PI Session: 2021.10.08_D and T_Radiology: Imaging of Pulmonary System #1_ 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. Compare and contrast the radiographic appearance of air-space disease and atelectasis.
3. Utilize a multitude of imaging modalities in the assessment of hallmark pleural diseases (including pleural effusions, pneumothorax, and pleural masses)
4. Discuss the role of imaging in the workup of acute and chronic sinusitis.

CT Imaging: Components of X-ray tube and detector array (in a CT unit)

-*X-ray tube*: source of x-rays

-*Filters*: tailors the beam quality (by absorbing low energy x-rays)
shapes the beam (which is referred to as 'fan-shaped' beam)

-*Anti-scatter septa*: positioned between detector elements

-*Detector array*: scintillators (produce light when x-ray photons are absorbed)

-Image acquisition

-Axial scanning: table and patient are stable, while x-ray tube rotates through 360 degrees (then table moves an increment…followed by another tube rotation)

-At each tube location, each detector measures the x-ray transmission through the patient (referred to as a ray)

-*Projection*: All rays for a given tube angular position (i.e. 1000 rays)

-Rotation: A 360-degree path around the patient (i.e. 1000 projections)

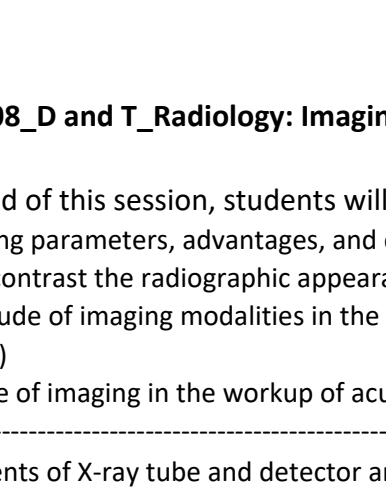
-*Sinogram*: Plot of projections -VS- tube angles

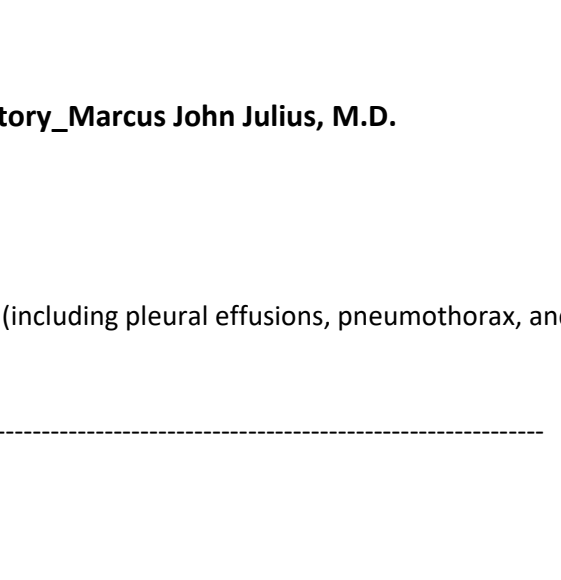
-Helical/spiral scanning: table/patient move linearly, while x-ray tube rotates thorough 360 degrees

-*Pitch*: Table incremental distance (during a 360-degree rotation)/beam width

-*Projection*: At any given positions along patient's long axis (i.e. z-axis), helical imaging provides 1 out of 1000 projections (with other data obtained using *interpolation algorithms* from other projections)

-Reduces total CT scan time (compared with axial scanning)





-*Image reconstruction*

-Actual reconstruction techniques (i.e. filtered back projection and iterative reconstruction) are beyond the scope of this course.

-Knowledge of the *display* of the data (i.e. native axial images), however, is vital.

-Tomography: Imaging by sectioning (in this case, axially, from head-to-toe)

-Patient is usually positioned supine (i.e. 'face-up') on the CT table, feet toward us.

-Envision the patient 'facing you' (i.e. if they were to sit up)

-Examples of normal CT anatomy will be provided throughout the course

CT IMAGING INTERACTION WITH MATTER

-Since CT imaging utilizes x-rays, the very same concepts involving x-ray interaction with matter hold true for CT imaging.

- *The more readily x-rays pass through matter, the less than are attenuated.*

-Gas permits x-rays to pass through most readily

-*The more readily x-rays are removed from a beam as it passes through matter (i.e. by photoelectric effect and scatter), the more they are attenuated.*

-Dense materials and materials of higher atomic number attenuate the x-ray beam

-Hounsfield units (HU) or CT numbers: the attenuation of a material relative to the attenuation of water (0 HU)

-Negative HU: matter attenuates x-rays LESS THAN water

-Air: (-1000 HU); Fat (-100 HU)

-Positive HU: matter attenuates x-rays MORE THAN water

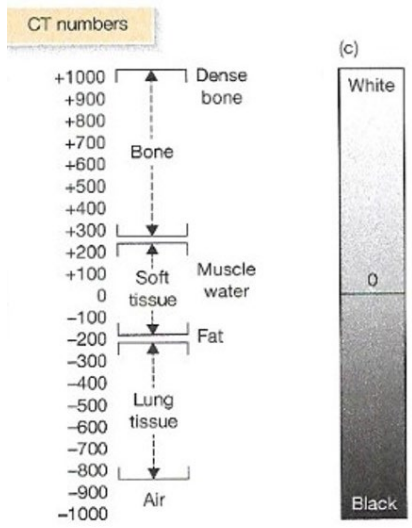
-Soft tissue: (+ 50 HU) ; Bone (+1000 HU)

-Spectrum from black…to…white on film or detector (based on x-ray interaction with matter): *Subjective*

Gas <Fat <Water/soft tissue < Bone < Metal

-CT spectrum from negative HU to positive HU: *Objective*

Gas (-1000 HU) <Fat (-100 HU) < Water (0 HU) <Soft tissue (+50 HU) <Bone (1000 HU) < Metal (**>**1000HU)



PATHOLOGIC CONDITIONS

Airspace disease: opacification secondary to abnormal filling of alveoli material that attenuates x-rays to a greater degree than normal lung parenchyma. Air space disease is the imaging correlate to pathologic consolidation.

