Use of CT Scan in Pregnant Patients

- While routine exposure to ionizing radiation is discouraged during pregnancy, current guidelines recommend that chest CT should not be withheld when clinically indicated as the radiation dose from a single scan remains sub-threshold to cause teratogenic effects when appropriate precautions are taken

- CT scans can play an important role in early screening, dynamic observation, and efficacy evaluation of suspected or confirmed cases of pregnant women with COVID-19.

- The consequences of radiation exposure can categorize into four broad groups, including pregnancy loss, malformation, developmental delay or retardation, and carcinogenesis.
- Pregnancy loss most often happens when radiation exposure happens during early gestation (less than two weeks).
- Malformations of body parts and developmental delays occur during the organogenesis period (2 weeks to 8 weeks) and are dependent on the radiation dose.Below the threshold level of radiation exposure, there is minimal disruption of organogenesis. Above the threshold, the degree of malformation is related to the dose of the radiation.
- Carcinogenesis the probability of developing cancer increases with the increase in the dose of radiation.

- The fetus radiation dose below 50 mGy is considered safe and not cause any harm. According to the Center for Disease Control (CDC), radiation dose between 50 mGy to 100 mGy is regarded inconclusive in terms of impact on the fetus. Doses above 100 mGy, especially doses above 150 mGy, are viewed as the minimum amount of dosage at which negative fetal consequences will occur, based on observation. The majority of the diagnostic studies performed during the pregnancy are below the threshold level.

- The effect of radiation exposure during pregnancy also depends on the gestational age of the fetus. The embryo/fetus is most susceptible to radiation during organogenesis (2 to 8 weeks gestational age) and in the first trimester. The fetus is more resistant to the radiation during the second and third trimester.

Plain Films

- A single plain radiograph does not contribute to a significant radiation dose to the fetus. The estimated radiation dose to the fetus varies and ranges from 0.001 mGy to 10 mGy depending on the type of the study.
- The highest radiation dose is the lumbar spine radiograph, which has a maximal fetal radiation dose of 10 mGy.
- Nonetheless, even fetus radiation exposure for the lumbar spine radiograph is significantly lower than the threshold limit of the safe radiation exposure dose of 50 mGy, radiation level that is considered safe and without significant harm
- Radiation doses from multiple plains films can easily accumulate.

Computed Tomography

- CT contributes to a significant amount of fetal radiation. The amount of fetus radiation exposure again varies by the type of study with CT pelvis contributing the highest amount of fetal radiation of 50 mGy.This dose is right at the limit above which there is a documented negative impact to the fetus
- Unnecessary multiphasic protocols should get simplified into a single-phase protocol.

- In humans, growth restriction, microcephaly, and intellectual disability are the most common adverse effects from high-dose radiation exposure.
- It appears that the risk of central nervous system effects is greatest with exposure at 8–15 weeks of gestation.
- Fetal risk of anomalies, growth restriction, or abortion have not been reported with radiation exposure of less than 50 mGy, a level above the range of exposure for diagnostic procedures.

Table 2. Effects of Gestational Age and Radiation Dose on Radiation-Induced Teratogenesis

Gestational Period	Effects	Estimated Threshold Dose*
Before implantation (0–2 weeks after fertilization)	Death of embryo or no consequence (all or none)	50–100 mGy
Organogenesis (2–8 weeks after fertilization)	Congenital anomalies (skeleton, eyes, genitals)	200 mGy
	Growth restriction	200–250 mGy
Fetal period	**Effects**	**Estimated Threshold Dose***
8–15 weeks	Severe intellectual disability (high risk)†	60–310 mGy
	Intellectual deficit	25 IQ-point loss per 1,000 mGy
	Microcephaly	200 mGy
16–25 weeks	Severe intellectual disability (low risk)	250–280 mGy*

*Data based on results of animal studies, epidemiologic studies of survivors of the atomic bombings in Japan, and studies of groups exposed to radiation for medical reasons (eg, radiation therapy for carcinoma of the uterus).

†Because this is a period of rapid neuronal development and migration.

Modified from Patel SJ, Reede DL, Katz DS, Subramaniam R, Amorosa JK. Imaging the pregnant patient for nonobstetric conditions: algorithms and radiation dose considerations. Radiographics 2007;27:1705–22.

Table 3. Fetal Radiation Doses Associated With Common Radiologic Examinations ⇦

Type of Examination	Fetal Dose* (mGy)
Very low-dose examinations (<0.1 mGy)	
Cervical spine radiography (anteroposterior and lateral views)	<0.001
Head or neck CT	0.001–0.01
Radiography of any extremity	<0.001
Mammography (two views)	0.001–0.01
Chest radiography (two views)	0.0005–0.01
Low- to moderate-dose examinations (0.1–10 mGy)	
Radiography	
Abdominal radiography	0.1–3.0
Lumbar spine radiography	1.0–10
Intravenous pyelography	5–10
Double-contrast barium enema	1.0–20
CT	
Chest CT or CT pulmonary angiography	0.01–0.66
Limited CT pelvimetry (single axial section through the femoral heads)	<1
Nuclear medicine	
Low-dose perfusion scintigraphy	0.1–0.5
Technetium-99m bone scintigraphy	4–5
Pulmonary digital subtraction angiography	0.5
Higher-dose examinations (10–50 mGy)	
Abdominal CT	1.3–35
Pelvic CT	10–50
^{18}F PET/CT whole-body scintigraphy	10–50

Abbreviations: CT, computed tomography; PET, positron emission tomography.

*Fetal exposure varies with gestational age, maternal body habitus, and exact acquisition parameters.

Note: Annual average background radiation = 1.1–2.5 mGy, ^{18}F = 2-[fluorine-18]fluoro-2-deoxy-D-glucose.

Modified from Tremblay E, Therasse E, Thomassin-Naggara I, Trop I. Quality initiatives: guidelines for use of medical imaging during pregnancy and lactation. Radiographics 2012;32:897–911.

Proposed Imaging Guidelines for Pregnant Women Suspected of Having COVID-19

- In general, ionizing radiation must be avoided in pregnant women as much as possible.
- Its utilization must be narrowed to limited indications with a high level of protection.
- The maximum permitted dose of radiation exposure is below 50 mGy in pregnant women.
- The absorbed dose of radiation for a fetus whose mother undergoes chest x-ray and chest CT scan are 0.002 mGy and 0.2 mGy respectively, which are not associated with known adverse effects on fetal health and thus are safe .

