PI Session: 2021.10.08_D and T_Radiology: Imaging of Pulmonary System #2_ Preparatory_Marcus John Julius, M.D.

Objectives: At the end of this session, students will be able to:

1. Examine imaging parameters, advantages, and disadvantages of CT imaging.
2. Describe the radiographic appearances of interstitial lung disease (ILD) and emphysema on chest radiography and CT imaging.
3. Discuss the role of imaging in the workup of pulmonary embolism.
4. Utilize a multitude of imaging modalities in the assessment of primary and secondary lung neoplasia.

Normal CT imaging

-CT Post-processing: **Windowing**

-Most common post-processing operation in CT

-CT image gray scale is manipulated with respect to the CT numbers (i.e. HU) of the image

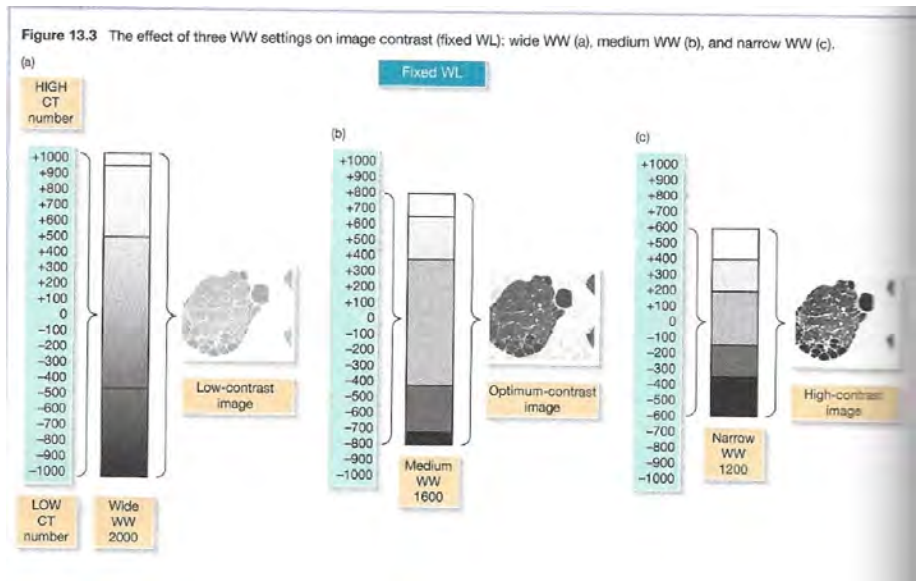
-Assists with *image contrast* and *image brightness*

-*WW:* Window width (range of CT numbers in the image)

-Maximum shades of gray that are displayed in the image (i.e. determines *image contrast*)

-Wide window width: Many shades of gray (but creates lower contrast)

-Narrow window width: Fewer shades of gray (but creates higher contrast)



-*WL:* Window level (center of the range of the CT numbers in the image)

-Determines the *brightness* or *darkness* of the image

-Location of the center of the range of CT numbers on the gray scale

-Increasing the WL causes the image to appear darker (as more of the lower CT numbers are displayed)

-'Bone window'

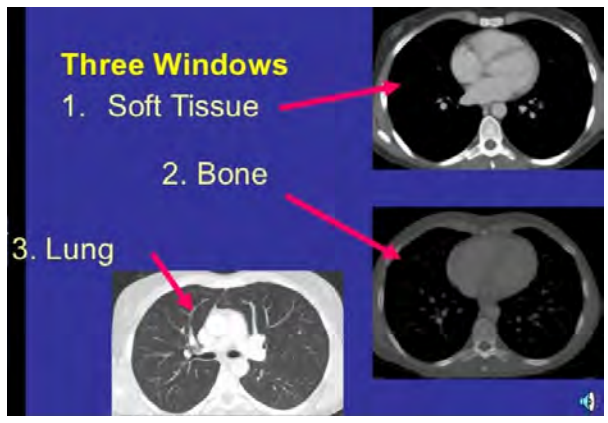
-Bone is white (while most of the remaining image is 'dark')

-Decreasing the WL causes the image to appear brighter (as more of the higher CT numbers are displayed)

-'Lung window'

-Lung is dark (while most of the remaining image is 'bright')

Note: 'Soft tissue window' is in between bone and lung windows (with respect to 'brightness')



-**Note:** Window width and window level *both* contribute to tissue appearance.

Table 13.1 Typical WW and WL values for different tissues.

Tissues	Window Width	Window Level
Temporal bone	3000	500
Spine	1600	300
Soft tissue (orbits)	400	30
Soft tissue (chest)	400	40
Abdomen	400	50
Brain (posterior fossa)	100	40
Soft tissue (cervical and thoracic spines)	500	60
Brain	80	40
Lung	1500	−400