D/D of air space (or alveolar) disease on CXR

-Pulmonary edema (fluid in alveoli)

-Pneumonia (purulent substance in alveoli)

-Pulmonary hemorrhage (blood in alveoli)

-Neoplasia (cells in alveoli)

-Alveolar proteinosis (protein in alveoli)

Radiographic appearance: Homogeneous ('cloud-like') opacity with patent bronchi (demonstrated as linear, black 'air-bronchograms')

-*Silhouette sign*: Loss of differentiation of normal boundaries between structures composed of different types of matter (secondary to pathologic processes)

-RML (right middle lobe) opacity: Loss of right heart margin

-RLL (right lower lobe) opacity: Loss of right hemidiaphragm margin

-Lingular opacity: Loss of left heart margin

-LLL (left lower lobe) opacity: Loss of left hemidiaphragm margin

-RUL and LUL opacity (if medially positioned) may 'silhouette' right and left mediastinal borders, respectively

-*Spine sign*: Loss of the gradually increasing relative lucency normally viewed progressing caudally over the spine (on lateral CXR), secondary to abnormal opacity posteriorly in the thorax

-LLL air space disease

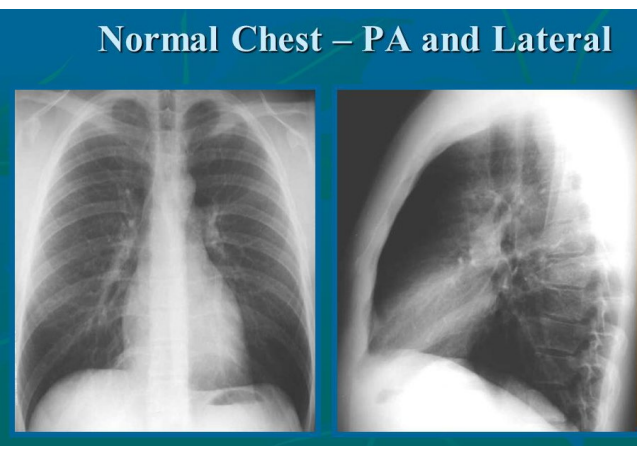
-Pleural effusion

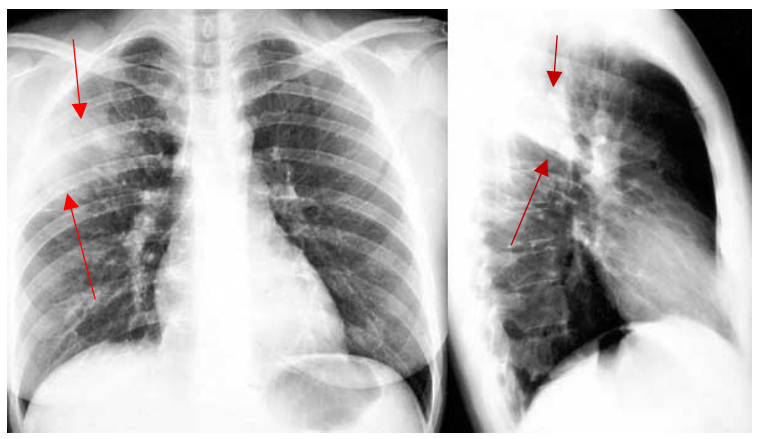
-Neoplasia

-Distribution of air space disease

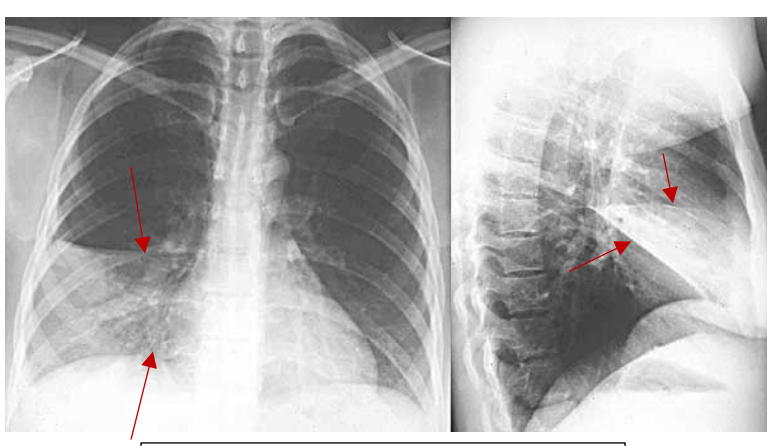
-Patchy, multifocal

-Lobar

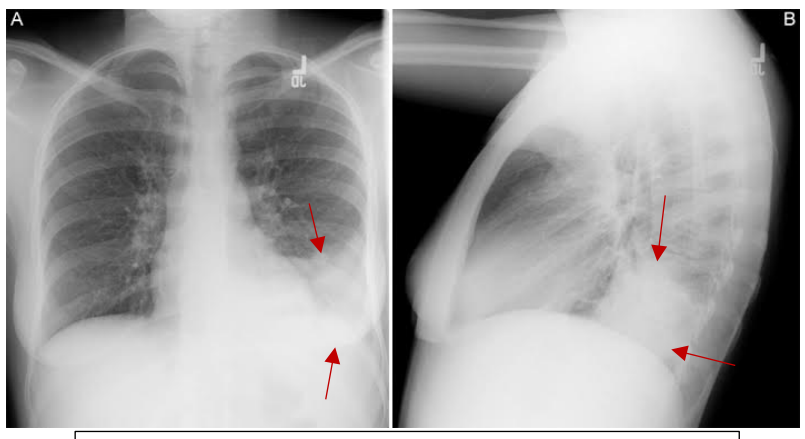




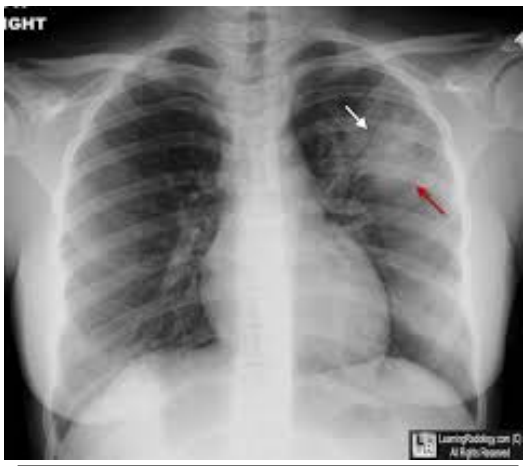
RUL air space disease (red arrows)



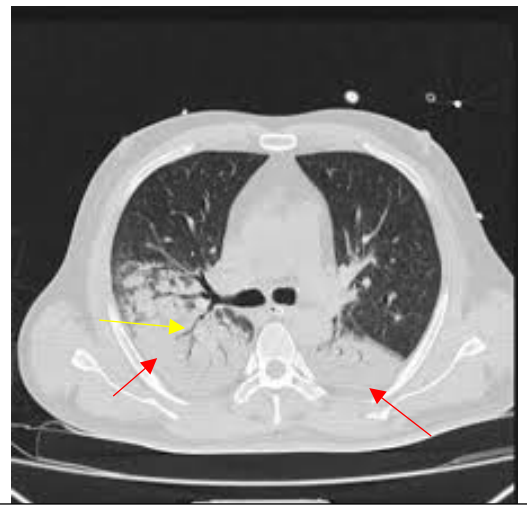
RML air space disease (red arrows)



LLL air space disease (with 'spine sign') (red arrows)



LUL air space disease (red arrow)
Air-bronchogram (white arrow)



