Radiographic Assessment of Tubes, Lines, Drains, and Other Devices - Normal Placement, Positioning Errors, Complications, and Indications for Radiological Evaluation

Kevin Kalisz

8/1/2017

Outline

- Endotracheal tubes
- Tracheostomy tubes
- Central venous catheters
- PA catheters
- Chest tubes
- Enteric tubes
- Cardiac pacemakers/defibrillators

1. Normal position
2. Abnormal position/complications
3. Indications of radiographic evaluation

Endotracheal Tubes – Normal Position

- Gold standard for determining placement in airway is end-tidal CO_2*
  - Limited ability to detect some complications
  - Physical exam maneuvers also may be helpful

- Radiographic assessment of tube position based on visualizing radio-opaque line on ETT

*In patients with adequate tissue perfusion

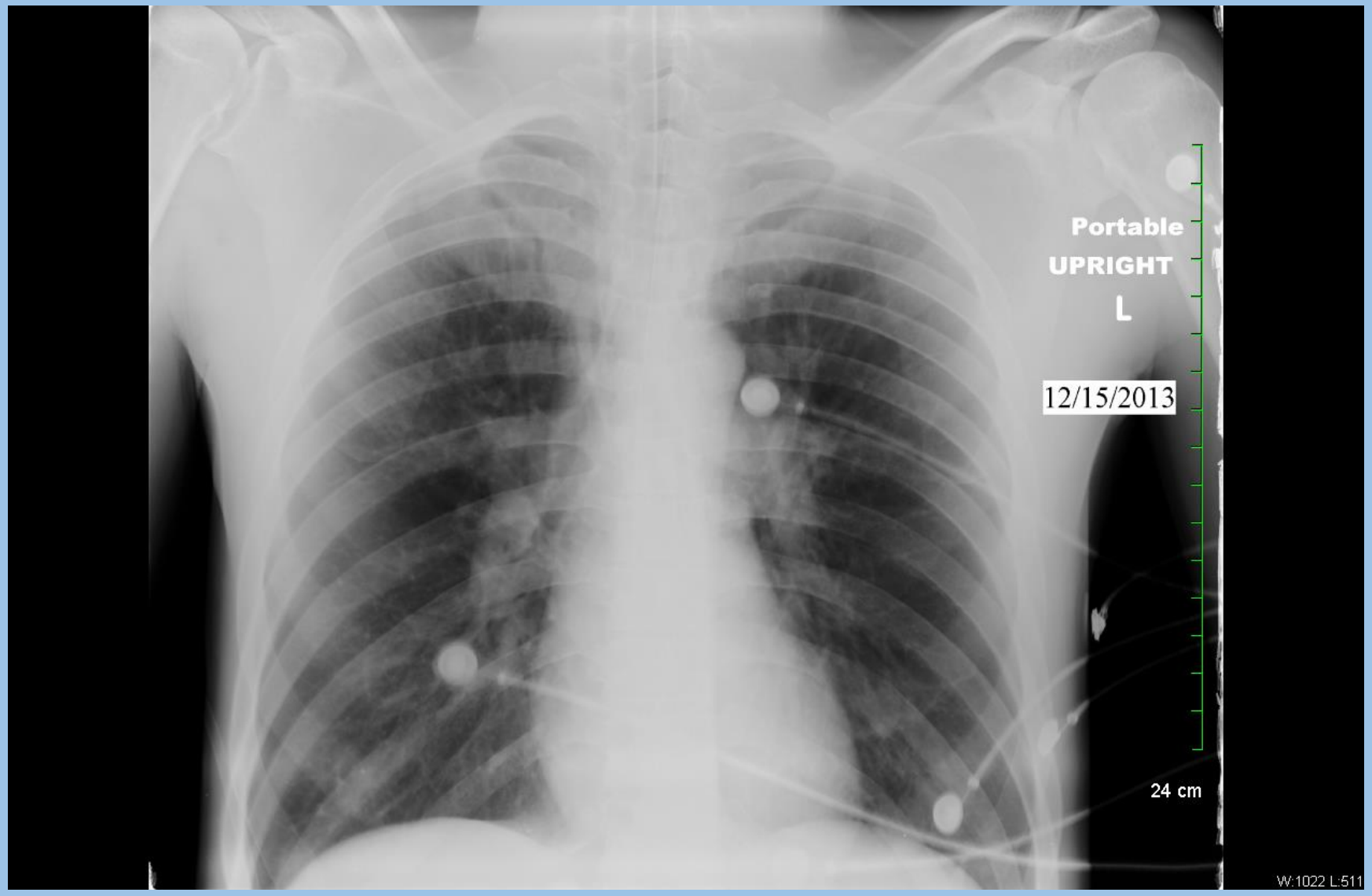
Endotracheal Tubes – Normal Position

- ETT position dependent on neck flexion and extension:
  - Neck flexion (mandible @ T1-2): ETT tip can descend up to 2 cm
  - Neck extension (mandible @ C4): ETT tip can ascend up to 2 cm