- 1.It is prudent to avoid radiation imaging modalities such as chest x-ray or CT scans in pregnant women suspected of having COVID-19, as much as possible.

- 2.Chest x-ray or CT scan requests must be based on thorough examination, in case of investigating differential diagnoses of respiratory problems during the COVID-19 pandemic, along with other conditions like pulmonary edema etc. or appraisement of COVID-19 pulmonary infection in case of clinical indications.

- 3.The patient must be well informed of the necessity, benefits and possible risks of the imaging procedures (chest radiography or CT scan), by the attending physician.

- 4.If requested by the physician, the imaging procedure (chest x-ray or CT scan) maybe done if the following conditions apply from the admitted ward to the imaging department: The CT scan request in the hospital information system is marked in red, and in coordination with the radiology department admission, the pregnant patient is transferred to the ward when no other patient is there and the ward is disinfected. Also, the patients' files should be placed in the red cover and the patient's clothing should be marked with a sign related to high-risk patients, so that maximum protection measures can be implemented as soon as they enter the imaging section and eliminate any possible errors.

- 5.To minimize the dose of exposure, the minimum possible dose for radiography must be utilized and CT scans must be carried out in accordance with the low dose CT protocol.

- 6.When chest CTs and chest x-rays are indicated, local protection for the fetus (abdominal lead shields) must be utilized.

- 7.Standard personal protection equipment for the corona virus like masks, gloves, gowns, goggles, and disinfectants must be available for the patients, the accompanying people and all other personnel who are involved in the procedure, in accordance with the relevant protection protocols.

- 8.During the first trimester of pregnancy, the decision to proceed with chest x-ray or CT scan must be made with meticulous consideration of the risks involved. It is advisable to initially perform chest x-ray with abdominal shield and then proceed to CT only if the chest X-ray turns out to be inconclusive. During the 2nd and 3rd trimesters, low dose CT may be requested in the first stage.

- 9.The attending physician is responsible for making decisions on requesting or repeating imaging procedures and continuation or termination of pregnancy.

- 10.It is compulsory to use lead abdominal shields especially in the 1st trimester, even if it hampers visualization of the sub-diaphragmatic areas in the imaging field

راهنمای تشخیص و درمان کووید-۱۹ در بارداری

۱ .فاز ریوی متوسط

- د-اقدامات تصویر برداری: اقدامات تصویر برداری)رادیوگرافی ریه/ scan CTریه(بر اساس شرایط بیمار و تصمیم پزشک توصیه می شود سی تی اسکن در صورت لزوم باید انجام شود و دوز اشعه با توجه به اندازه آن باعث آسیب به جنین نخواهد شد.

راهنمای تشخیص و درمان کووید-۱۹ در بارداری

۲ .فاز ریوی شدید/ بحرانی

- -توصیه های رادیولوژیک:

انجام سی تی اسکن در صورت لزوم برای بررسی از نظر وسعت بیماری باید انجام شود و HRCT DOSE LOWدر بارداری مجاز می باشد. تکرار سی تی اسکن بر اساس شرایط مادر و اندیکاسیونهای خاص قابل انجام است

پروتکل low dose CT در تشخیص و پیگیری و روند درمانی بیماران کرونا

با توجه به نقش CT Scan در تشخیص و پیگیری و روند درمانی بیماران کرونا و با توجه به خطر اشعه، پروتکل با دوز پائین (low dose CT) تهیه شده توسط اساتید گروه رادیولوژی شهید بهشتی و انجمن رادیولوژی ایران به این شرح ارسال می شود:

HRCT در مقاطع inspiration با روش اسپیرال با دتکتور ۴ به بالا و بصورت یکنواخت KV=100-120 و mAs: 50-100

Pitch =0.8-1.5 single breath hold, spiral, thickness =1-3 mm برای همه بیماران با هر شرایط وزنی و body habitus انجام گردد.

Chest CT Scan Findings in Covid19 Infection

Initial CT-findings

- Initial CT-findings in COVID-19 cases include bilateral, multilobar ground glass opacification (GGO) with a peripheral or posterior distribution, mainly in the lower lobes and less frequently in the middle lobe .
  Consolidation superimposed on GGO as the initial imaging presentation is found in a smaller number of cases, mainly in the elderly population.
- Septal thickening, bronchiectasis, pleural thickening, and subpleural involvement are some of the less common findings, mainly in the later stages of the disease.
- Pleural effusion, pericardial effusion, lymphadenopathy, cavitation, CT halo sign, and pneumothorax are some of the uncommon but possible findings seen with disease progression.
- There is much overlap of the CT-pattern of COVID-19 with other viral pneumonias

intitial CT-patterns in COVID-19

Ground-glass opacification	88%
Bilateral involvement	88%
Posterior distribution	80%
Multilobar involvement	79%
Peripheral distribution	76%
Consolidation	32%