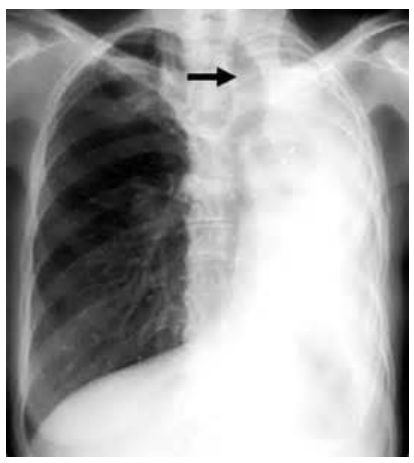
Alveolar/air space disease (red arrow)
Air bronchograms (yellow arrow) Radiopaedia.org

<u>Atelectasis</u>: Incomplete expansion of lung parenchyma (alveoli)

-<u>Chest radiographic signs of atelectasis</u>
-*Direct*: Displacement of interlobar fissures
Crowding of pulmonary vessels
-*Indirect*: Pulmonary opacity
Hyperinflation of adjacent aerated lung
Mediastinal shift (toward side of volume loss)
Elevation diaphragm leaflet (on side of volume loss)
Crowding of ribs (on side of volume loss)

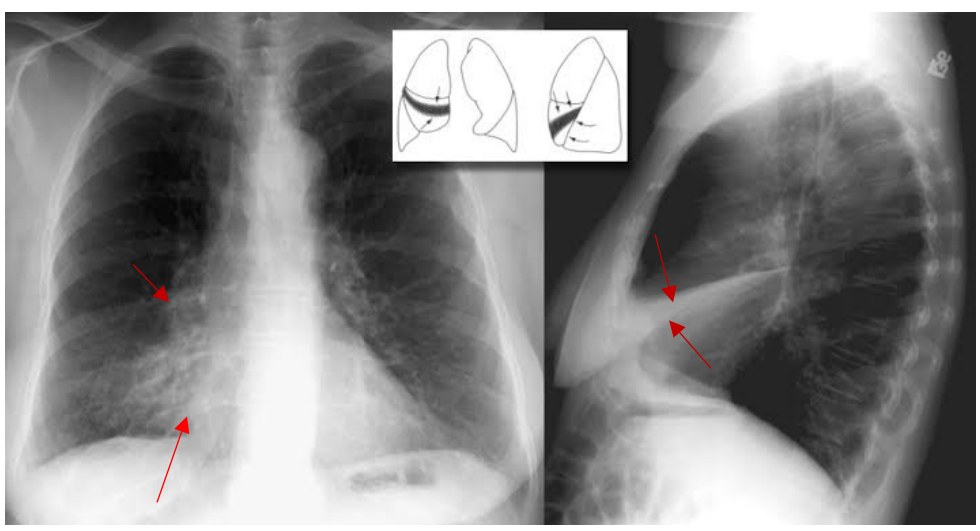
<u>Types of atelectasis</u>
-*Resorptive/Obstructive*: Secondary to complete airway obstruction
-Neoplasia, mucus plugging, foreign body
-*Passive/Relaxation*: Loss of contact between visceral and parietal pleura
-Pleural effusion, pneumothorax
-*Compressive*: Lung compression secondary to space-occupying lesion
-*Cicatricial:* Adjacent to scarring/fibrosis
-*Adhesive*: Associated with surfactant deficiency
-*Dependent*: Based on inherent weight of lungs (i.e. posterior parenchyma in supine position)
-*Round*: Mass-like density at site of infolding of pleura (most commonly associated with asbestos exposure)

<u>Degrees of atelectasis</u>
-Entire lung ('white-out' of hemithorax)
-D/D with large pleural effusion
-Lobar
-Segmental
-Subsegmental

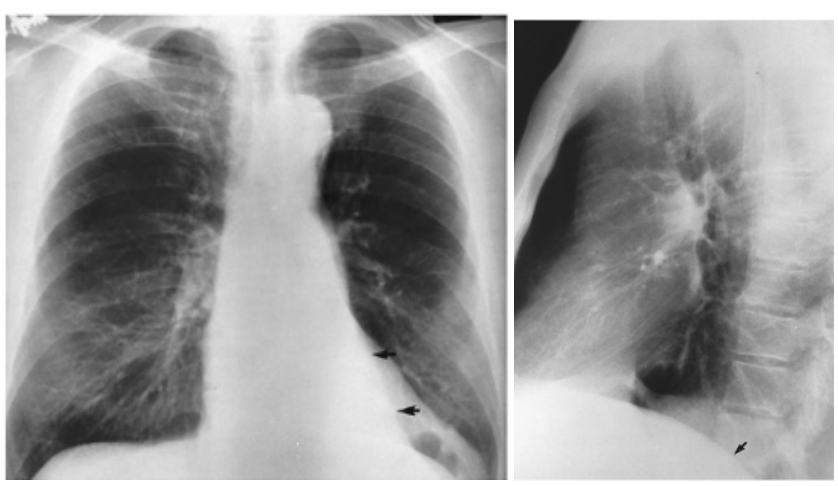


Entire left lung atelectasis with tracheal/mediastinal shift

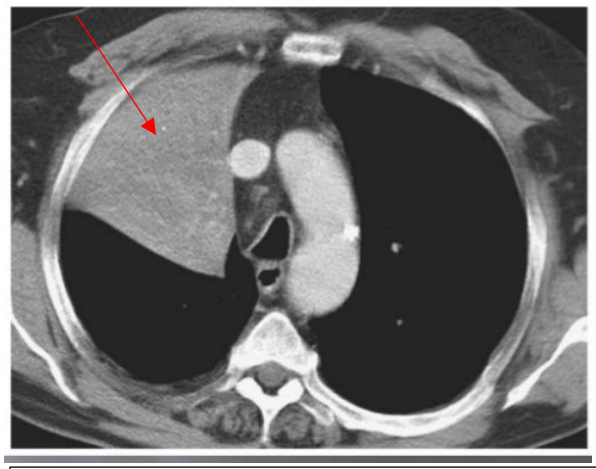
Subsegmental, discoid atelectasis (arrows)



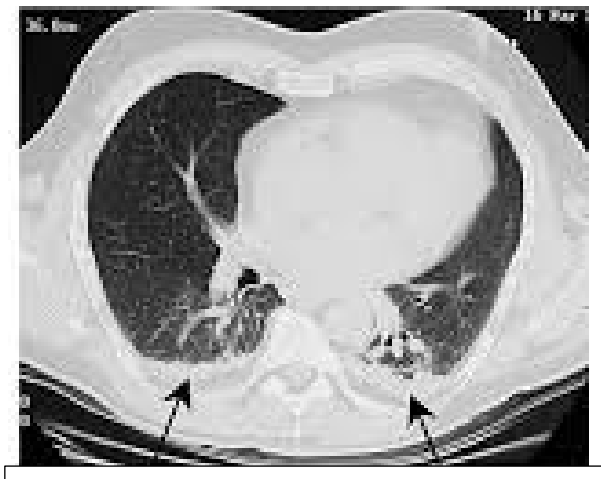
RML atelectasis (arrows)