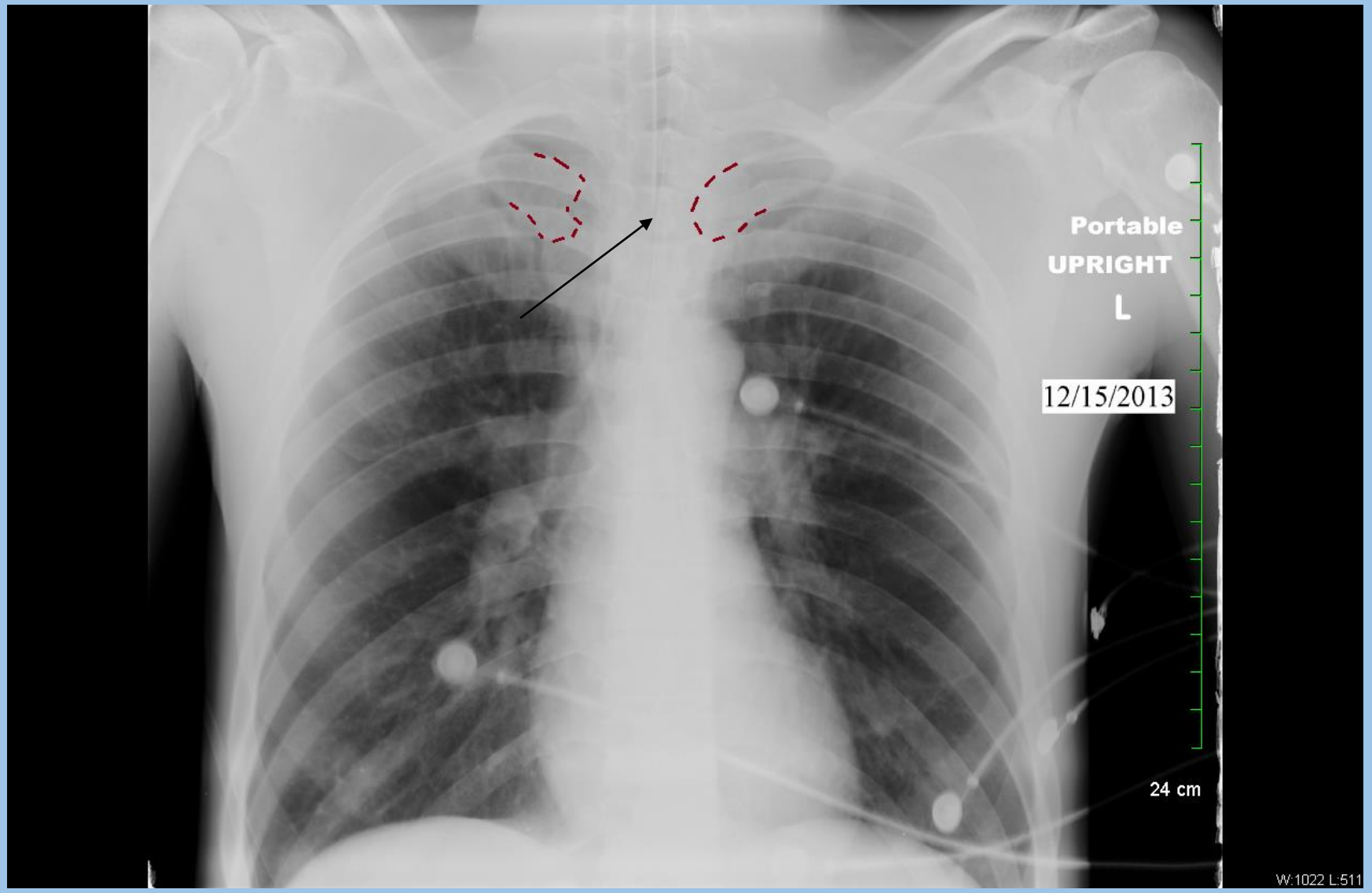
- Acceptable positioning:
  - Proximal tube tip: level of medial heads of the clavicle
    - Too proximal – risk upper airway/vocal cord injury
  - Distal tube tip: 2 cm above carina
    - Too distal – mainstem bronchus intubation with neck flexion