CT-changes over time

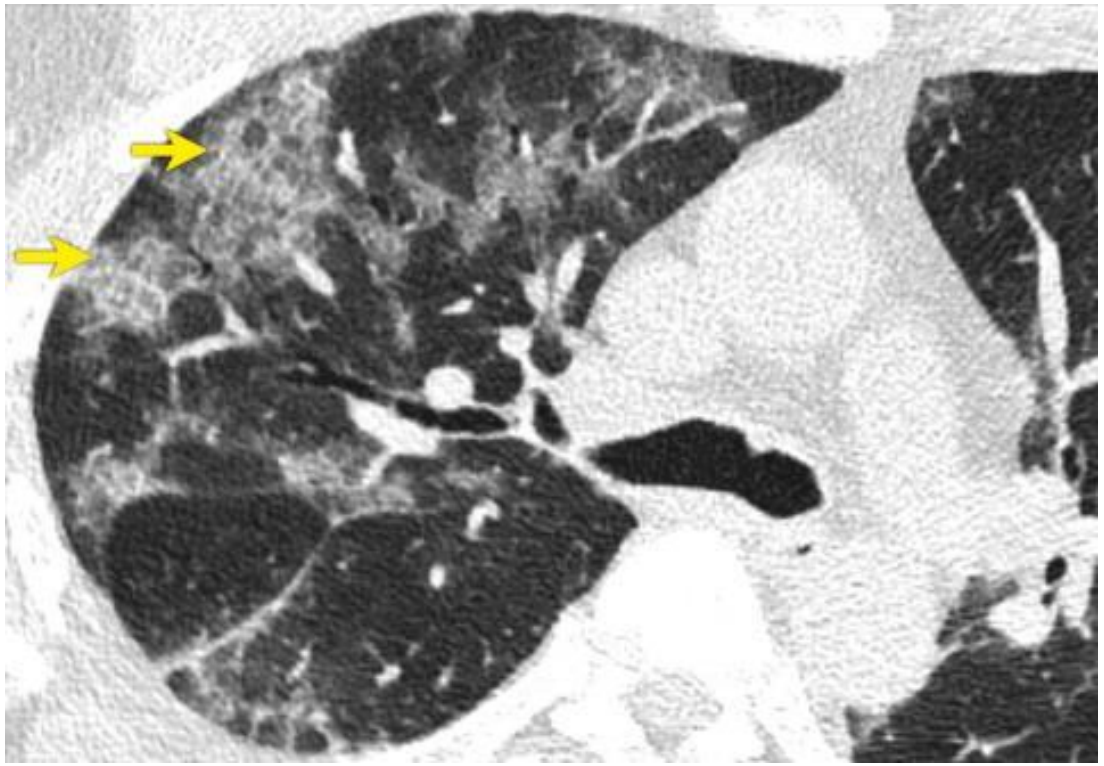
Early stage	0-4 days	GGO, partial crazy paving, lower number of involved lobes
Progressive stage	5-8 days	Progressive (5-8 days): Extension of GGO, increased crazy paving pattern
Peak stage	10-13 days	Consolidation
Absorption stage	≥14 days	Gradual resolution

Four stages of COVID-19 at chest CT have been described:

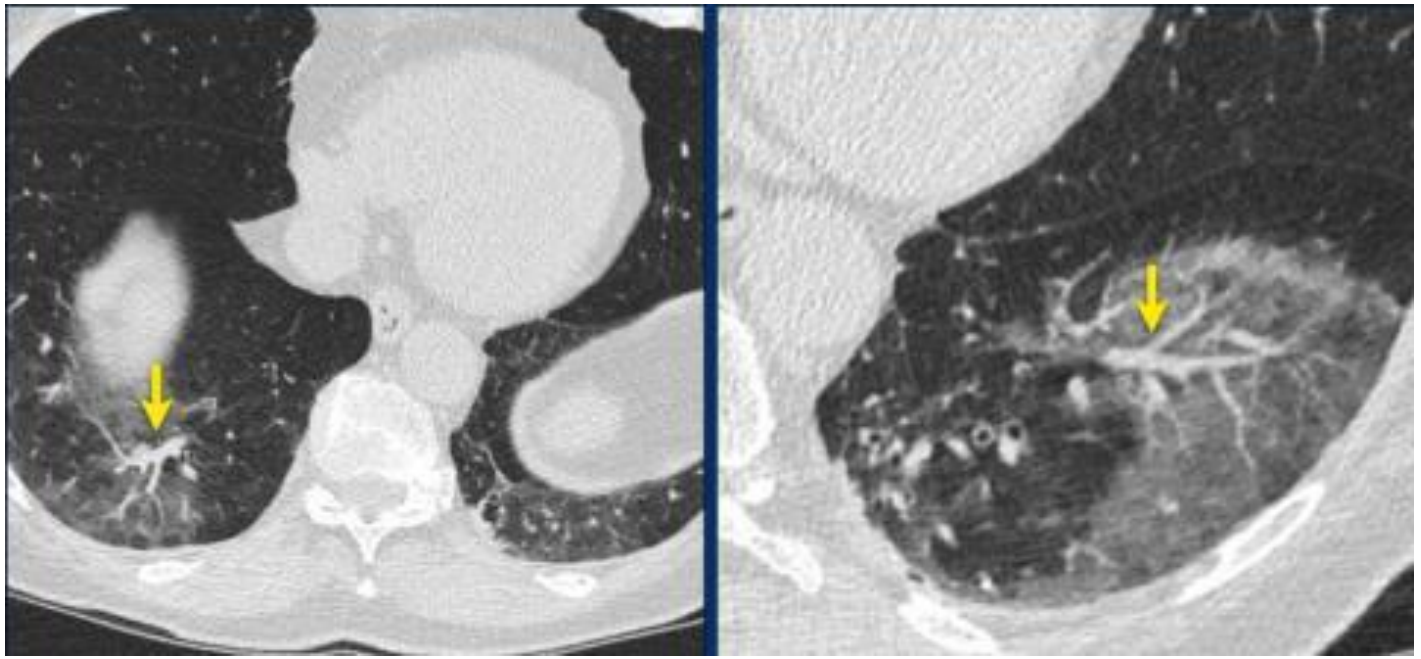
- *(a)* early stage (0–5 days after symptom onset), which is characterized by either normal findings or mainly ground-glass opacities
- *(b)* progressive stage (5–8 days after symptom onset), which is characterized by increased ground-glass opacities and crazy-paving appearance
- *(c)* peak stage (9–13 days after symptom onset), which is characterized by progressive consolidation
- *(d)* late stage (≥14 days after symptom onset), which is characterized by a gradual decrease of consolidation and ground-glass opacities, while signs of fibrosis (including parenchymal bands, architectural distortion, and traction bronchiectasis) may manifest