LLL atelectasis (black arrows)



RUL atelectasis (arrow) on soft tissue window (Slideshare.com)



Dependent atelectasis (arrows) on lung window (Stepward.com)

<u>Pleural disease</u>:

-**Pleural effusion**: Abnormal accumulation of fluid within the pleural space

-<u>Radiographic appearance</u>

-*Upright PA CXR*:

-blunting of costophrenic angles (>200 cc of fluid)

-blunting of cardiophrenic angles

-fluid in interlobar fissures

-complete 'white-out' (with large amount of fluid)

-shifting mediastinum away from the side of fluid

-D/D with complete lung atelectasis

-*Lateral CXR*:

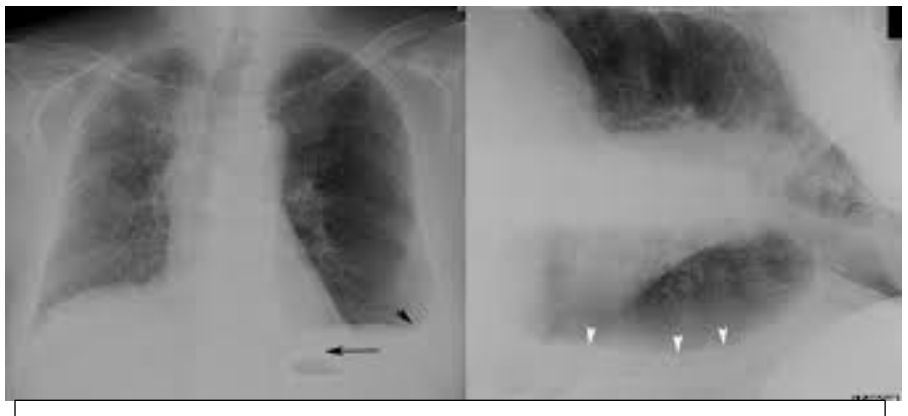
-blunting of more inferior posterior costophrenic angle (>50 cc of fluid)

-*Lateral decubitus CXR*: patient lying on their side

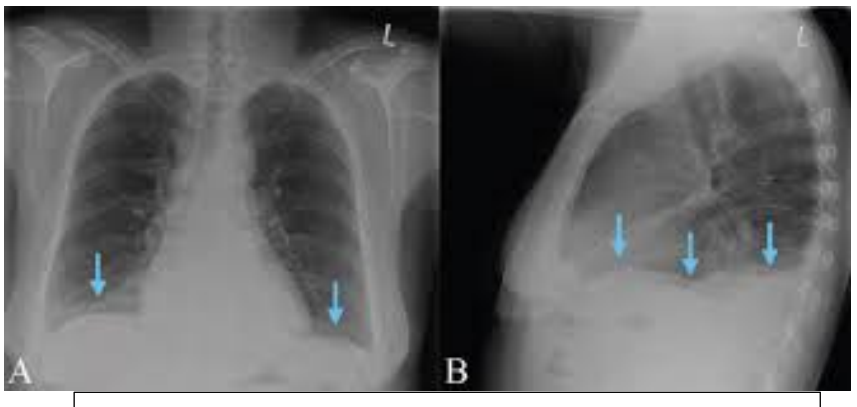
-layering out of free-flowing fluid (>15-25 cc of fluid)

-S*upine frontal CXR*: Fluid layers out posteriorly, creating subtle haziness

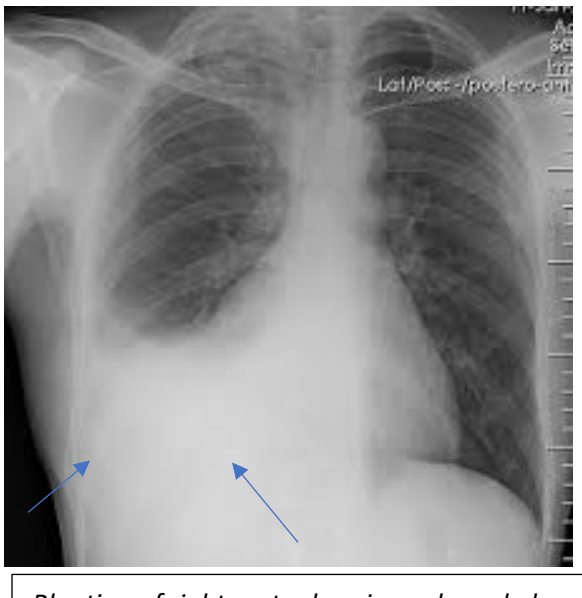
-fluid is often difficult to ascertain (even in higher volumes)



Blunting of costophrenic angle (black arrowheads).
Blunting of cardiophrenic angle (black arrow).
Layering out of fluid (white arrowheads) (Stritch.luc.edu)



Faint haziness on frontal view (arrows in A)
Blunting of posterior costophrenic angle (arrows in B)
(Researchgate.net)

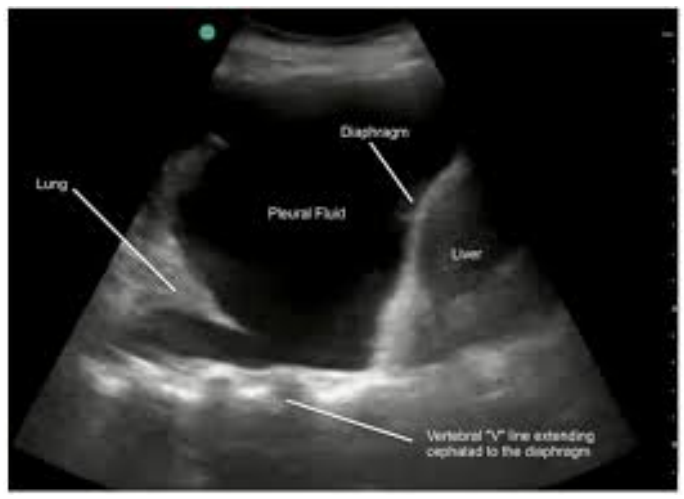


Blunting of right costophrenic angle and obscuration of hemidiaphragm (arrows)
(Radiopaedia.org)

Right-sided 'white-out'
(with leftward mediastinal shift)
(Radiopaedia.org)