  - Tracheal cuff should fill tracheal wall (not bulge)

Endotracheal Tubes – Normal Position

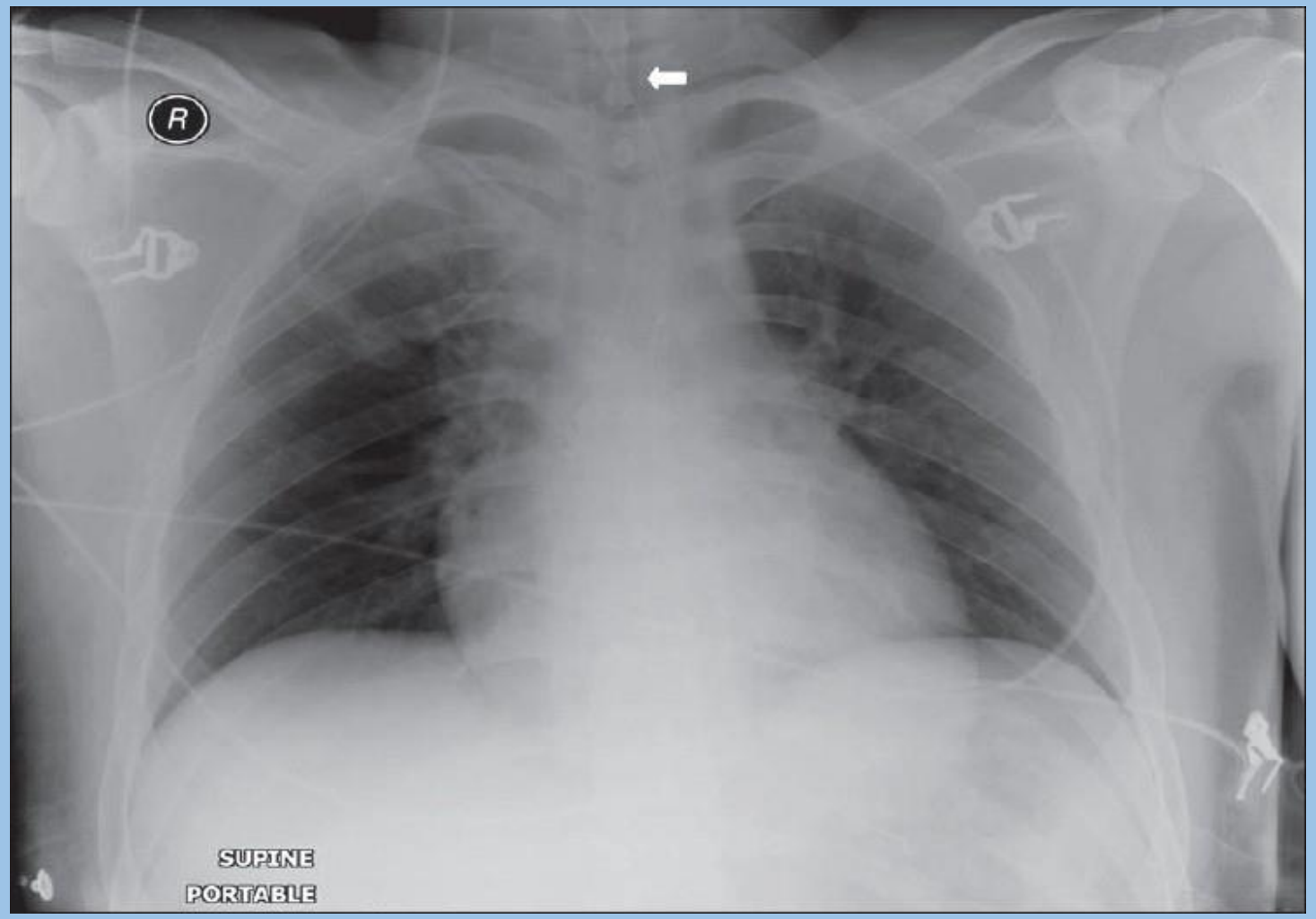


Endotracheal Tubes – Normal Position