CT TERMINOLOGY

-***Density***: root word

-hypodense (or of decreased density): lower HU

-hyperdense (or of increased density): higher HU

-***Attenuation***: root word

-decreased attenuation: lower HU

-increased attenuation: higher HU

ADVANTAGES OF CT IMAGING

-Optimal soft tissue differentiation

-Excellent osseous detail

-Submillimeter imaging with potential for multiplanar reconstruction

-3-dimensional imaging

-Fast scanning techniques

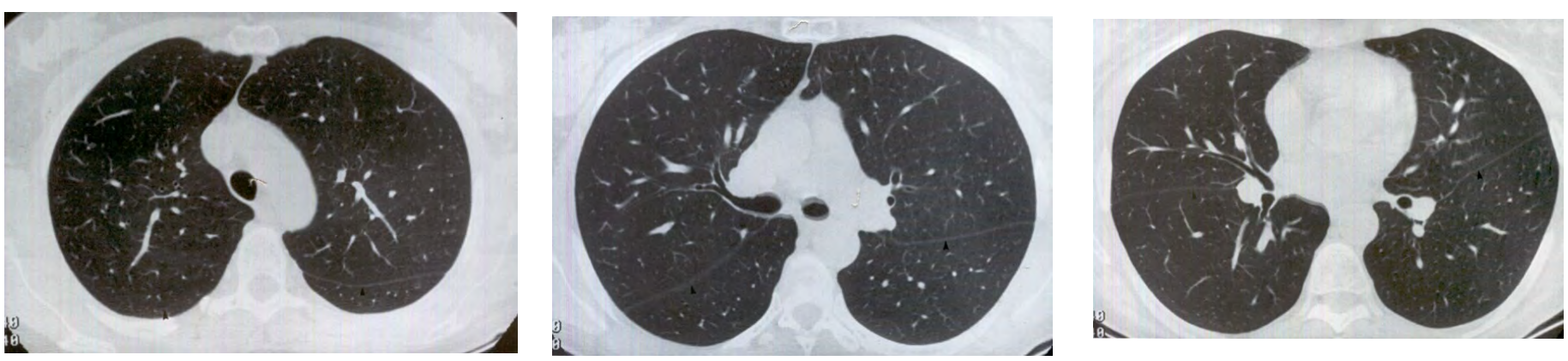
DISADVANTAGES OF CT IMAGING

-Exposure to ionizing radiation

-Cost

EXAMPLES OF NORMAL CT THORACIC ANATOMY

CT Thorax (soft tissue window): Aortic arch (left), Main pulmonary arteries (middle), and Mid-cardiac (right) levels



CT Thorax (lung window): Distal trachea (left), Mainstem bronchi (middle), and Mid lung (right) levels

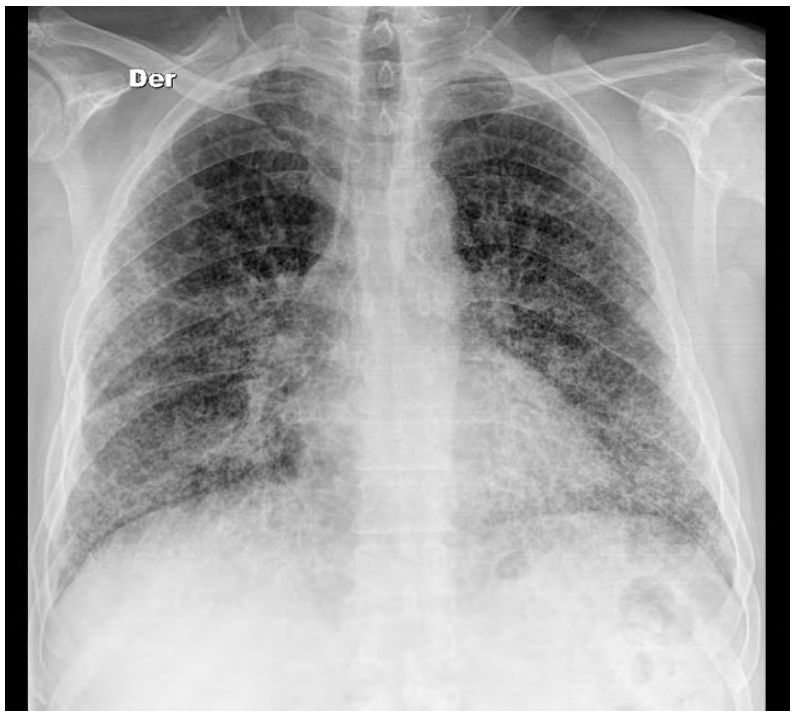
PATHOLOGIC CONDITIONS

Interstitial lung disease (ILD): collection of a large number of diverse disease processes (manifesting as involvement of the lung interstitium).

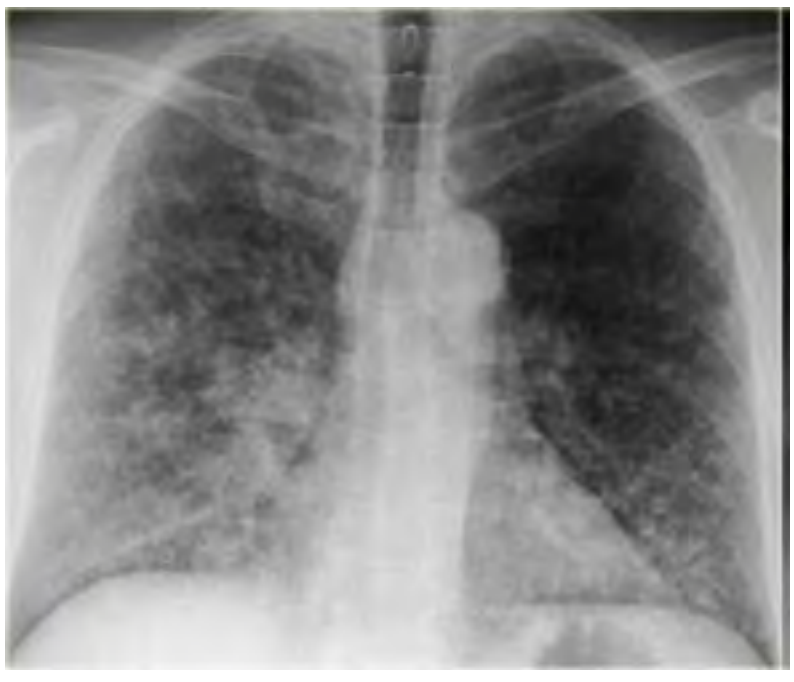
-A bit of a misnomer, in that many of the ILD conditions may also involve the alveolar/air-spaces

-Radiographic appearance:

-CXR may demonstrate linear (reticular) densities, nodular densities, or both (reticulonodular) densities



Reticular pattern (Usual interstitial pneumonia, UIP)
(Radiopaedia.org)



Nodular pattern (Sarcoidosis)
(Radiology assistant)

Note: In ILD, suspected CXR abnormality (along with clinical history and physical examination), may warrant follow-up imaging. If so**, chest CT is the examination of choice.**

Note: Many differential diagnoses will be provided during CT discussion of ILD. These are presented to complement your clinical lectures (and are ***not*** meant to be strictly memorized). By no means are these D/D exhaustive in degree. Other entities may be added in concert with your clinical lectures. (Please note that some diseases may fall into more than one pattern).