-Sonographic appearance

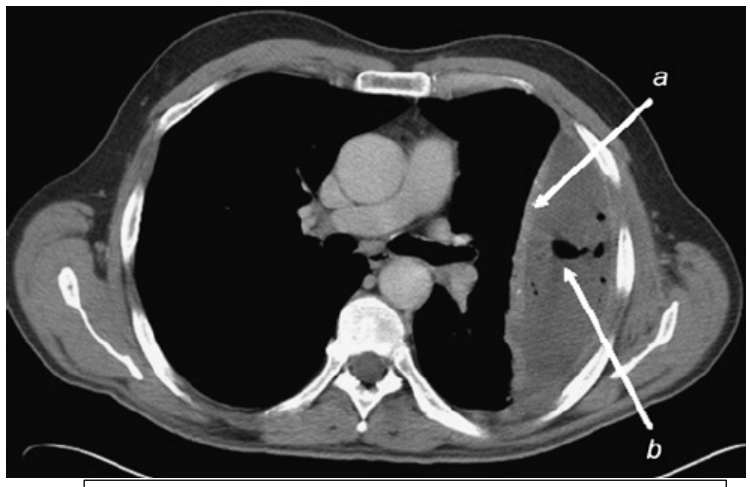
-Imaging performed via intercostal spaces
-Detects small fluid volumes (<10 cc of fluid)
-Simple effusion is *anechoic* (image to right)
-Complicated effusion (i.e. hemorrhage, infection, neoplasia) demonstrates underlying echoes (more *echogenic*)
-Sonography is utilized to guide thoracentesis (needle draining of fluid from pleural space)



-CT appearance

-Excellent at differentiating pleural fluid from pleural thickening and pleural masses
-Allows for assessment of associated pulmonary parenchymal abnormalities (neoplasia, pneumonia)
-Simple effusions demonstrate water density (0-20 HU)
-Complicated pleural effusions demonstrate increased density (> 20 HU)
-**Empyema:** infected pleural effusion (with pleural thickening and contrast enhancement)

Pleural effusions (white arrows)
(Stritch.luc.edu)



Empyema with enhancing periphery (arrow a)
Gas bubbles (arrow b)
(Researchgate.com)

Pneumothorax: presence of gas (often air) in pleural space

-*simple*: gas collection without mediastinal shift or diaphragm depression
-*tension*: enlarging collection with mediastinal shift and potential diaphragmatic depression; decreases venous return/cardiac output; life-threatening emergency!

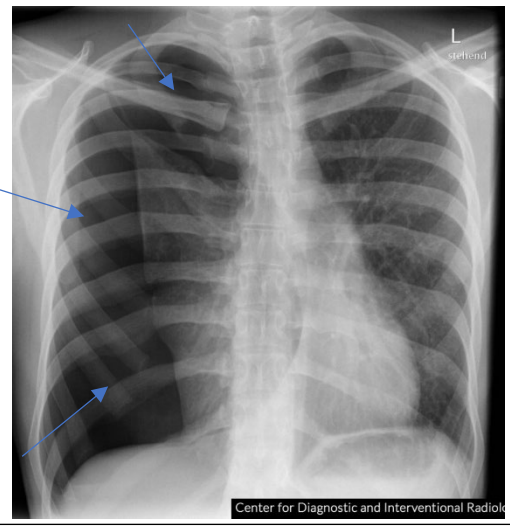
Radiographic appearance

-*Upright CXR*:
-visceral pleural line (thin opaque line)
-radiolucency peripheral to pleural line (void of lung markings)
-associated atelectasis in adjacent lung
-mediastinal shift/diaphragmatic depression (in cases of tension pneumothorax): decreased venous return…decreased cardiac output

-*Supine CXR:*
-anterior position of gas in non-dependent position makes detection of pneumothorax more difficult

-*Lateral decubitus CXR:*
-gas rises to the non-dependent side (opposite of layering out pleural fluid)

-*Expiratory CXR:*
-Normal lung volume is decreased (making abnormal pneumothorax more conspicuous)



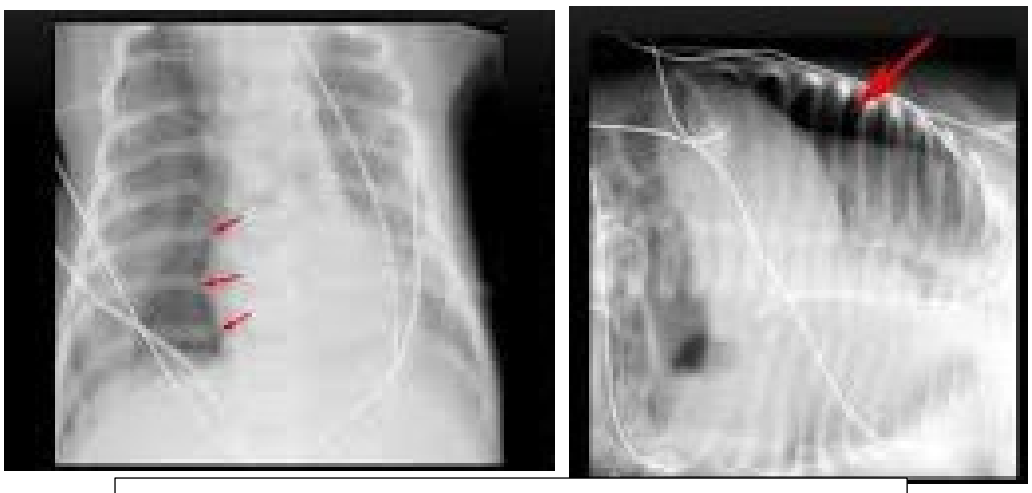
Large right-sided pneumothorax (arrows)
(AMBoss.com)

CT appearance

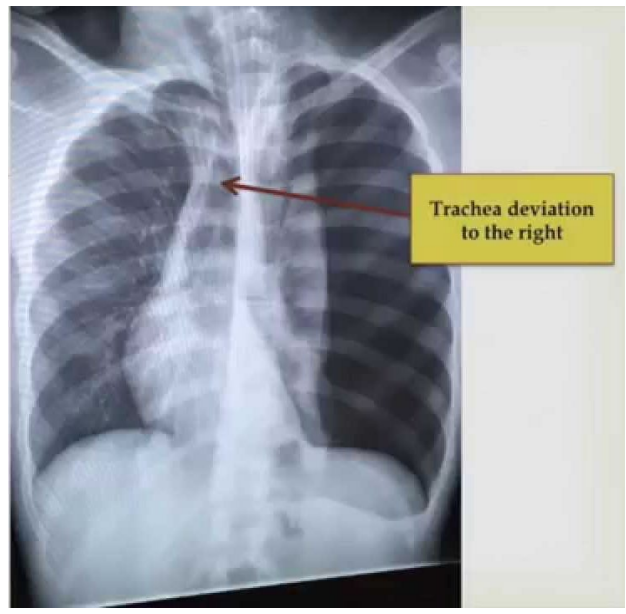
-Lung window demonstrates extrapulmonary gas (as well as associated atelectasis and potential signs of 'tension')