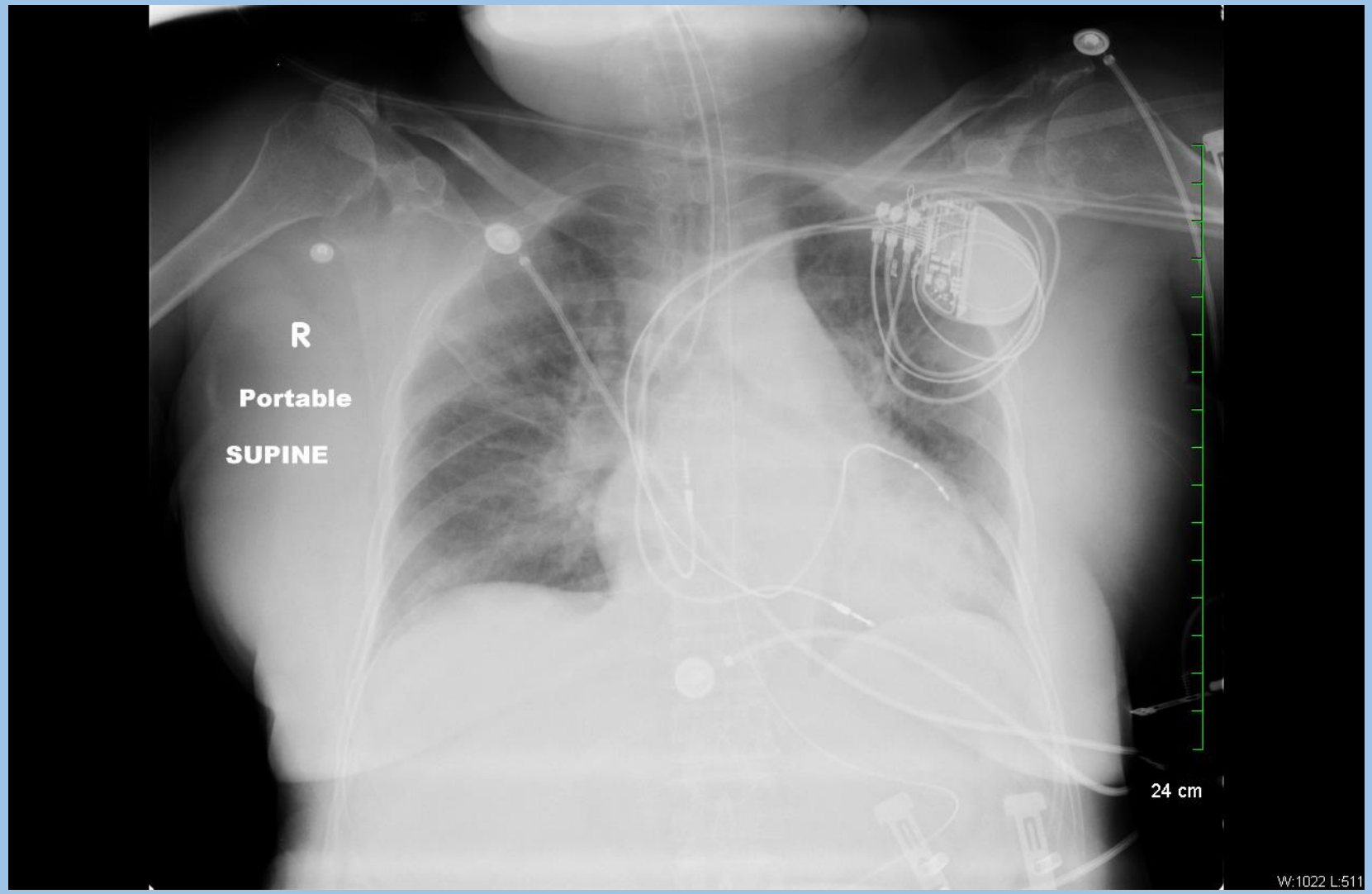
Endotracheal Tubes – Abnormal Position

- Potential Complications:
  - Increased risk of spontaneous extubation
  - Aspiration
  - Vocal cord injury
  - Gastric distension



