MDCT findings, the clinical severity is determined as GGOs occupying more than 4 lobes and more than 1/3 of lobe were classified as severe infection which can affect the plan of treatment directions either at the hospital or at the home as severe cases isolated and treated at ICU while moderate cases treated at hospital room and mild cases treated at home.

Recommendation

Because of non contrast chest MSCT can detect minor lung lesions in patients even at an early stage of disease and some patients with suspicion of COVID-19 pneumonia may have negative initial RT-PCR results for COVID-19. We recommend chest MSCT to support faster triage when access to the test kits is limited or when there is a concern for false negative test

result demonstrating its utility in guiding the diagnosis and early treatment which facilitates the limitation of this emergency disease.

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Table Legends

Table1: Baseline data of enrolled patients (n = 260),Major clinical symptoms & Clinical severity.

Table2:Distribution of the studied cases according to Cardinal CT findings (ground Glass opacity& consolidation).

Table3: Distribution of the studied cases according to other CT findings.

Table4: Distribution of the studied cases according to CO-RADS relative to PCR.

Table5: Distribution of the studied cases according to follow up CT results.

Table6: Relation between clinical severity and Ground Glass opacity.

Table7: Validity (AUC, sensitivity, specificity) for Diagnostic accuracy of CO_RADS (CT) in detection of COVID-19 infection

Figure Legends

Fig. 1: Diagnostic accuracy of MSCT in detection of COVID-19 findings.

Fig. 2: A 42 year old female patient with history of past contact with COVID-19 positive patient presented by fever with Positive RT-PCR and mild clinical severity.

- Non enhanced MSCT examination findings:

A. Axial, B. Coronal and C. Sagittal CT images show subtle single focus of GG opacity (**red arrow**) at upper lobe of left lung.

- Radiological Diagnosis(CT): CO-RADs 3.
- Management: COVID-19 protocol treatment at home.

Fig.3: A 5o year old male patient presented by fever, and dry cough with Positive RT-PCR and mild clinical severity.

- Non enhanced MSCT examination findings:

A. axial CT image(first scan) shows normal study at time of first presentation. B. and C. first follow up study, axial CT images show multi focal GGOs (***white arrows***) and consolidation (**red arrows**) scattered peripherally mainly at both lower lobes. D. and E. second follow up study, axial CT images show previous consolidations returns to GGOs(***white arrows***) and new patches of GGOs appear with fissural effusion(**black arrow**).

- Radiological Diagnosis(CT): First scan diagnosis is

CO-RADs 1.

First (5days later)& Second follow up study (9 days after first follow up) are CO-RADs 5

- Follow up: disease progression and became clinically severe.
- Management: COVID-19 protocol treatment at ICU.

Fig.4: A 63 year old male patient with history of past contact with COVID-19 positive patient, presented by fever with Positive RT-PCR and mild clinical severity.

- Non enhanced CT examination findings:

A. Axial CT image(first scan) shows speculated lung mass (white arrow) and no typical features for COVID-19.B, C. and D. first follow up study, axial CT images show multifocal GGOs (**black arrows**) and consolidations (**red arrows**) peripherally located at both lungs. E. second follow up study, axial CT images show previous GGOs and consolidations disappears and replaced by subpleural line extending parallel to pleura(**blue arrow**) indicate regression of disease.

- Radiological Diagnosis(CT): First scan diagnosisis CO-RADs 1

First Follow up scan (24days later) diagnosisis CO-RADs 5

Second Follow up (2months later after first follow up scan) diagnosis is CO-RADs 1

- Follow up: Regression of the disease
- Management: COVID-19 protocol treatment at hospital room then he completed treatment at home.

Fig.5: A 55 year old male patient presented by fever and dry cough with Positive RT-PCR and mild clinical severity.

- Non enhanced MSCT examination findings: first scan A. and B. Axial CT image show multiple bilateral patches of GGOs(***white arrow***) and consolidation(**black arrow**) peripherally located. C.Axial and D. Sagittal CT images, follow up study show new patches of GGOs appear located in curvilinear pattern (***white arrow***) and crazy paving pattern(**red arrow**).
- Radiological Diagnosis(CT): First scan and follow up scan (11days later) are CO-RADs 5
- Follow Up: disease progression and became moderate clinical severity.
- Management: COVID-19 protocol treatment at hospital room.

N.B: Azygous fissure (**blue arrow**, image C) is also seen as an incidental finding.