Ground glass opacities

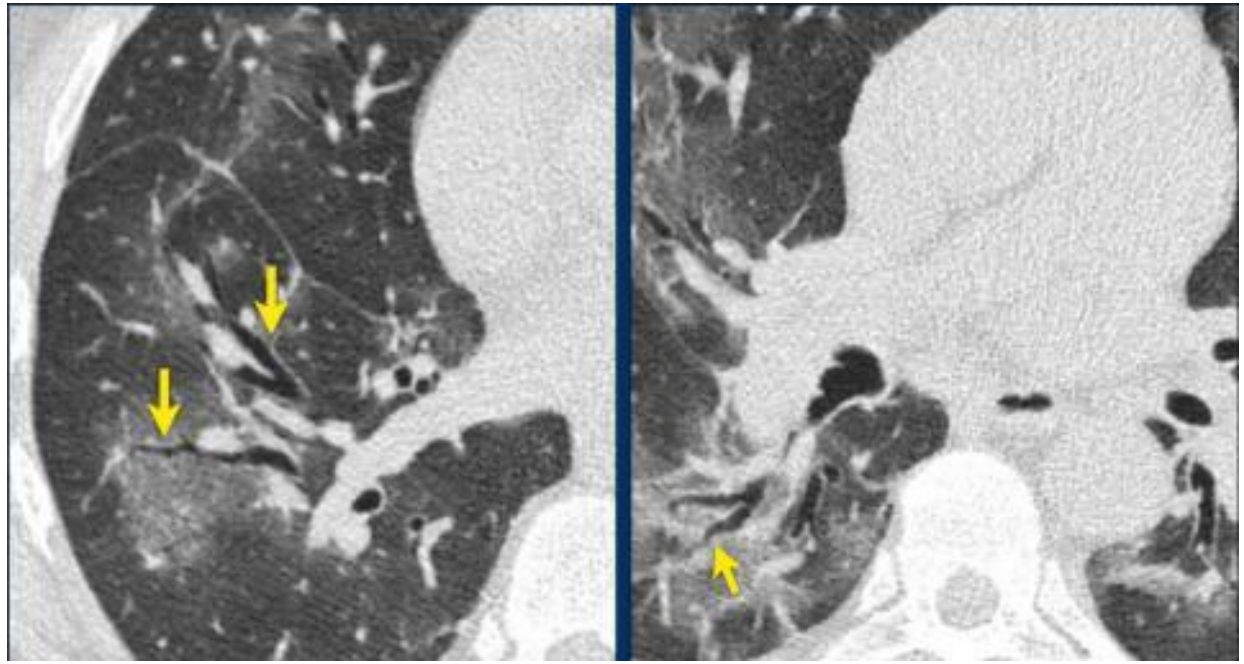
Crazy paving



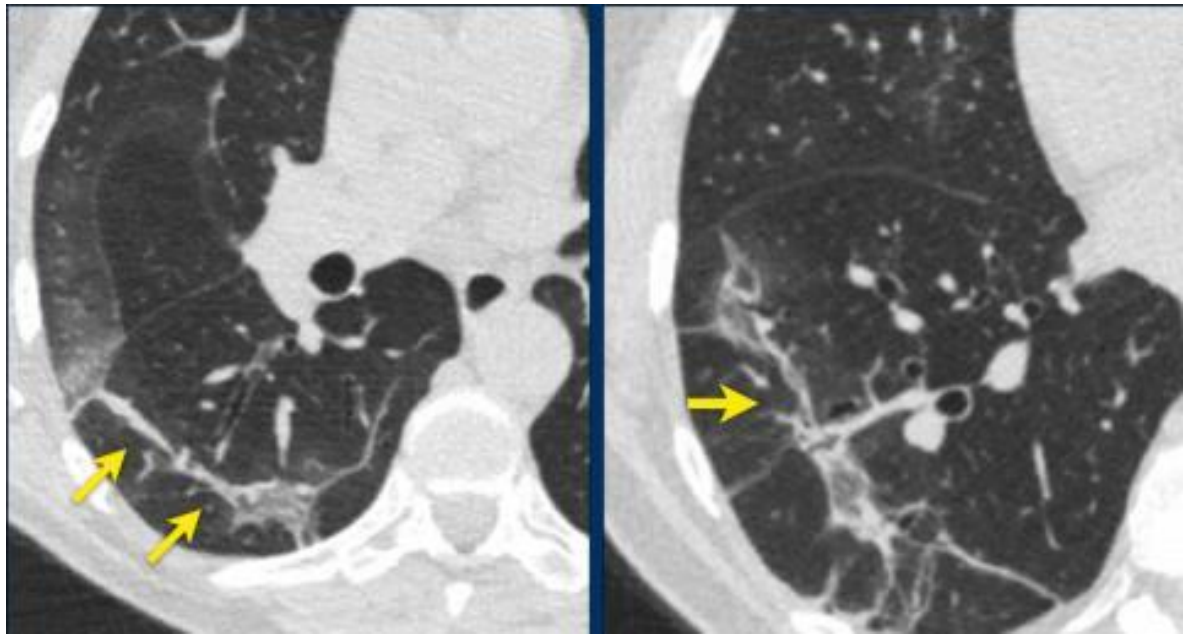
Vascular dilatation



Traction Bronchiectasis

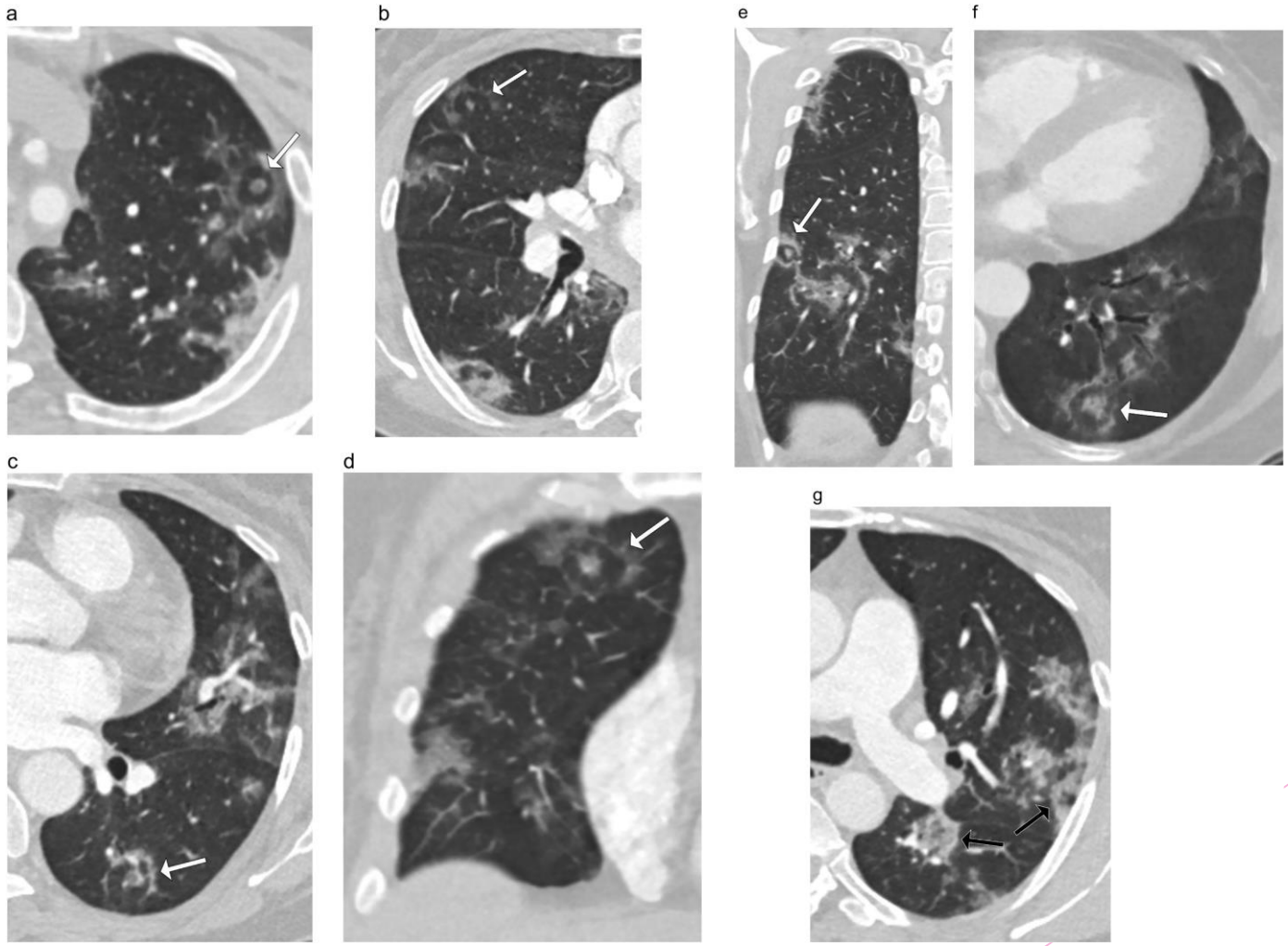


Sub pleural bands and Architectural distortion



The “bull’s eye sign”

A variant of the RHS and most likely represents the organizing phase of COVID-19 pneumonia



Chest CT Scan Findings

- The most common features on CT imaging of patients in the general population with COVID-19

multifocal, patchy, ground-glass opacities (GGOs) with or without superimposed consolidation in a peripheral or posterior distribution

Chest CT Scan Findings

- Most frequently pulmonary findings on chest CT of pregnant patients

ground-glass opacities (77.2)

posterior lung involvement (72.5%)

multilobar involvement (71.8%)

bilateral lung involvement (69.4%)

peripheral distribution (68.1%)

consolidation (40.9%)

Comparison between rates of imaging findings in pregnant patients and the general population

Imaging finding	Pregnant rate (%)	General population rate (%)
Bilateral involvement	69.4	79.0–87.5
Peripheral distribution	68.1	76.0–100