CT appearance:

-**Examination of choice for assessment of ILD**

-Thin section, high-resolution

-Pattern approach (see hemi-thorax CT images, below)

-*nodular* (small focal lesions, ranging from 1mm to 1cm)

-**D/D**: silicosis, coal-worker's pneumoconiosis (CWP), lymphangitic carcinomatosis, sarcoidosis, miliary infection, metastases

-*reticular* (linear densities)

-**D/D**: idiopathic pulmonary fibrosis (IPF), chronic interstitial pneumonias, collagen vascular diseases, asbestosis, interstitial pulmonary edema

-*recticulonodular* (linear *and* focal opacities)

-**D/D**: silicosis, lymphangitic carcinomatosis, sarcoidosis, lymphoma,

-*cystic* (lucencies)

-*lung cysts* (>10mm in diameter; <2mm wall thickness)

-lymphangioleiomyomatosis

-*cavitary nodules*

-histiocytosis X

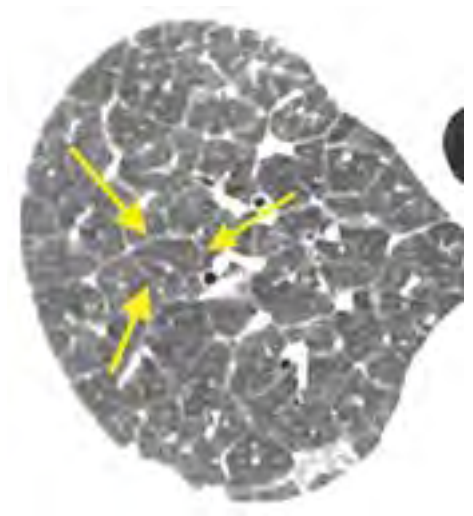
-*honeycombing* ('end-stage lung')(<10mm in diameter; >2mm wall thickness)

-fibrosis (including IPF)

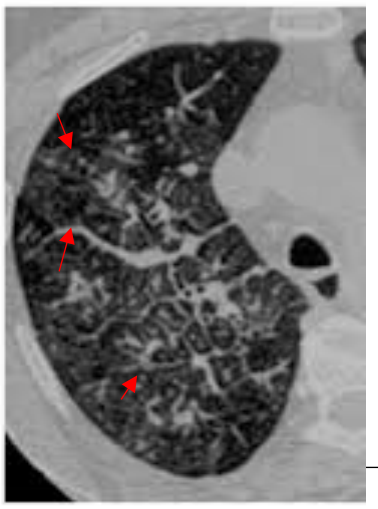
-*ground glass opacification* (amorphous increased CT density, with pulmonary vessels remaining visualized)

-**D/D:** hypersensitivity pneumonitis, desquamative interstitial pneumonitis (DIP), alveolar proteinosis, pulmonary edema, pulmonary hemorrhage, pneumocystis carinii pneumonia, COVID-19 pneumonia

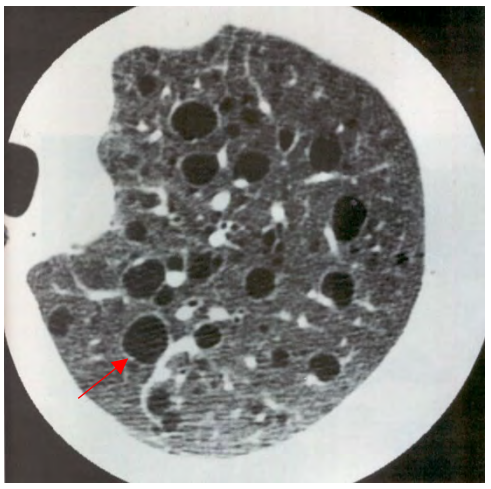
Nodular pattern (silicosis)



Reticular pattern (pulmonary edema) (Radiology Key)



(Lymphangitic carcinomatosis) (Research Gate)



Cystic pattern (Lymphangioleiomyomatosis)

Cystic pattern (Honeycombing) (RSNA.com)

Ground glass pattern (COVID-19 pneumonia) (Radiology Assistant)

D/D: Lung Zone Position of ILD

-'*Upper*'

-Cystic fibrosis, sarcoidosis, silicosis

-'*Lower*'

-Bronchiectasis, aspiration pneumonia, dermatomyositis, lymphangitic carcinomatosis, asbestosis, scleroderma, collagen vascular disease

D/D: Adenopathy (in ILD)

-Sarcoidosis, silicosis, neoplasia (including lymphangitic carcinomatosis and lymphoma)

D/D: Pleural effusions (in ILD)

-Lymphangitic carcinomatosis, asbestosis, collagen vascular disease, pulmonary edema, lymphangioleiomyomatosis

D/D: Pleural thickening (in ILD)

-Asbestosis, collagen vascular disease

D/D: Pneumothorax (in ILD)

-Honeycombing, lymphangioleiomyomatosis

Emphysema: permanent abnormal enlargement of air spaces distal to the terminal bronchiole (with destruction of acinar wall, but no fibrosis)

-*Acinus* is distal to terminal bronchiole (and includes respiratory bronchioles, alveolar ducts, and alveolar sacs, and alveoli). *Acinus* is the basic structural/functional unit of pulmonary parenchyma

-*Lobule* is the smallest radiographically visualized (by CT) unit of lung parenchyma. *Lobule* is composed of 3 to 5 terminal bronchioles (and more distal lung parenchyma)

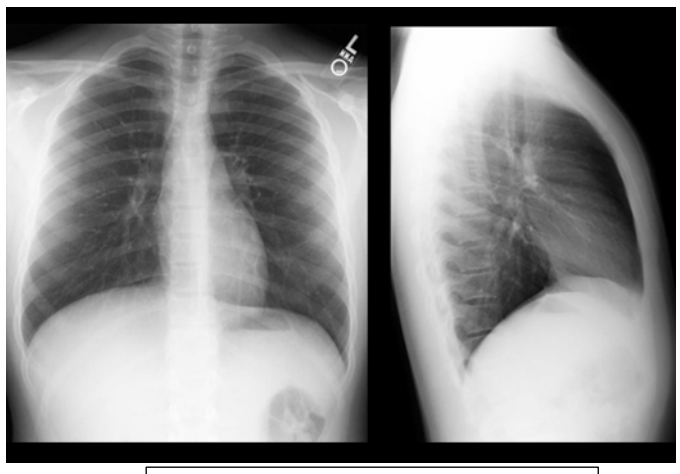
-Subtypes of emphysema (an entity of COPD):