Fig.6: A 40 year old male patient presented by fever and dry cough with Positive RT-PCR and mild clinical severity.

- Non enhanced MSCT examination findings:

A, B. and C. Axial CT images (first scan) show: multifocal patches of GGO (***white arrow***) and consolidations (**red arrow**) located only at upper lobe of left lung. D. Axial CT image, follow up study shows no abnormalities at the lung parenchyma.

- Radiological Diagnosis(CT):

First scan diagnosis is CO-RADs 4.

Follow up scan (17 days later) diagnosis is CO-RADs1

- Follow Up: complete resolution of the disease
- Management: COVID-19 protocol treatment at hospital room.

Fig.7: A 24 year old female patient presented by fever, dry cough and dyspnea with Positive RT-PCR and moderate clinical severity.

- Non enhanced MSCT examination findings:

A. and B.: Axial CT images (first scan) show multiple patches of GGO(***white arrow***) and consolidations(**black arrow**) peripherally located at both lungs. C. Axial CT image (follow up study) shows no abnormalities at the lung parenchyma.

- Radiological Diagnosis(CT):

First scan diagnosis is CO-RADs5

Follow up scan (1month later) diagnosis is CO-RADs1

- Follow Up: Complete resolution of the disease.

Management: COVID-19 protocol treatment at hospital room.

Table (1): Baseline data of enrolled patients (n = 260),Major clinical symptoms & Clinical severity.

Demographic data	No.	%
Sex		
Male	165	63.5
Female	95	36.5
Age (years)		
Min. – Max.	18.0 – 82.0	
Mean ± SD	48.87 ± 16.28	
Median (IQR)	51.0 (35.0 – 62.0)	
Clinical symptoms		
Fever	**256**	**98.5**
Dry cough	**198**	**76.2**
Dyspnea	**112**	**43.1**
Clinical Severity		
Mild	**86**	**33.1**
Moderate	**82**	**31.5**
Severe	**92**	**35.4**

Table (2): Distribution of the studied cases according to Cardinal CT findings (ground Glass opacity& consolidation).

Cardinal CT findings	No.	%
Ground glass opacity	231	88.8
Consolidation	156	60.0
Ground Glass opacity	**No.**	**%**
Bilateral		
Yes	176	67.7
No	84	32.3
Number of lobes		
<4	79	30.4
>4	152	58.5
Size>1/3 of lobe		
Yes	94	36.2
No	166	63.8

Table (3): Distribution of the studied cases according to other CT findings

	No.	%
Crazy paving appearance	56	21.5
Pleural thickness	48	18.5
Air bronchogram sign	44	16.9
Vacuolar sign	26	10.0
Sub pleural lines	16	6.2
Pleural effusion	12	4.6
Halo sign	10	3.8
Reversed halo sign	8	3.1

Table (4): Distribution of the studied cases according to CO-RADS relative to PCR

CO-RADS		PCR	
	No.	**Positive(N0.)**	**Negative(No.)**
CO-RADS 1	24	18	6
CO-RADS 2	4	0	4
CO-RADS 3	38	38	0
CO-RADS 4	18	18	0
CO-RADS 5	176	176	0

Table (5): Distribution of the studied cases according to follow upCT results (n=60)

Follow up CT results	Yes	
	No.	**%**
Progression	48	18.4
Regression	12	4.6

Table (6): Relation between clinical severity and Ground Glass opacity

Ground Glass opacity	Clinical Severity						χ^2	P
	Mild (n = 86)		Moderate (n = 82)		Severe (n = 92)			
	No.	%	No.	%	No.	%		
Number of lobes								
<4	53	61.6	14	17.1	12	13.0	163.959*	<0.001*
>4	4	4.7	68	82.9	80	87.0		
Size>1/3 of lobe								
Yes	0	0.0	2	2.4	92	100.0	251.547*	<0.001*
No	86	100.0	80	97.6	0	0.0		

χ^2: **Chi square test** *: Statistically significant at $p \leq 0.05$

Table (7): Validity (AUC, sensitivity, specificity) for Diagnostic accuracy of CO_RADS (CT) in detection of COVID-19 infection.