Posterior involvement	72.5	80.4
Multilobar involvement	71.8	78.8
Ground-glass opacities (GGOs)	77.2	88.0
Consolidation	40.9	21.0–31.8
Pleural effusion	30.0	5.0

- more frequently consolidation (40.9% vs. 21.0–31.8%) and pleural effusion (30.0% vs. 5.0%) in comparison to the general population

- Considering that consolidation and pleural effusion are indicative of more severe disease progression, results suggest that pregnant patients may be more prone to presentation at advanced disease stages

- Pregnant patients appear to present more commonly with more advanced COVID-19 CT findings compared to the general adult population

A 27-year old female with menopause for 38^{+2} weeks presented with fever and cough for 2 days.

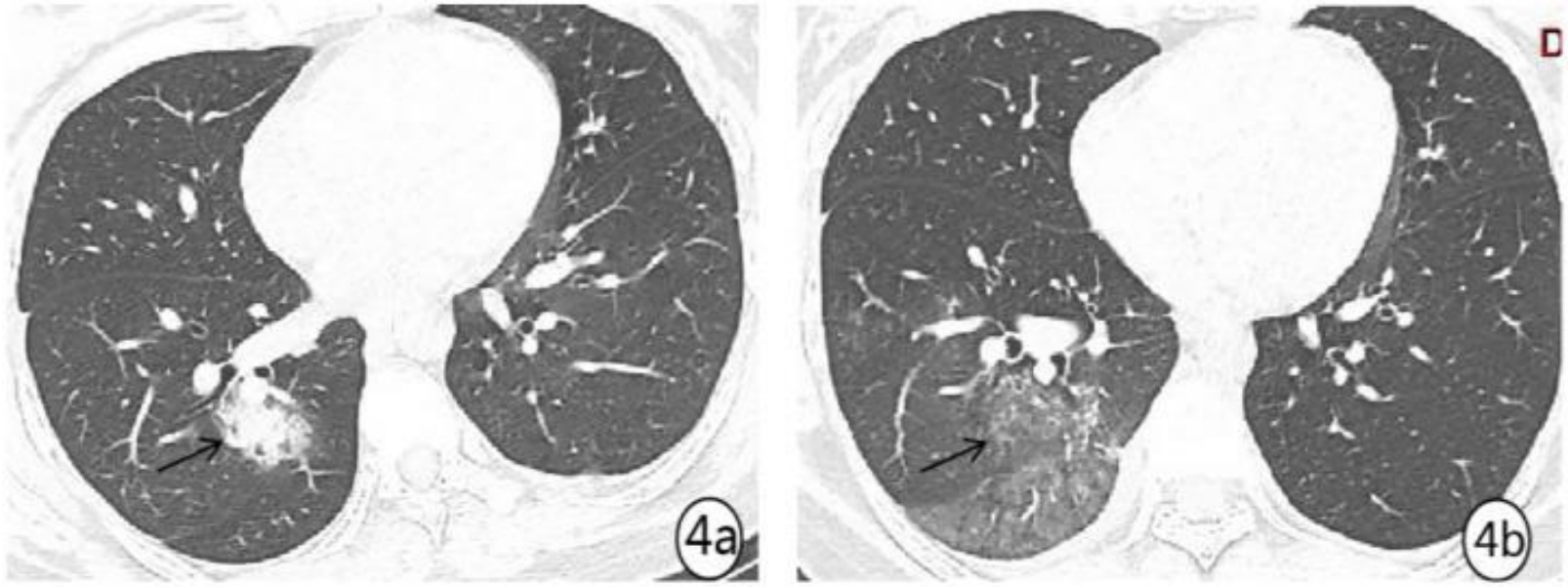
Her husband was diagnosed with COVID-19 three days ago. She was diagnosed with COVID-19. The left upper lobe and the dorsal segment of the right lower lobe showed patchy shadow. Faint density shadows were seen throughout the lungs, displaying a halo sign

A 27-year old female with menopause for 38^{+6} weeks was confirmed as positive for COVID-19.