Sonographic appearance

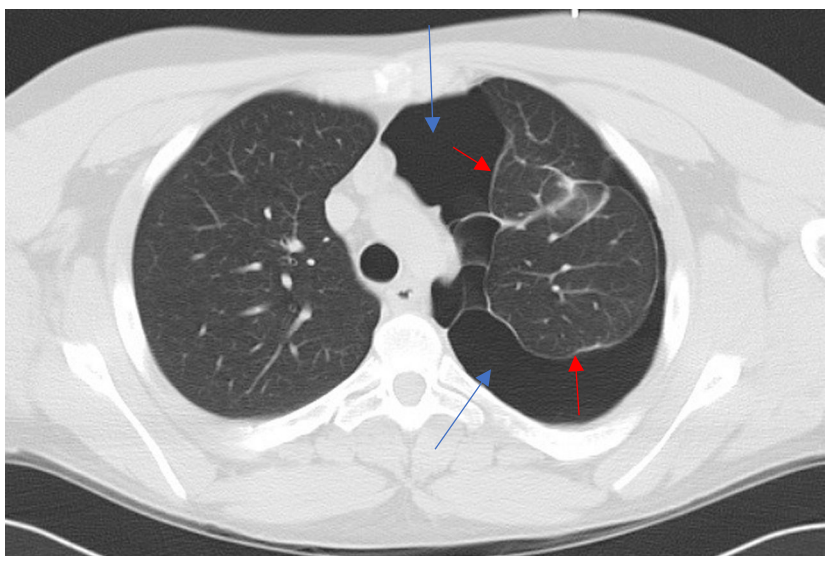
-Often utilized in emergency medicine (EM) and critical care



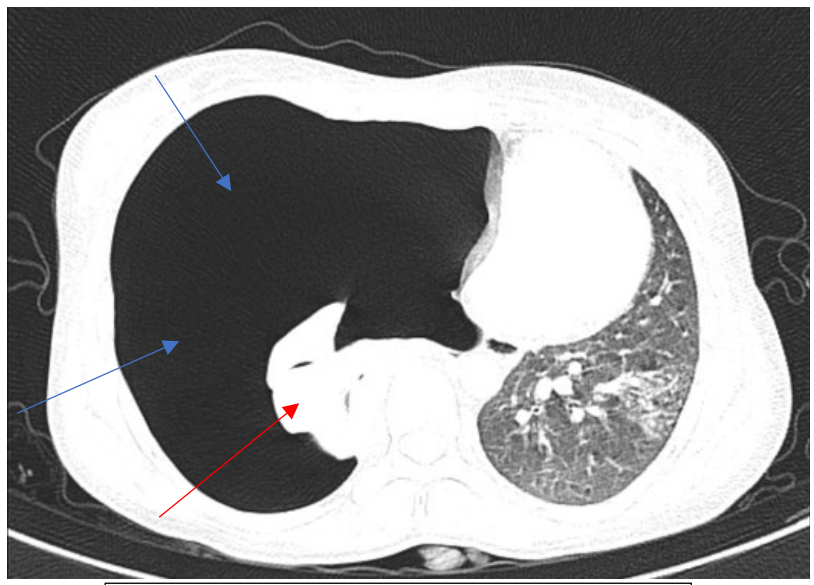
Right-sided pneumothorax, questionable on supine view and verified on decubitus imaging (arrow)



Left-sided tension pneumothorax (with mediastinal shift and diaphragm depression)
(Youtube.com)



Pneumothorax (blue arrows). Visceral pleura (red arrows)
(ERR.com) Lung window



Right tension pneumothorax (blue arrows)
Atelectasis (red arrow)
(Radiopaedia.org) Lung window

<u>Pleural masses</u>:

-<u>Pleural plaque</u>: common manifestation of asbestos exposure

Radiographic appearance

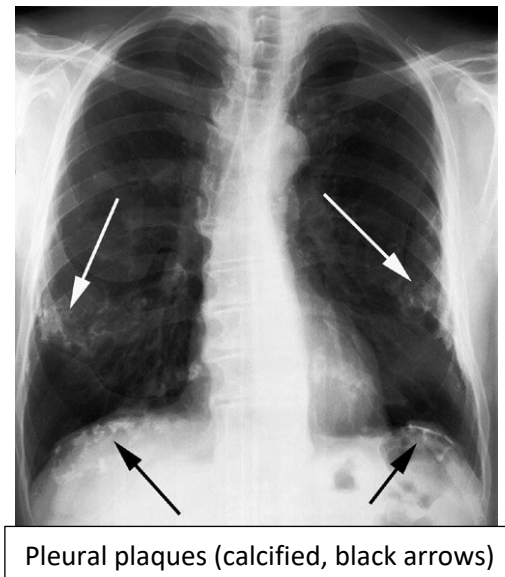
-faint density (better defined at inner margin than outer margin)

-'leaf-like'

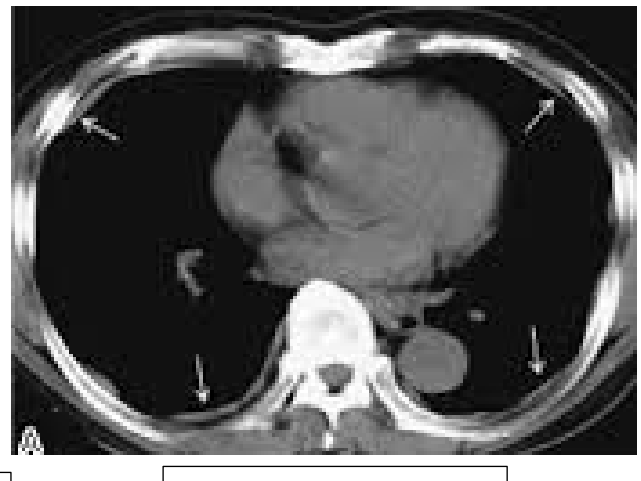
CT appearance

-modality of choice to assess asbestos-related disease (including pleural plaques)

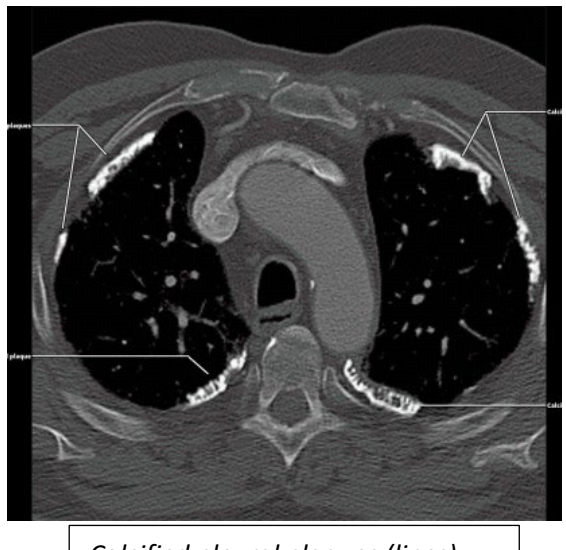
-peripheral, pleural-based soft tissue foci (calcified in 5-15%)