	AUC	p	95% C.I	Cutoff	Sensitivity	Specificity	PPV	NPV
CO_RADS (CT)	0.947*	<0.001*	0.918-0.976	>2	92.4	100	100	34.5

AUC: Area Under a Curve

CI: Confidence Intervals

NPV: Negative predictive value

*: Statistically significant at $p \leq 0.05$

#Cut off was choose according to Youden index

p value: Probability value

PPV: Positive predictive value

Fig.1

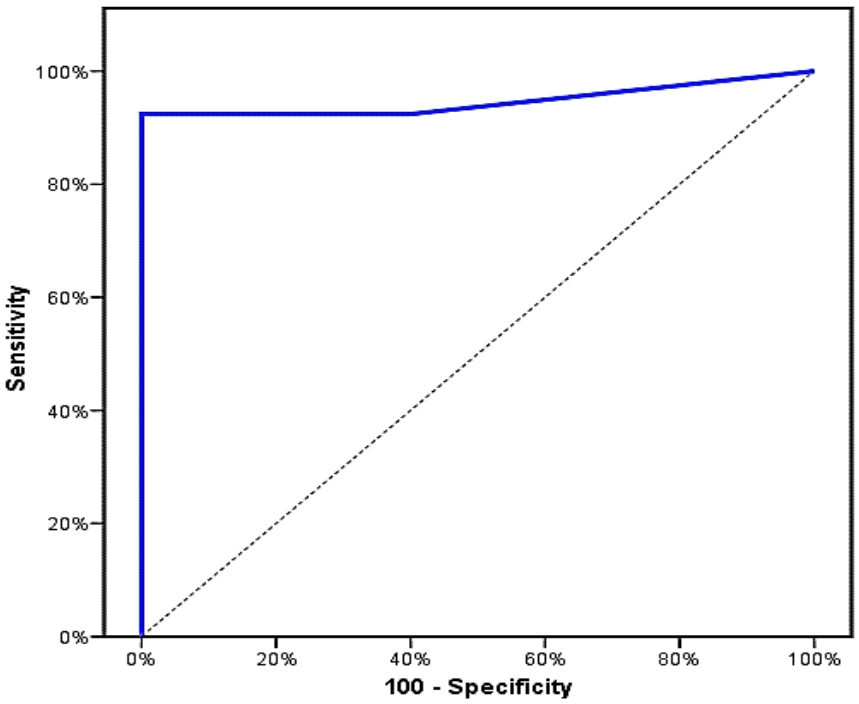
100%
80%
60%
40%
20%
0%
Sensitivity
0%
20%
40%
60%
80%
100%
100 - Specificity