Patchy consolidation could be seen in left lingular segment within sign of intra-bronchial air-bronchogram.
A small effusion in bilateral pleural cavity was confirmed.

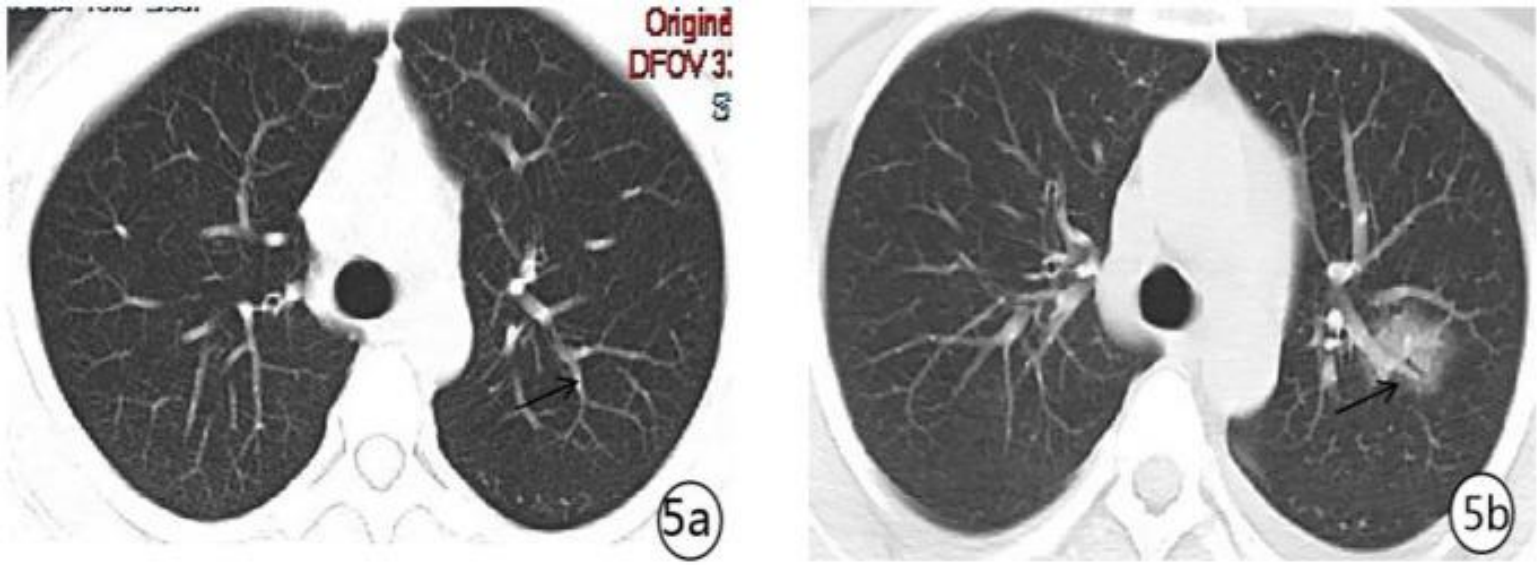
A 27-year old female with menopause for 37^{+3} weeks.

Mediastinal window showed bilateral pleural effusion



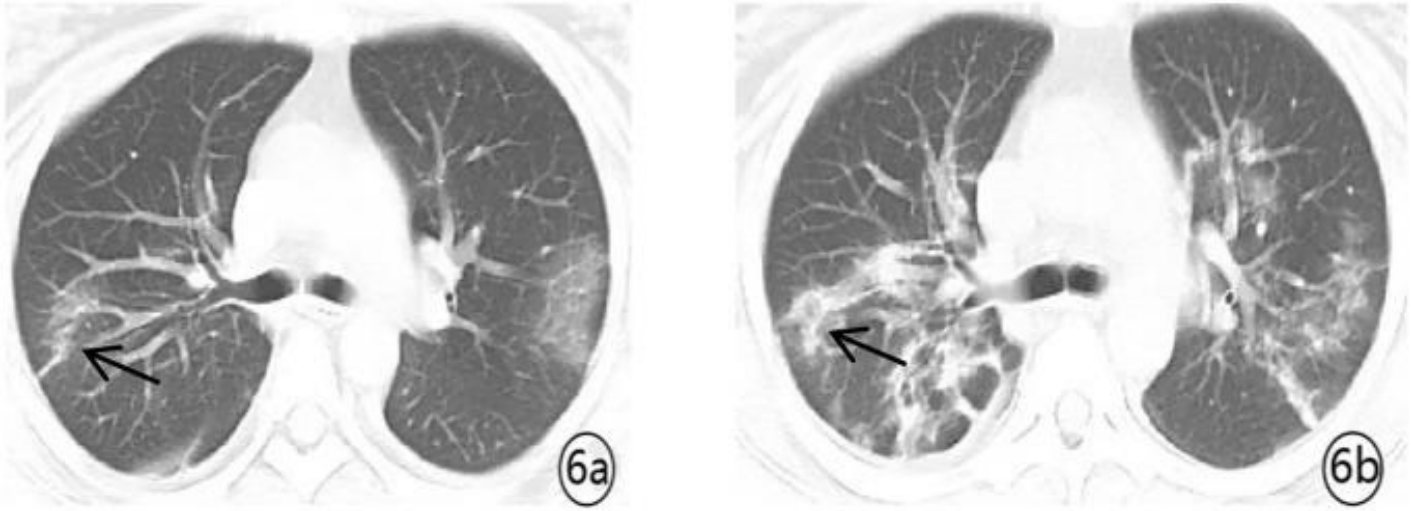
A 33-year old female with menopause for 37^{+2} weeks, was diagnosed with COVID-19.

(a) chest CT at admission. Patchy increased density was seen in the right lower lung, with bronchiectasis, increased small vascular network, and ground glass opacity (GGO) throughout. (b) same area as 4a after 3 days of treatment. A re-examination showed obvious absorption and thinning density of the lesion, which was replaced by light GGO



A 26-year old female with menopause for 36^{+2} weeks presented with fever and paroxysmal abdominal distension for 2 days.