-*Centrilobular*
-*Panlobular*
-*Paraseptal*
-*Paracicatricial*

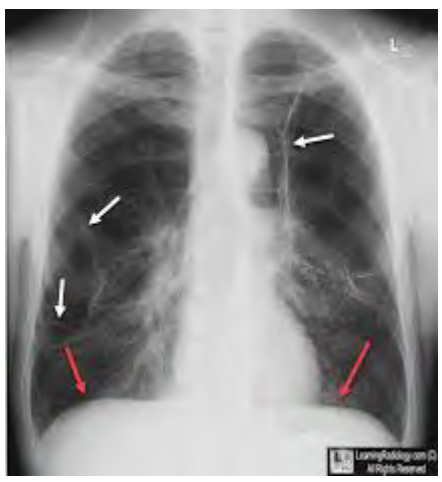
Radiographic appearance (centrilobular emphysema)

-Chronic hyperinflation
-Flattened diaphragm
-Increased retrosternal space
-Tapering of central pulmonary vessels
-Lucent areas within the lung fields (upper lobe predominance)
-*Bullae*: avascular radiolucent foci >1cm in diameter (with wall <1mm in thickness)

Note: In *panlobar* emphysema, overt lucency may involve the entire lung (or may show Lower lobe predominance)

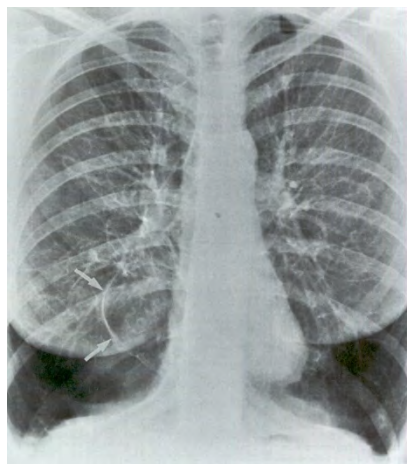


Normal CXR (for reference)



Bullous emphysematous disease (Bullae, white arrows. Hyperinflation, red arrows)

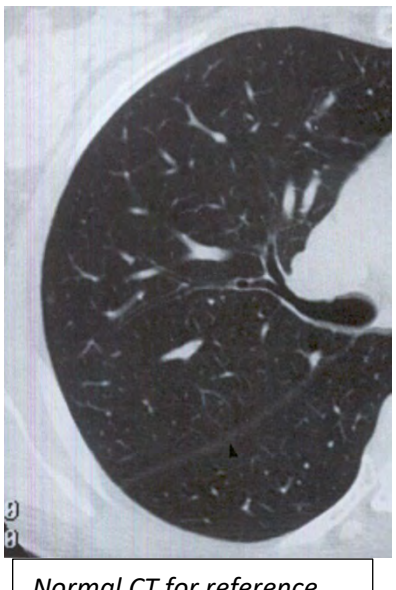
Severe emphysema



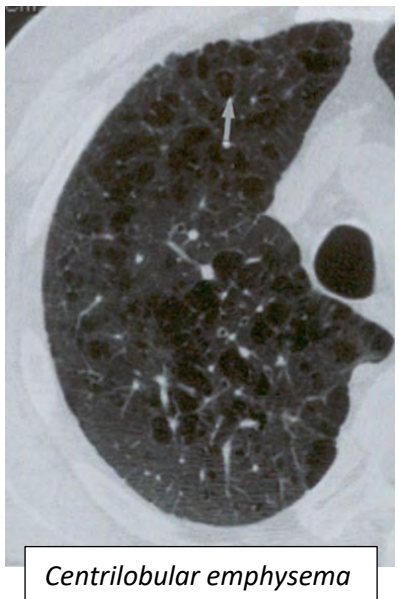
Panlobular emphysema (lower lobe predominance) (Bulla, white arrow)

CT appearance

-optimal assessment of lung parenchyma
-appearance depends on the subtype of emphysema
-centrilobular
-areas of low density (up to 1cm) are scattered throughout the lungs (upper lobe predominance)
-low density foci usually lack walls
-*bullae*: more well-defined, avascular radiolucent foci >1cm in diameter (with wall <1mm in thickness)
-panlobular
-pulmonary vessels are diminished in size and fewer in number
-potential lower lobe predominance (vs global distribution)
-"alpha-1 antitrypsin deficiency" association

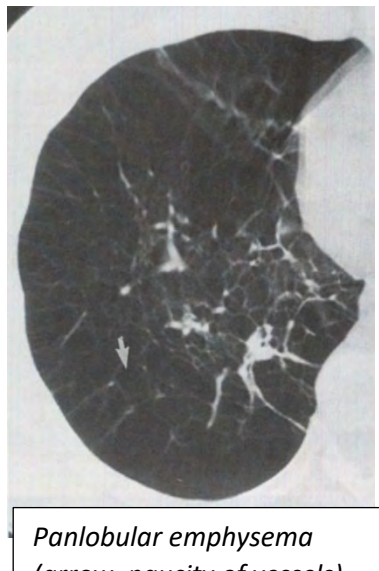


Normal CT for reference



Centrilobular emphysema (arrow, low density focus)

Bullae (arrows)



Panlobular emphysema (arrow, paucity of vessels)