Fig.2

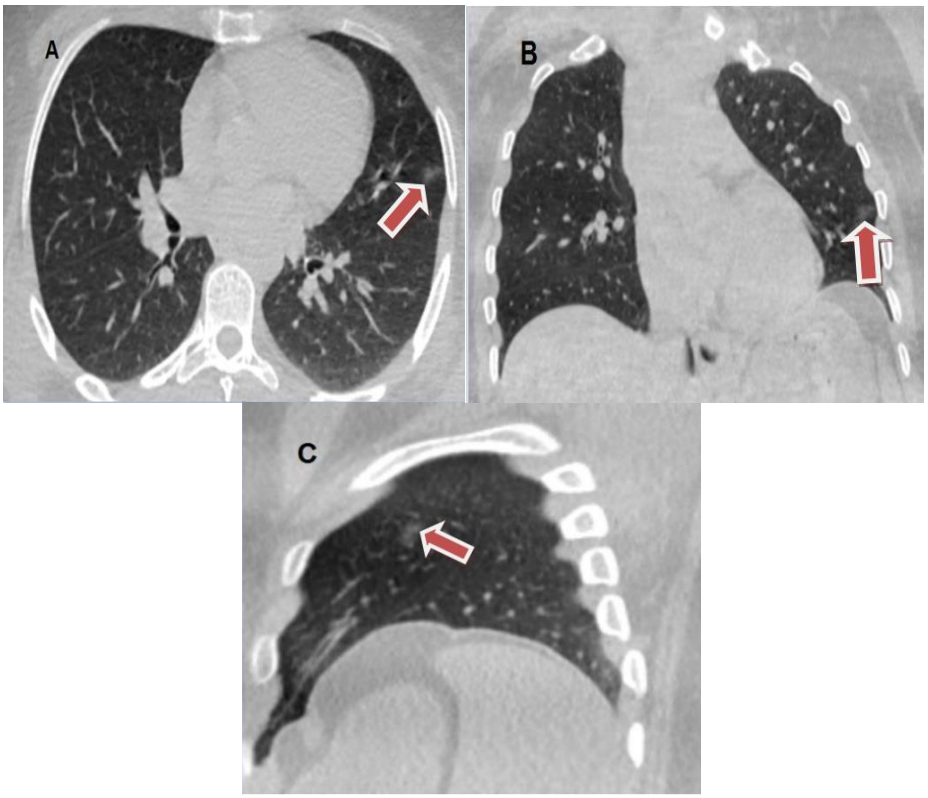
A
B
C

Fig.3

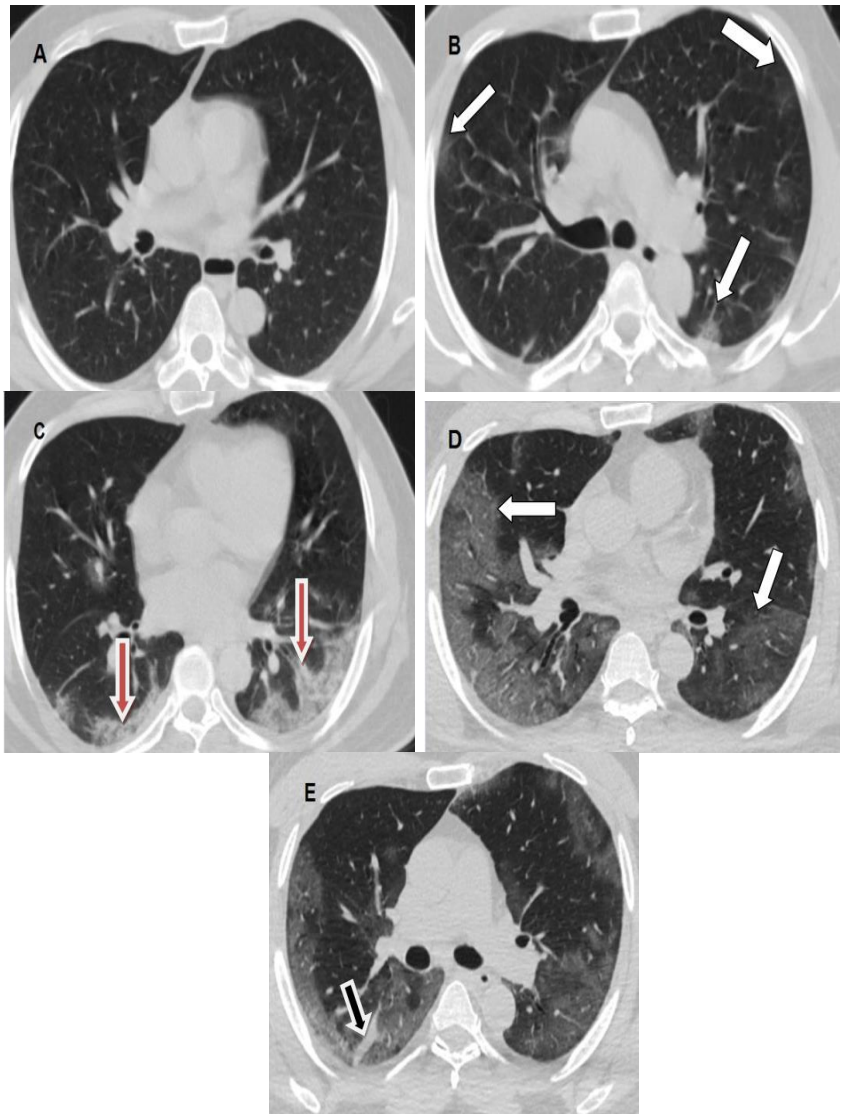