She was diagnosed with COVID-19. (a) showed normal on the chest CT at admission. 3 days later, (b) CT re-examination revealed a new lesion in the left lingular segment, showing a patchy GGO with bronchiectasis



A 33-year old female with menopause for 37^{+2} weeks presented with abdominal distension and diarrhea for 2 days.

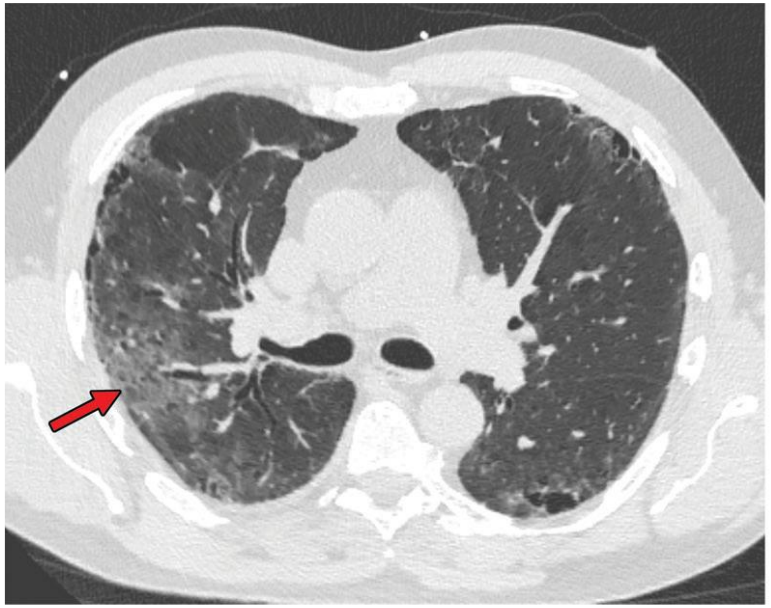
She was diagnosed with COVID-19. (a) chest CT at admission showed small flashed-glass shadow in the posterior segment of the upper lobe of the right lung and the lobe of the left tongue. 7 days later.
(b) re-examination showed a significant increase in lesions in both the lungs with increased density. It was observed as strip shadow, surrounding ground glass opacity, with interlobular septal thickening

Chest CT of COVID-19 Complications

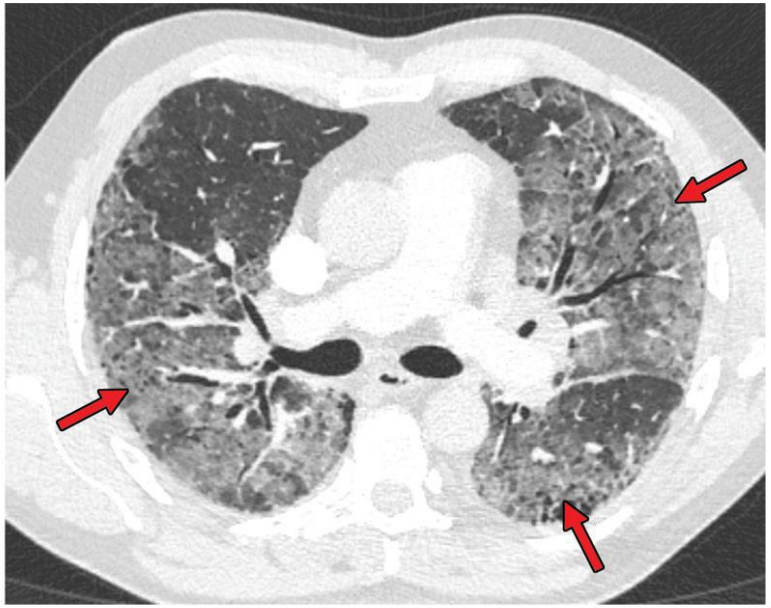
Acute Respiratory Distress Syndrome

- COVID-19 may rapidly progress to ARDS, with older patients being at higher risk. ARDS seen with COVID-19 is a cytokine release syndrome, in which immune and non immune cells release large amounts of pro inflammatory cytokines that cause damage to the host. ARDS is characterized by an **acute onset of non cardiogenic pulmonary edema**, hypoxemia, and the need for mechanical ventilation. Diffuse alveolar damage is the pathognomonic histologic finding . ARDS is the most common reason for patient admission to the intensive care unit and the main cause of mortality in patients with COVID-19

Development of ARDS



a.