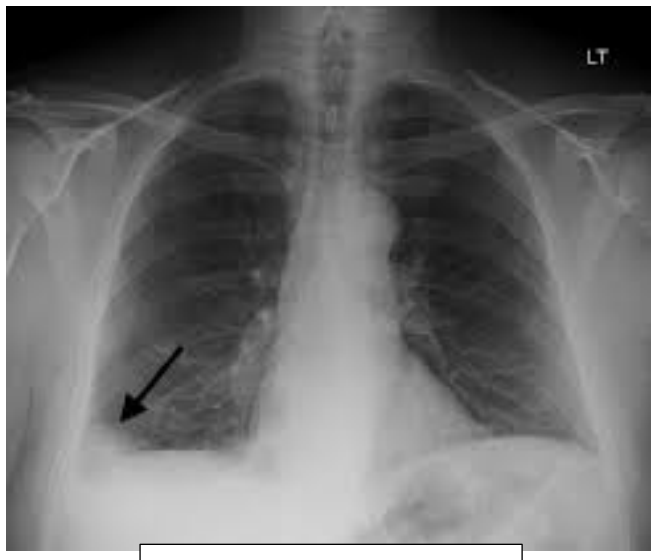
-<u>paraseptal emphysema</u> (CT appearance)
-single row of thin-walled low density foci
-subpleural location as well as along interlobar fissures

<u>Note</u>: The other entities of COPD (chronic obstructive pulmonary disease), including Chronic bronchitis and Asthma will be discussed in other clinical sessions.

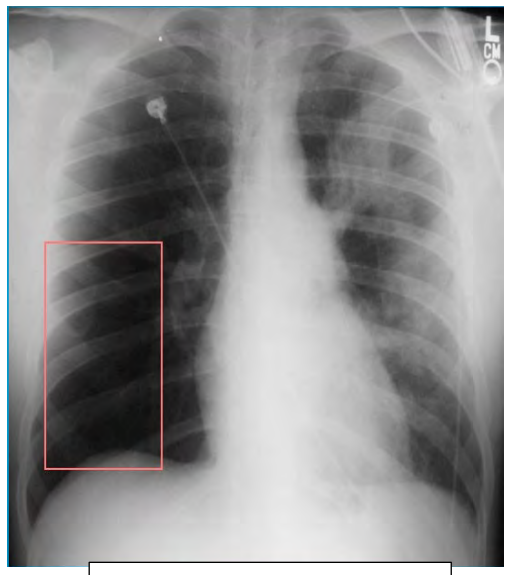
Paraseptal emphysema

<u>Pulmonary embolism</u>

-<u>Radiographic appearance</u>:
-CXR: neither sensitive nor specific for PE
-used to exclude other diagnoses (such as pneumonia, pneumothorax)
-potential radiographic signs
-*Hampton's hump*: peripheral, wedge-shaped air-space disease, suggestive of pulmonary infarction
-*Westermark sign*: regional lucency, representing oligemia (lack of blood flow)

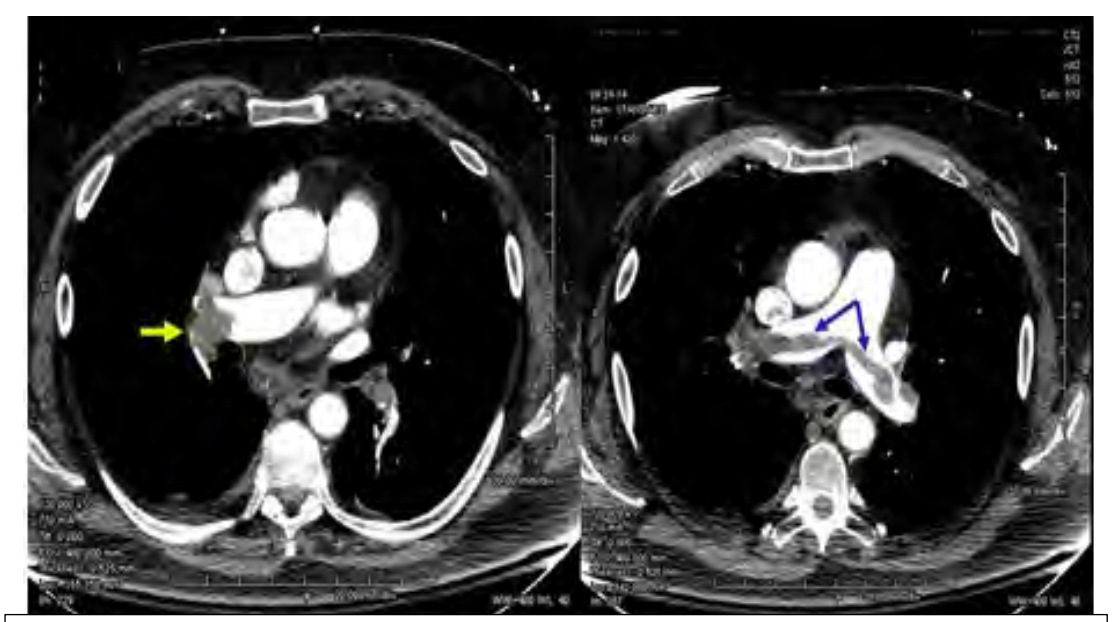


Hampton's hump (arrow)
(pmj.bmj.com)



Westermark sign (box RLL)

-<u>CT examination</u>: modality of choice for assessment of pulmonary embolism
-utilizes iodinated contrast enhancement (CT-angiography)
-requires normal renal function (or subsequent dialysis)
-iodine allergy is a contraindication (unless premedication is a clinical option)
-appearance:
-*filling defect* within otherwise opacified pulmonary arteries
-occlusive: obstructs contrast from flowing more distally
-non-occlusive: allows a portion of contrast to flow more distally
-acute emboli for acute angles with vessel wall (while chronic emboli form obtuse angles)
-'saddle embolus' extends into both main pulmonary arteries



Pulmonary emboli (two different patients): Right main pulmonary artery (yellow arrow) Saddle embolus (blue arrows)

-Nuclear medicine appearance

-*V/Q scan*: ventilation/perfusion imaging (by mechanism of compartmental localization/capillary blockade)

-potential screening examination for pulmonary emboli (in patients unable to undergo enhanced chest CT-angiography)