Pleural plaques (calcified, black arrows) (non-calcified, white arrows)
(Merck.com)



Pleural plaques (arrows)
(Researchgate.com)



Calcified pleural plaques (lines)
(Sciencedirect.com)

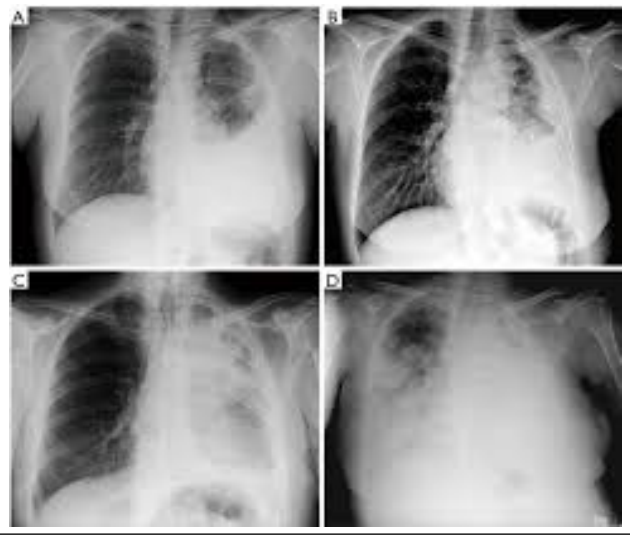
-Pleural mesothelioma: malignant neoplasm of pleura (strongly associated with asbestos exposure)

Radiographic appearance

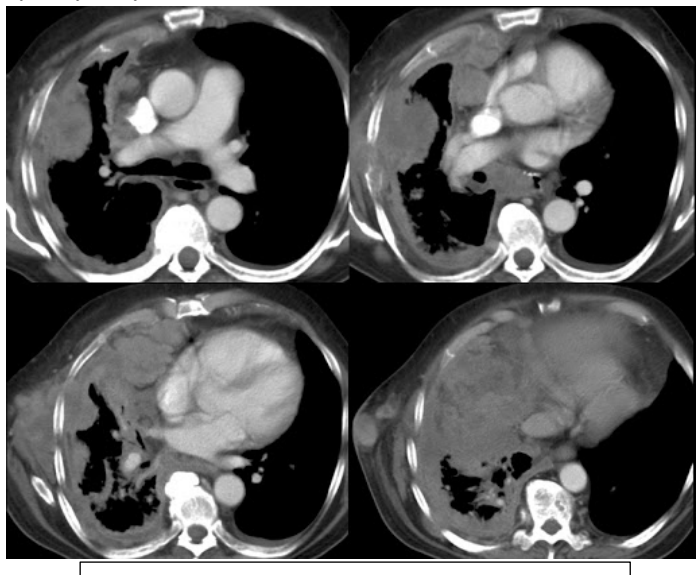
-pleural-based opacity

-ranging from small focal density to encasement of the hemithorax

-pleural effusion and mediastinal lymphadenopathy may coexist



Serial worsening of left-sided mesothelioma (A-C) with contralateral involvement (D)
(Journal of thoracic disease)



Right-sided mesothelioma
(chestatlas.com)

CT appearance

-modality of choice for staging of disease

-nodular pleural thickening (including mediastinal pleural involvement, a worrisome sign)

-potential encasement of entire pleural space (with decreased volume)

-chest wall and diaphragmatic extension possible

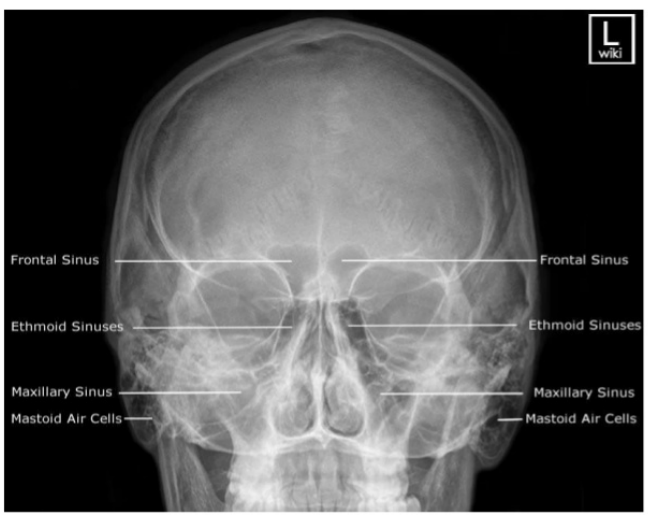
-D/D: pleural metastases

Paranasal sinus imaging

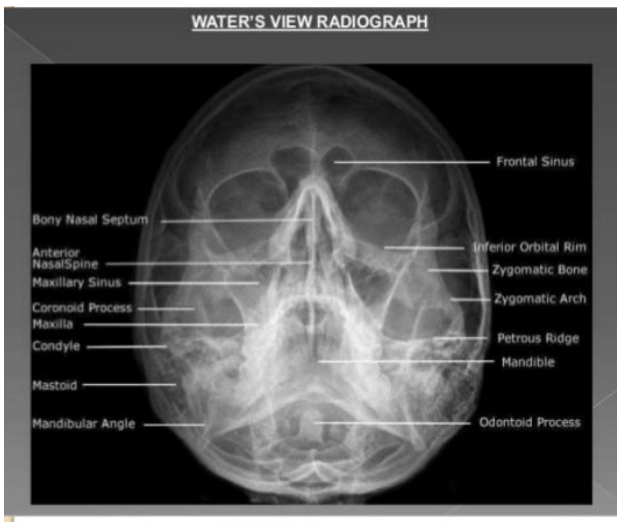
Radiographic examination:

-radiographs are limited in their depiction of detailed anatomy and pathology of the paranasal sinuses

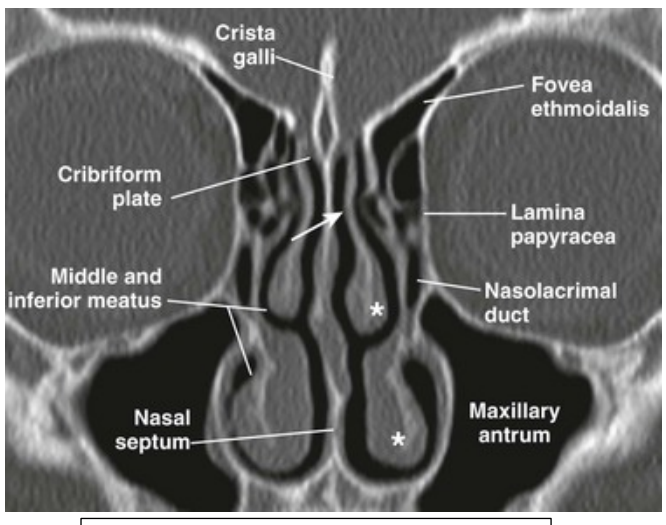
-multiple imaging projections are necessary to assess all paranasal sinuses