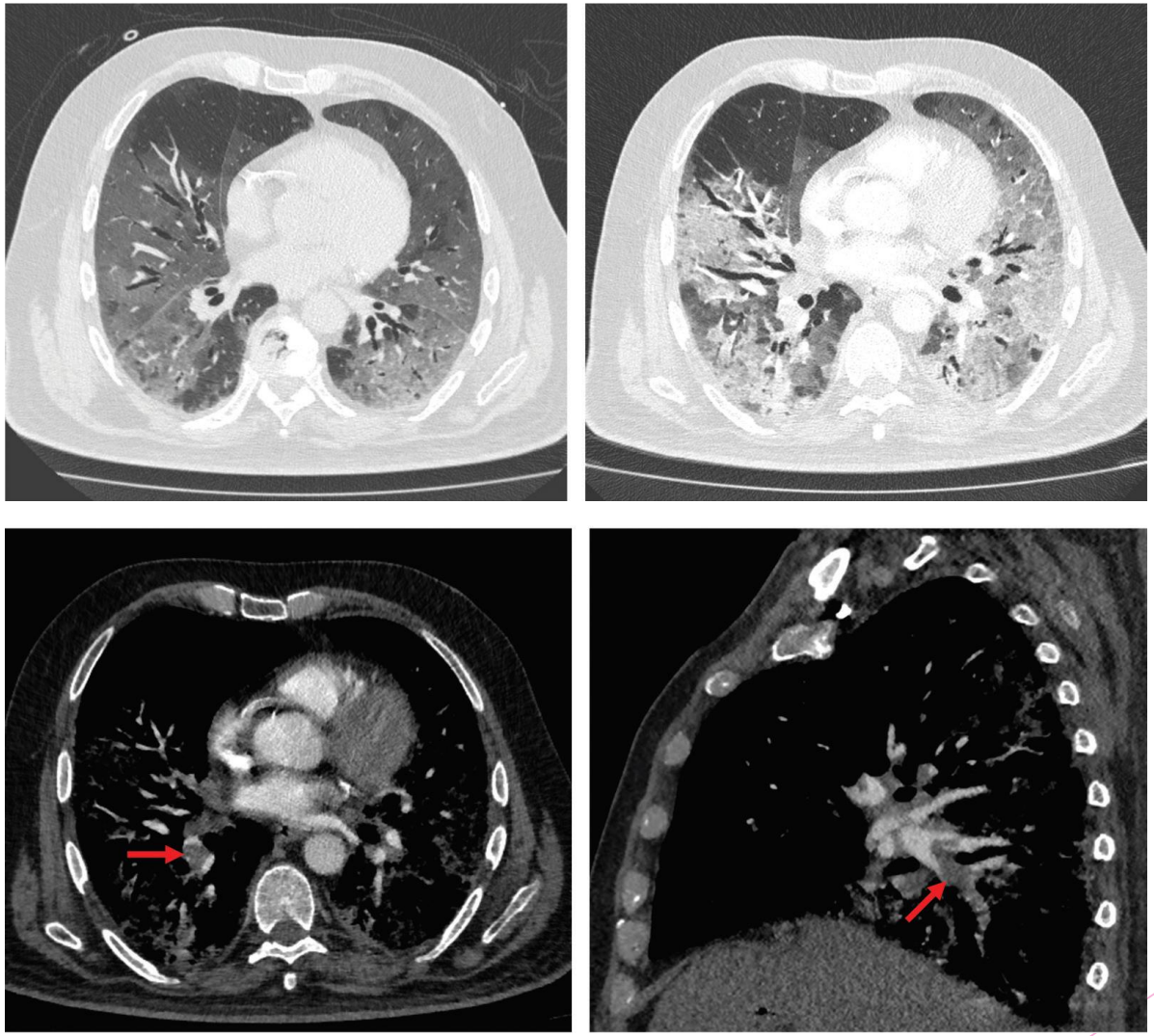


b.

Pulmonary Embolism

- Patients with COVID-19 are at risk for developing thromboembolic complications, which may be caused by activation of the coagulation cascade by SARS-CoV-2 or by local or systemic inflammation. Patients with thromboembolic complications have a more than fivefold higher risk of all-cause death. However, at present, there are insufficient data to recommend for or against the routine use of prophylactic thrombolytic therapy or increasing anticoagulant therapy doses in hospitalized patients with COVID-19. The incidence of PE in patients with COVID-19 who underwent CT pulmonary angiography has been reported to range between **17% and 35%** . Prevalence may be highest in critically ill patients , but even patients with milder disease can develop acute PE.

Pulmonary Thrombo Emboli



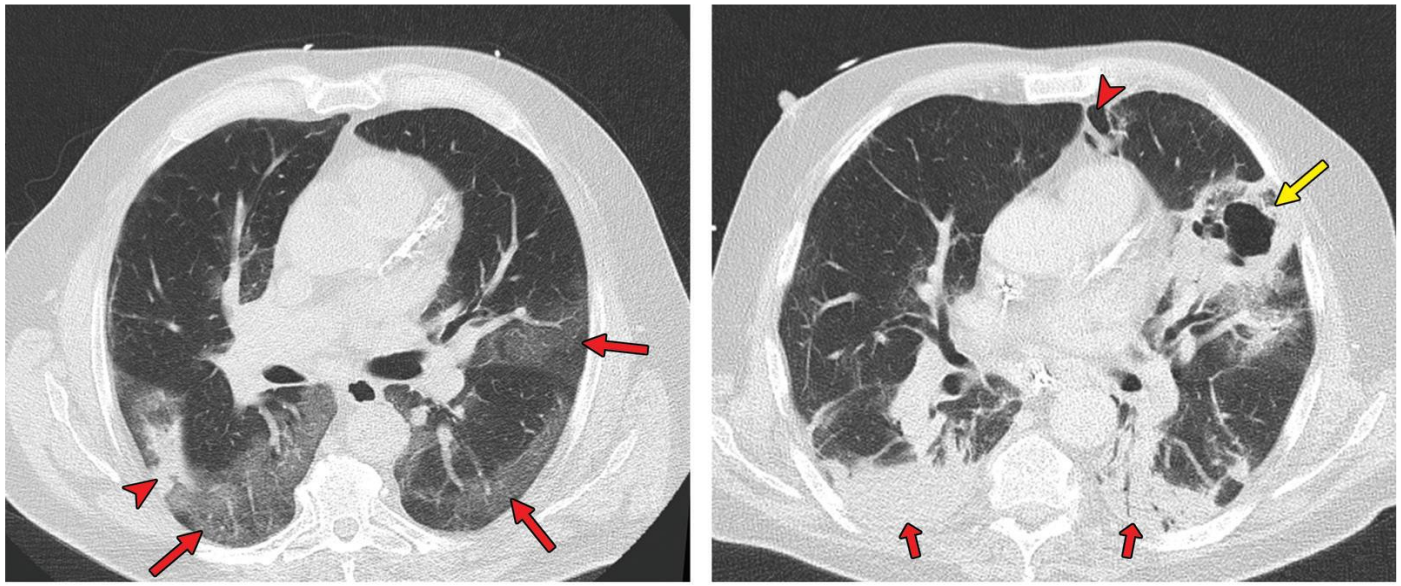
Superimposed Pneumonia

- Patients with COVID-19 are vulnerable to superimposed pneumonia, which occurs in approximately 10% of hospitalized patients. Patients with COVID-19 and ARDS may die owing to superimposed bacterial or fungal infection. Therefore, if during COVID-19 treatment secondary respiratory worsening occurs, one should think of the possibility of superimposed pneumonia and consider obtaining lower respiratory tract cultures and performing chest imaging. **Lobar consolidation** at chest imaging may reflect a superimposed bacterial pneumonia.

Cardiac Injury

- Cardiac injury occurs in 12.5%–19.7% of hospitalized patients with COVID-19 and is an independent risk factor for in-hospital mortality. **Pericardial effusion** manifests in an estimated 5.2% of patients with COVID-19, with a higher incidence in those with severe or critical illness. Pericardial effusion may also be **a sign of cardiac injury** in COVID-19. Although pericardial effusion is a nonspecific finding, radiologists should suggest the possibility of COVID-19–related cardiac injury when pericardial effusion is depicted on chest CT images.

Superimposed pneumonia



Thanks for Your Attention