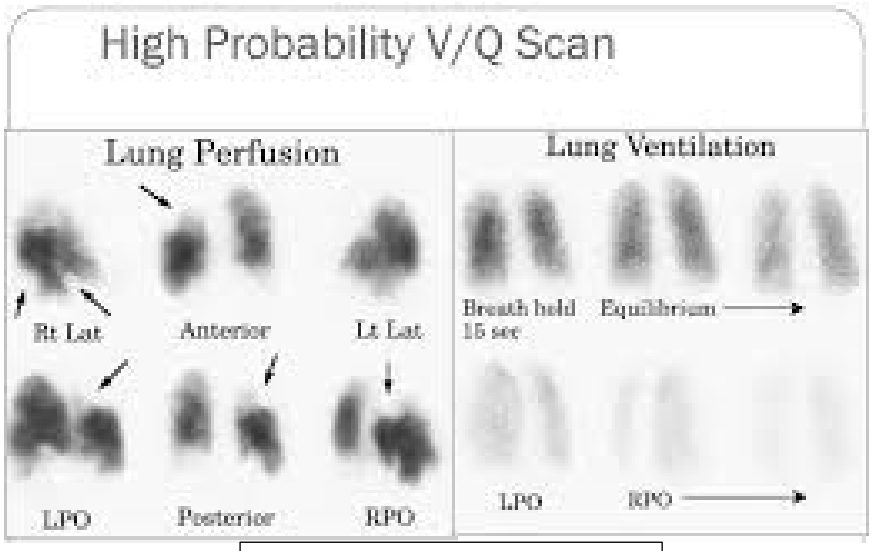
-examination is interpreted in concert with a CXR (performed within 6-24 hours of timing of V/Q scan)

-based on size and number of perfusion defects, a probability of pulmonary embolus is determined:

-'low': less than 20% chance of PE

-'intermediate': 20%<X<80% chance of PE

-'high': greater than 80% chance of PE



Perfusion defects (arrows)
(Slide player.com)

-Sonography: echocardiography may be of value for assessment of severe right ventricular (RV) dysfunction (in the presence of PE)

-Conventional (catheter) pulmonary angiography: invasive (but gold-standard) examination. Allows for diagnosis (in equivocal cases not optimally assessed by screening examinations).

Primary lung neoplasia:

Radiographic appearance:

-chest radiographs demonstrate a multitude of different imaging findings in patients with lung neoplasia.

CT appearance:

-CT imaging provides optimal assessment of primary lung cancer, mediastinal/hilar lymph nodes, and osseous structures

-Examples (multimodality approach)

-solitary pulmonary nodule (SPN): <3cm soft tissue focus; no adjacent LAP nor atelectasis

-Upon initial note of SPN, look *retrospectively* to prior CXR or CT examinations for stability.

-If stable (looking back for 2 years), no additional imaging is warranted

-If no prior imaging (or if change in size from prior), serial CT exams (+/- biopsy) prospectively for 2 years

-potentially adenocarcinoma

-persistent pneumonic infiltrate (despite treatment): Always F/U pneumonia after Tx with CXR to document resolution

-distal to an obstructive tumor, 'post-obstructive pneumonitis' (potentially endobronchial squamous cell CA)

-tumor itself mimics pneumonia ('invasive mucinous adenocarcinoma')

-persistent or worrisome atelectasis

- distal to an obstructive tumor (potentially endobronchial squamous cell carcinoma)

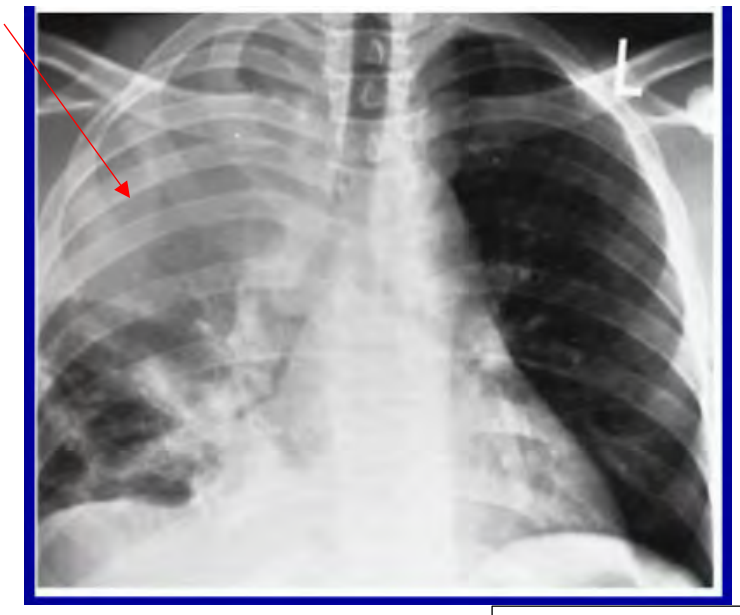
-mass (+/- cavitation)

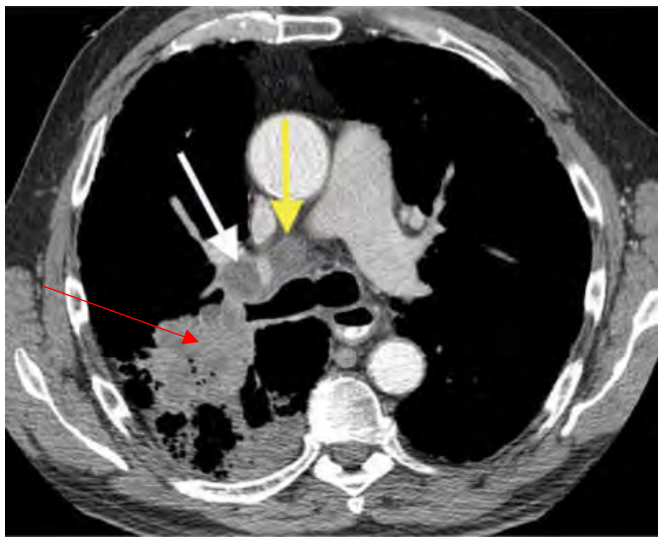
-commonly squamous cell carcinoma (with potential paraneoplastic syndrome of parathyroid-like hormone)

-lymphadenopathy (mediastinal/hilar)