Proximal ETT position

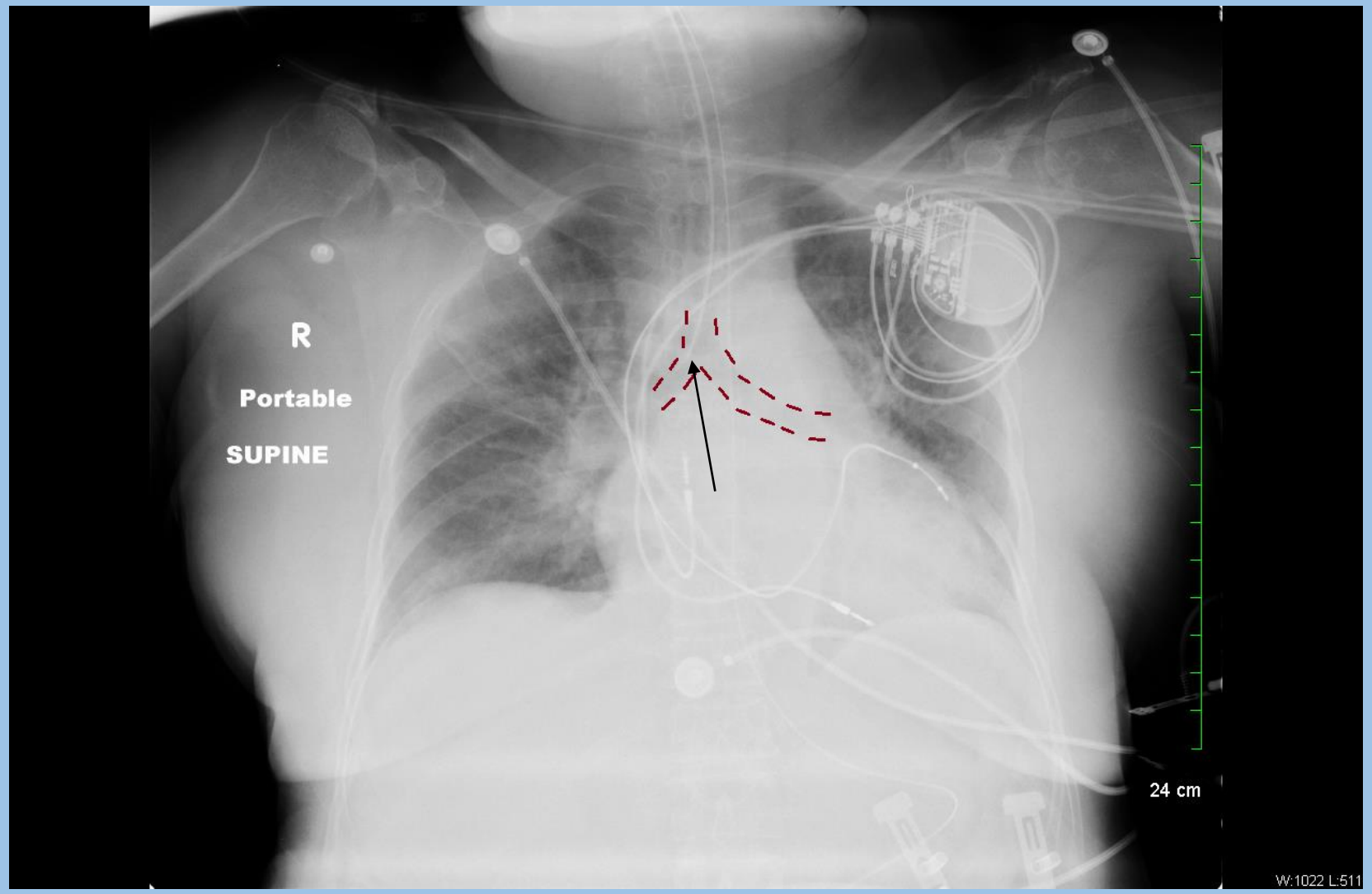
Endotracheal Tubes – Abnormal Position



Endotracheal Tubes – Abnormal Position

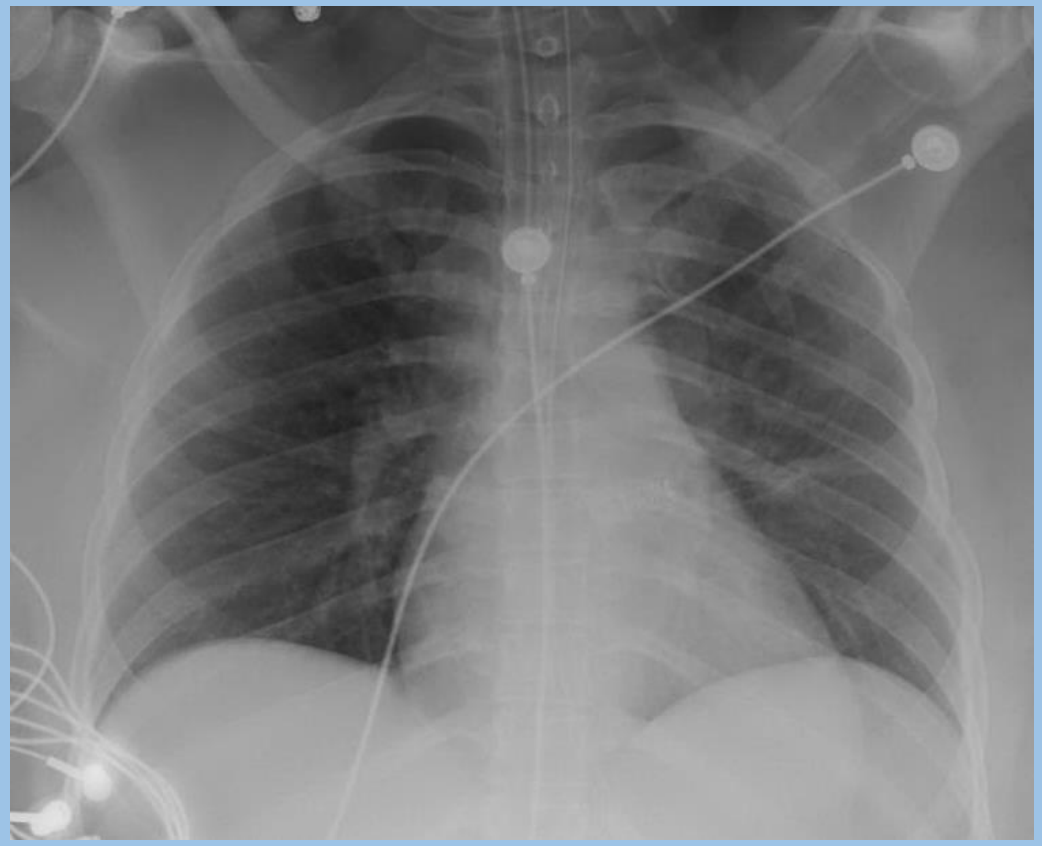
- Potential Complications:
  - Left lobe (R main stem bronchus) or right upper lobe (R inferior intermediate bronchus) collapse/atelectasis
  - Tension pneumothorax

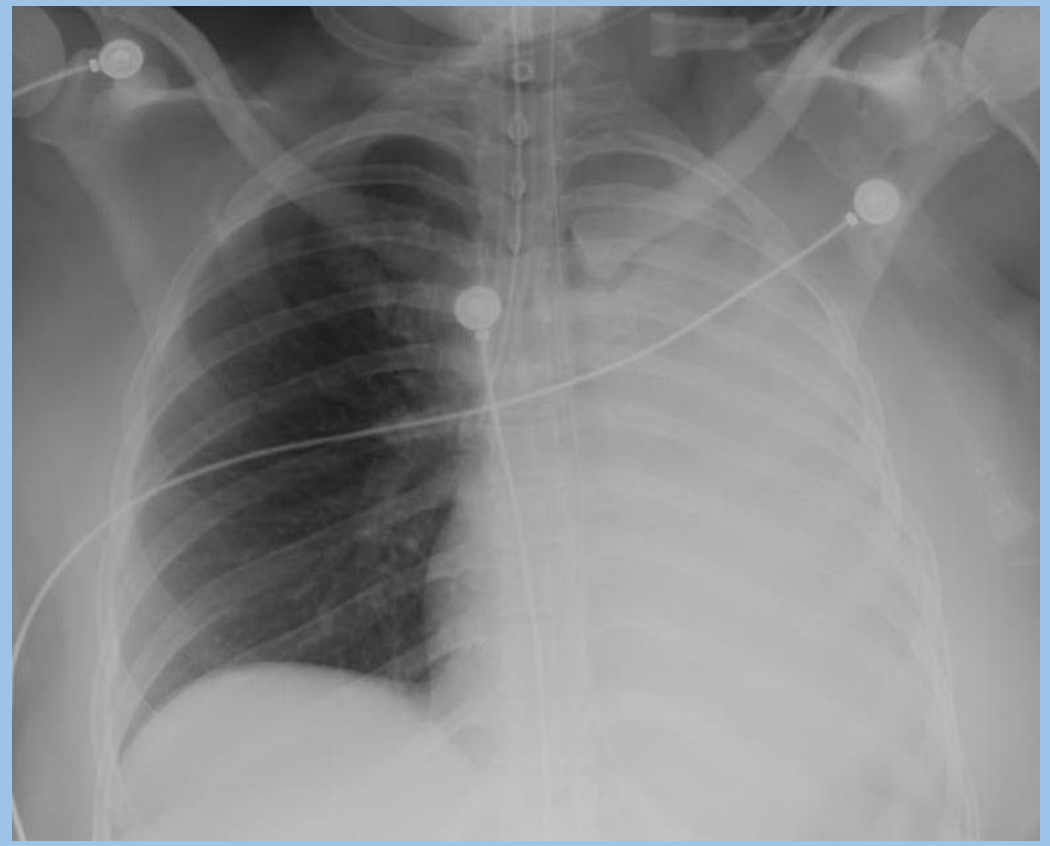
*Right main stem bronchus intubation is most common positioning error