Fig.4

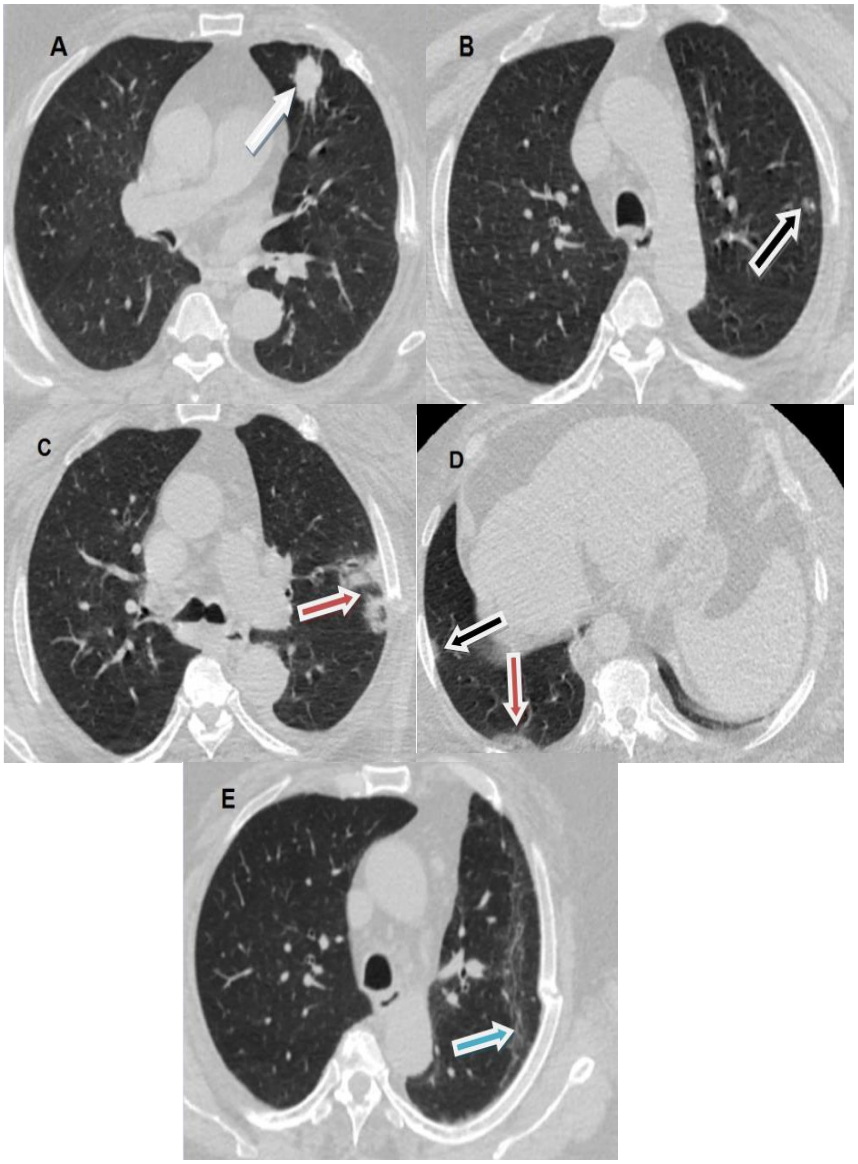

Fig.5