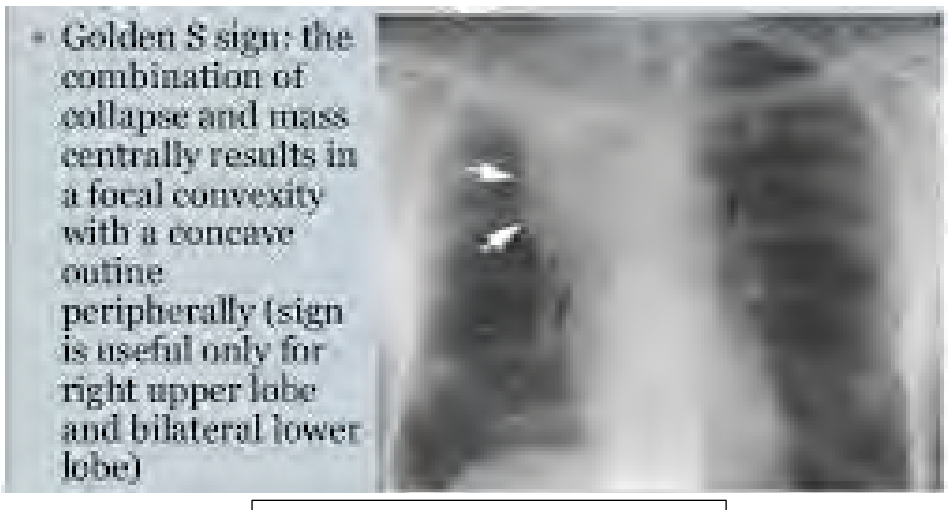
-potentially small cell carcinoma (with potential paraneoplastic syndromes, including SIADH)

SPN (arrows), located in lingula

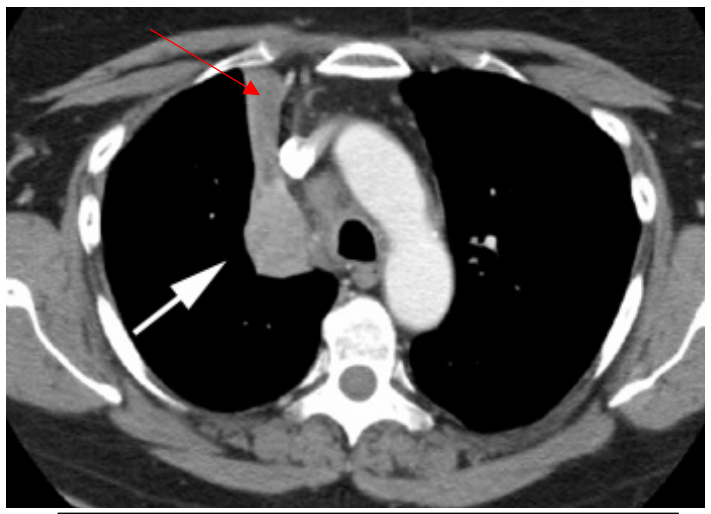




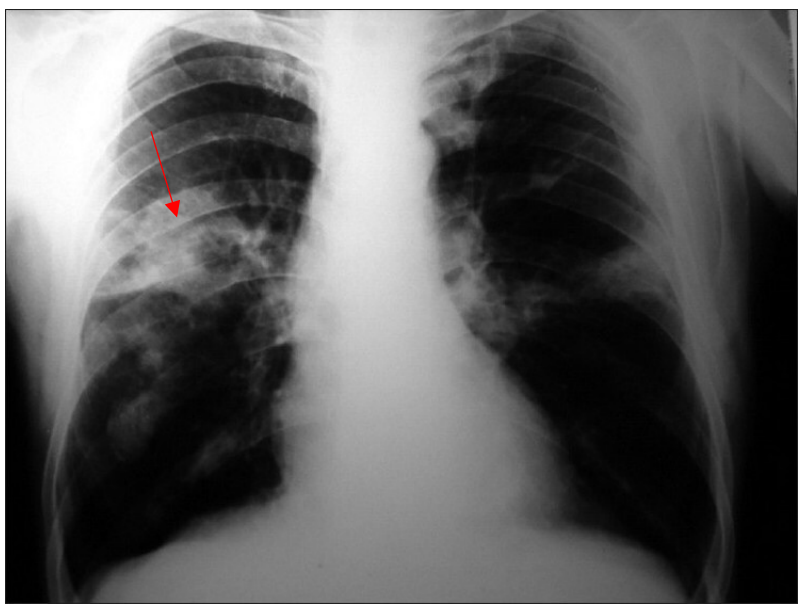
Post-obstructive pneumonia (red arrows)
(Yellow arrow: mediastinal lymph node)
(White arrow: hilar lymph node)



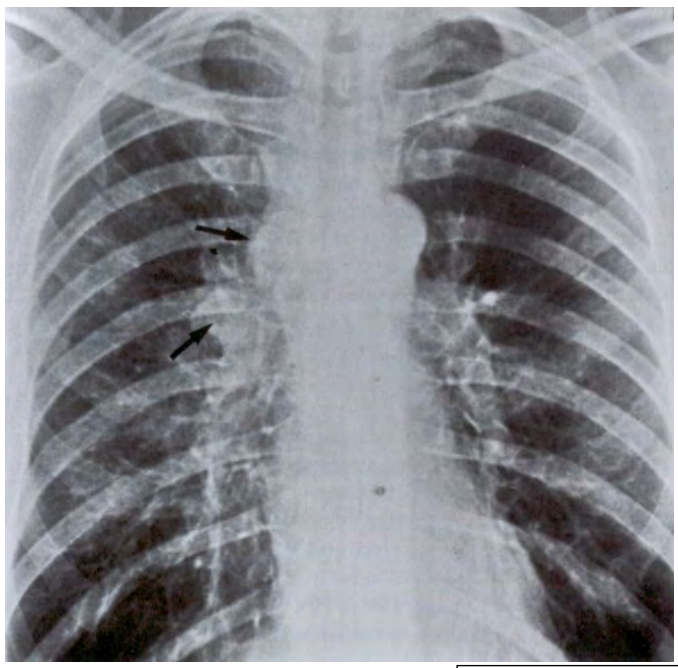
RUL post-obstructive atelectasis
(Slideshare.com)