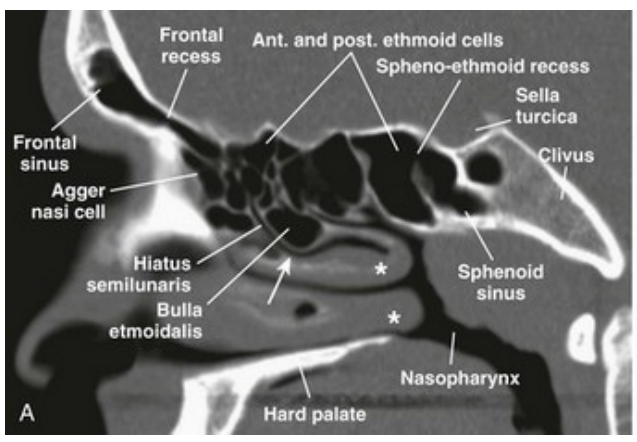
Caldwell projection
(Slideshare.com)



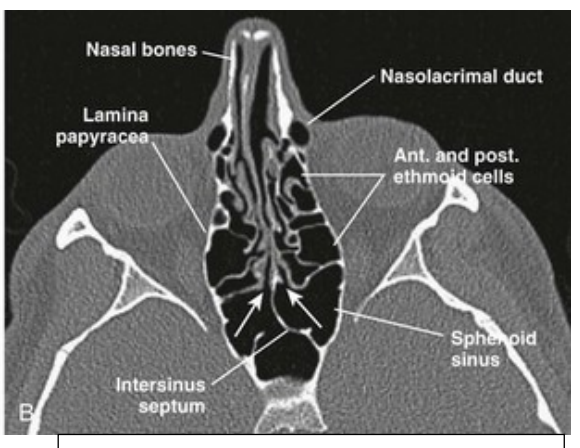
Lateral projection
(Slideshare.com)



Coronal plane (bone window)
**: middle and inferior turbinates*
(Radiologykey)



Sagittal plane (bone window)
**: middle/inferior turbinates*
Arrow: middle meatus (Radiologykey)



Axial plane (bone window)
Arrow: sphenoethmoid recesses
(Radiologykey)

CT examination:

-modality of choice to assess paranasal sinus anatomy and drainage patterns

-optimal assessment of infectious, inflammatory, and neoplastic conditions

-MRI examination

-complementary to CT imaging

-allows for optimal assessment of soft tissue and intracranial extension of neoplasia/infection

Normal anatomy

-*sphenoethmoidal recess*: drains the sphenoid sinuses and the posterior ethmoid air cells into the superior meatus

-*ostiomeatal complex (OMC):* common passage linking the frontal sinus, maxillary sinus, and anterior ethmoid air cells to their site of drainage at the middle meatus.

-*nasolacrimal duct* drains into the inferior meatus

PATHOLOGIC CONDITIONS:

Acute sinusitis: inflammation of paranasal sinuses lasting less than 4 weeks

Radiographic appearance:

-gas-fluid level in paranasal sinuses

-mucosal/mucoperiosteal thickening

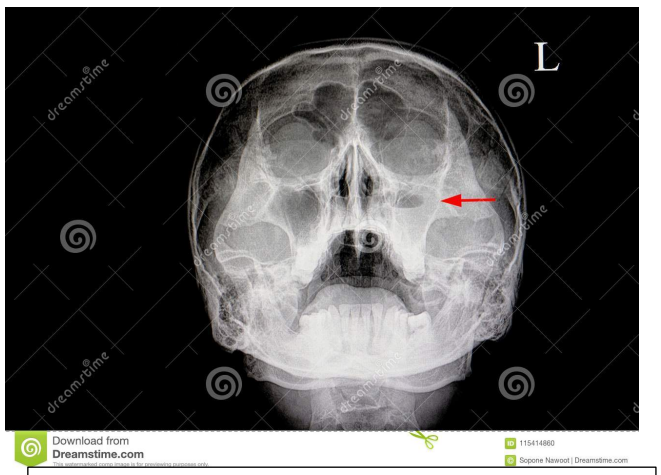
CT appearance: examination of choice

-peripheral mucosal thickening

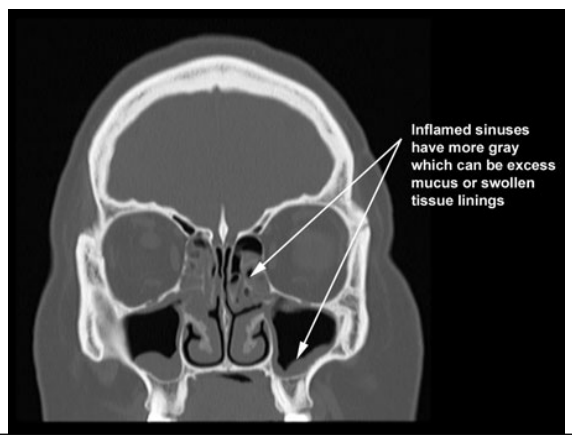
-gas-fluid level in paranasal sinuses

-gas bubbles amidst intra-sinus fluid

-ostiomeatal complex obstruction



Air-fluid level and mucosal thickening (arrow), left maxillary sinus (secondary to acute sinusitis)



Acute bilateral ethmoiditis and maxillary sinusitis
(Henry Ford) CT bone window

Chronic sinusitis: long-standing paranasal sinus inflammation/infection

Radiographic appearance

- thickening and increased sclerosis of paranasal sinus walls

CT appearance: examination of choice

-thickening and increased sclerosis of paranasal sinus walls

-intra-sinus calcification

Chronic sinusitis: Osseous wall thickening (and opacification) of bilateral maxillary sinuses (arrows)

Paranasal sinus mucocele: complete opacification of a paranasal sinus with mucus, secondary to obstruction of drainage

-Most common to least common site: Frontal>ethmoid>Maxillary/sphenoid

Radiographic appearance:

-complete opacification (and bony expansion) of a paranasal sinus

CT appearance: examination of choice

-complete sinus opacification

-thinning and expansion of osseous margins of sinus (with potential of complete osseous absorption)

Right ethmoid sinus mucocele (arrows)
(SciELO.br)

Note: Paranasal neoplasia often utilizes both CT and MR imaging for optimal assessment

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?

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