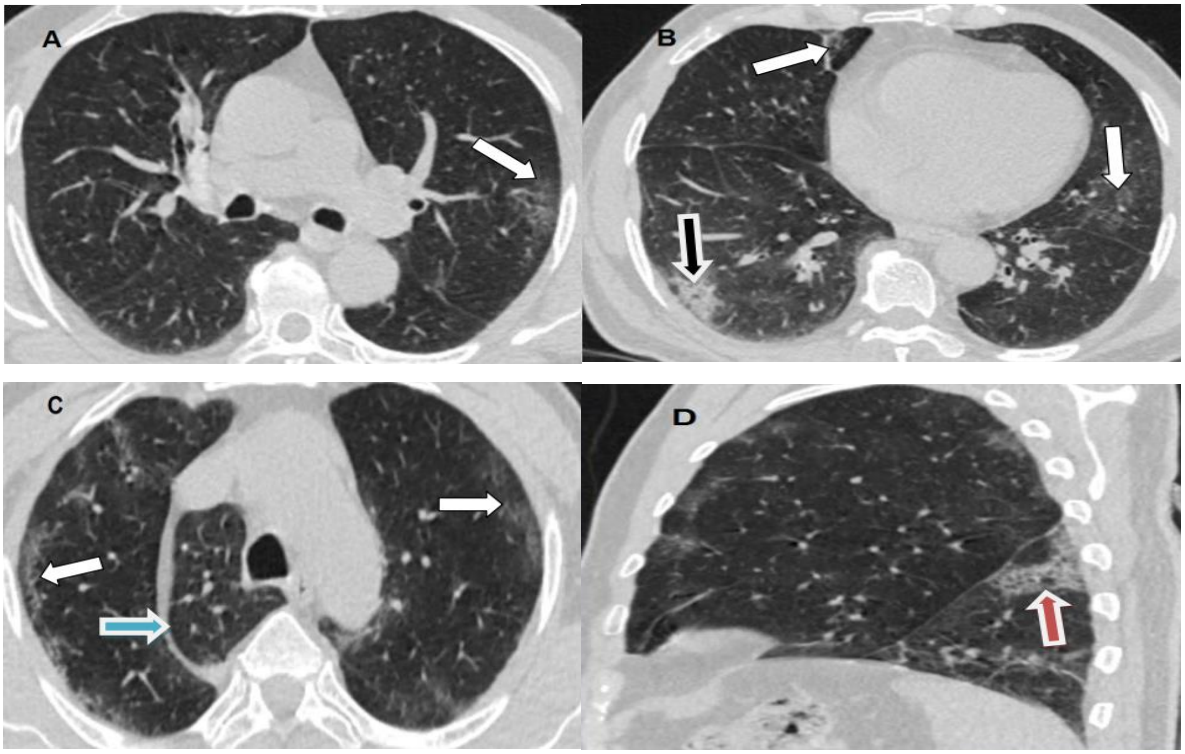

Fig.6

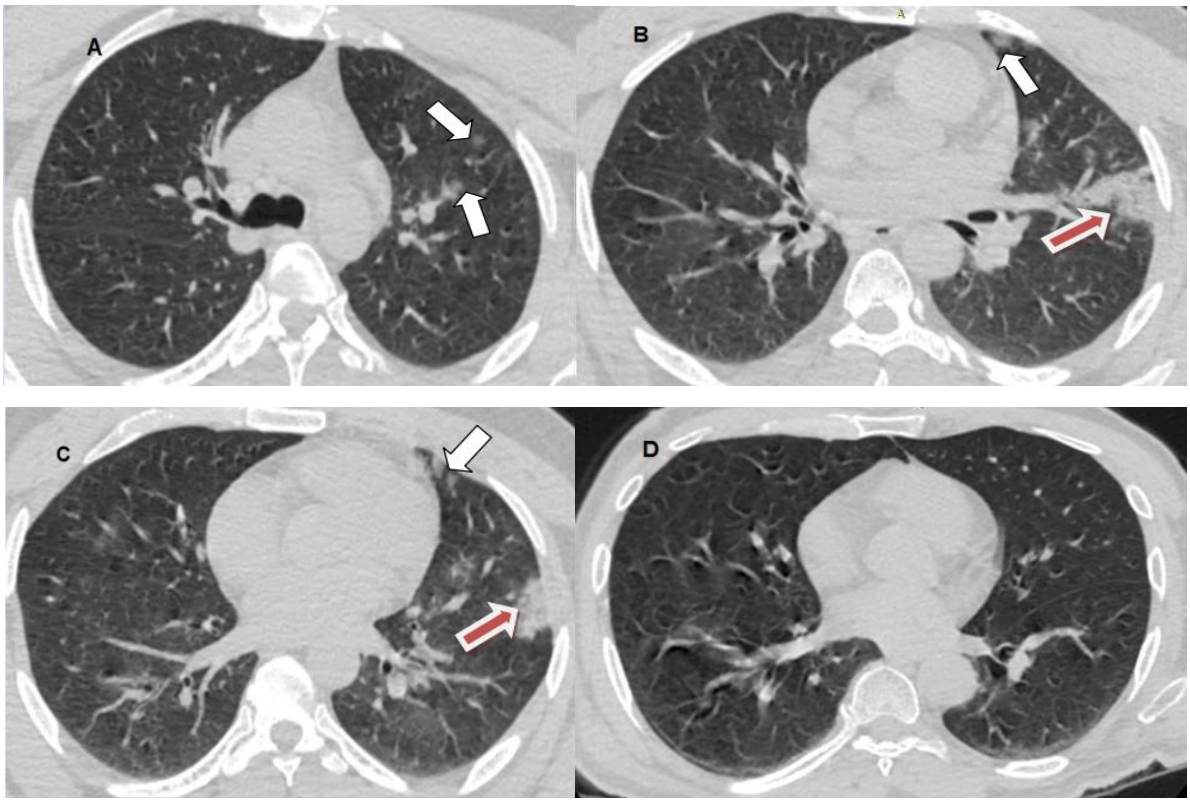

Fig.7