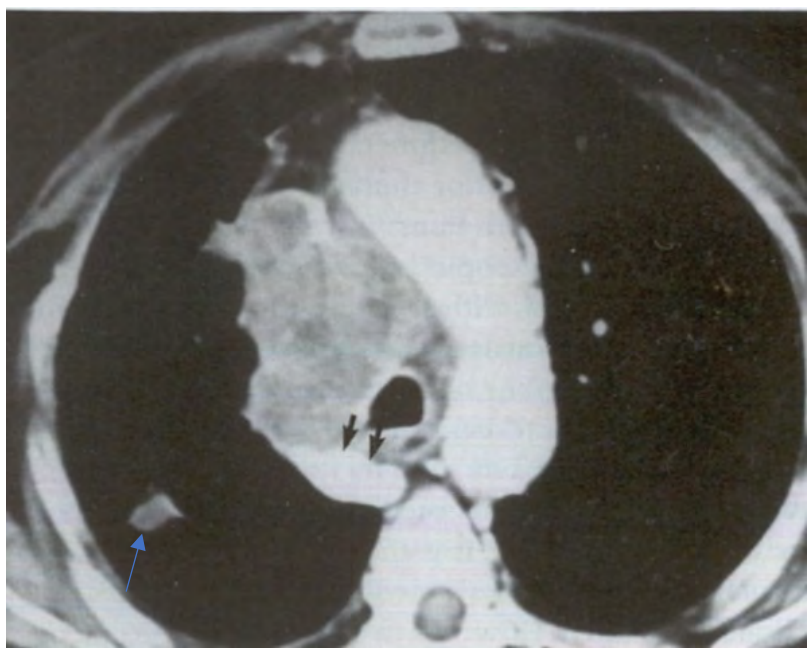


RUL post-obstructive atelectasis
(white arrow: mass) (red arrow: volume loss)
(auntminnie.com)



RUL cavitary mass (arrows)

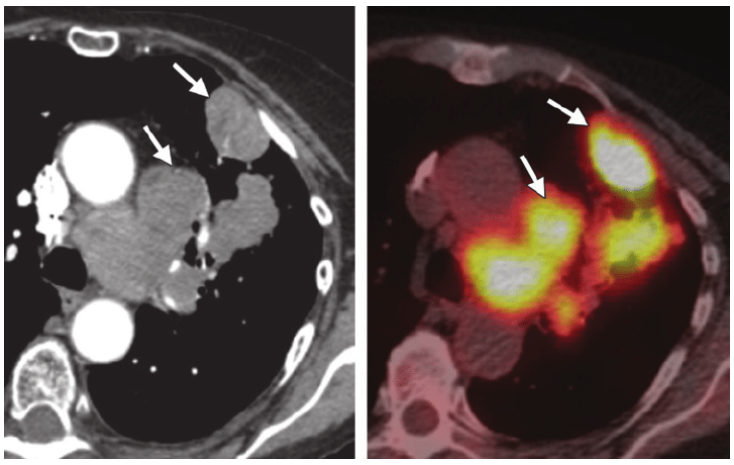




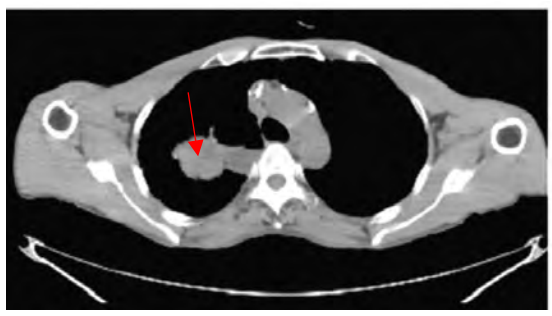
Mediastinal lymphadenopathy (LAP): black and red arrows
Pulmonary Nodule: blue arrow

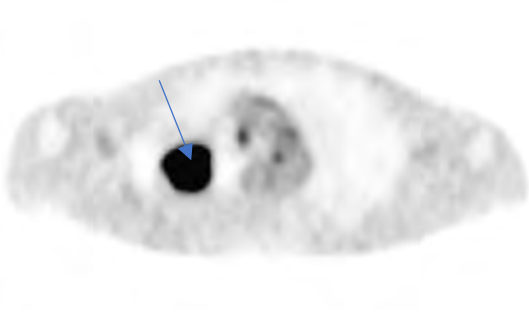
PET (positron emission tomography) appearance:

-allows for assessment of hypermetabolic neoplasms
-'fusion' of PET with CT images
-merges function with structure
-allows for staging of neoplasia
-TNM system
-'T'umor
-'L'ymph nodes
-'M'etastases
-allows for serial assessment (treatment response and potential recurrence



CT (left) and PET-CT (right) peripheral LUL mass with central mediastinal LAP





PET-positive RUL neoplastic mass: arrows
(Access medicine)

Note: Metastatic lung cancer may be seen with a multitude of primary cancers.
-Adult primaries: Breast, colorectal, renal cell, uterine, head/neck squamous cell
-Pediatric primaries: Rhabdomyosarcoma, osteosarcoma, Wilms tumor, Ewing sarcoma, neuroblastoma
-CT is optimal modality to assess for pulmonary metastases
-common CT features:
-multiple
-soft tissue density
-well-circumscribed
-round
-peripheral predominance
-potential for calcification or cystic necrosis

Pulmonary metastases (from breast cancer)
(Radiopaedia.org)

References:

-Clinical Radiology: The Essentials. Daffner et al. 4th ed. (Chapters 1, 2, 4, and 12).

-Primer of Diagnostic Imaging. Weissleder et al. 4th ed. (Chapters 1 and 7)

-Note: Medical images are from anonymized patient data and online archives (as detailed)

OPTIONAL: Want to know more?

https://www.med-ed.virginia.edu/courses/rad/

www.auntminnie.com

www.acr.org

www.rsna.com