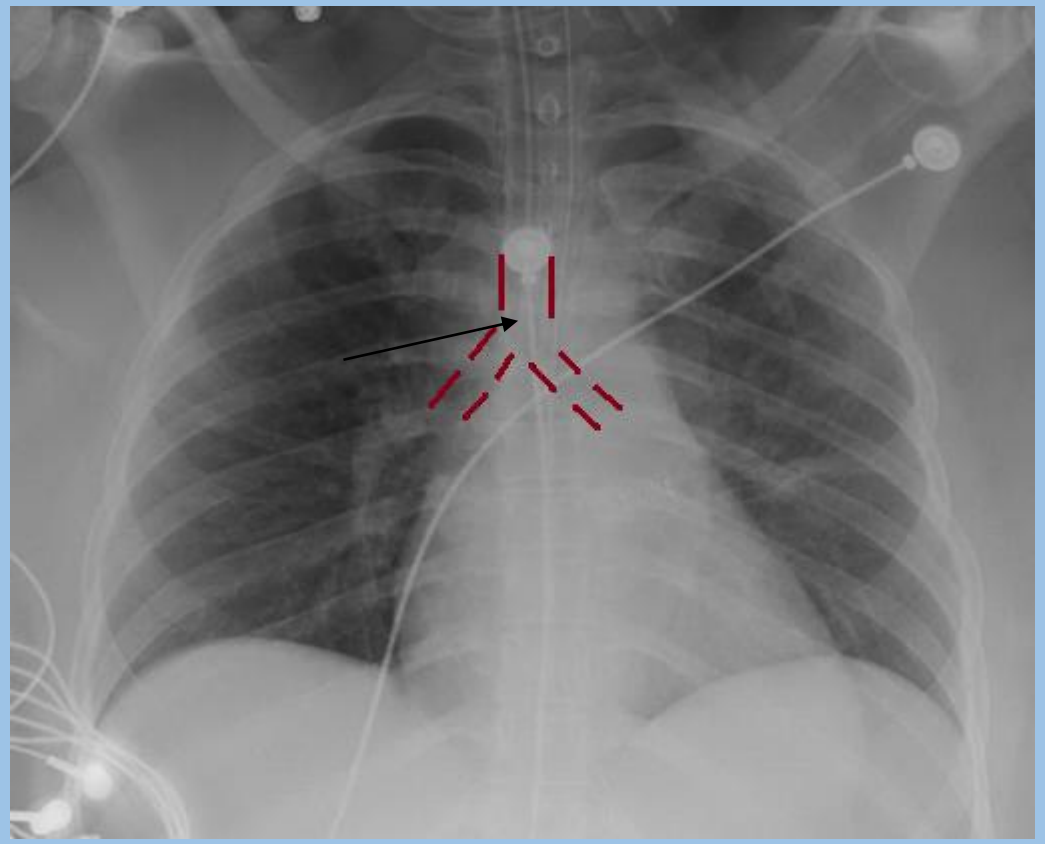
Uncomplicated right main stem bronchus intubation

Endotracheal Tubes – Complications





Endotracheal Tubes – Complications



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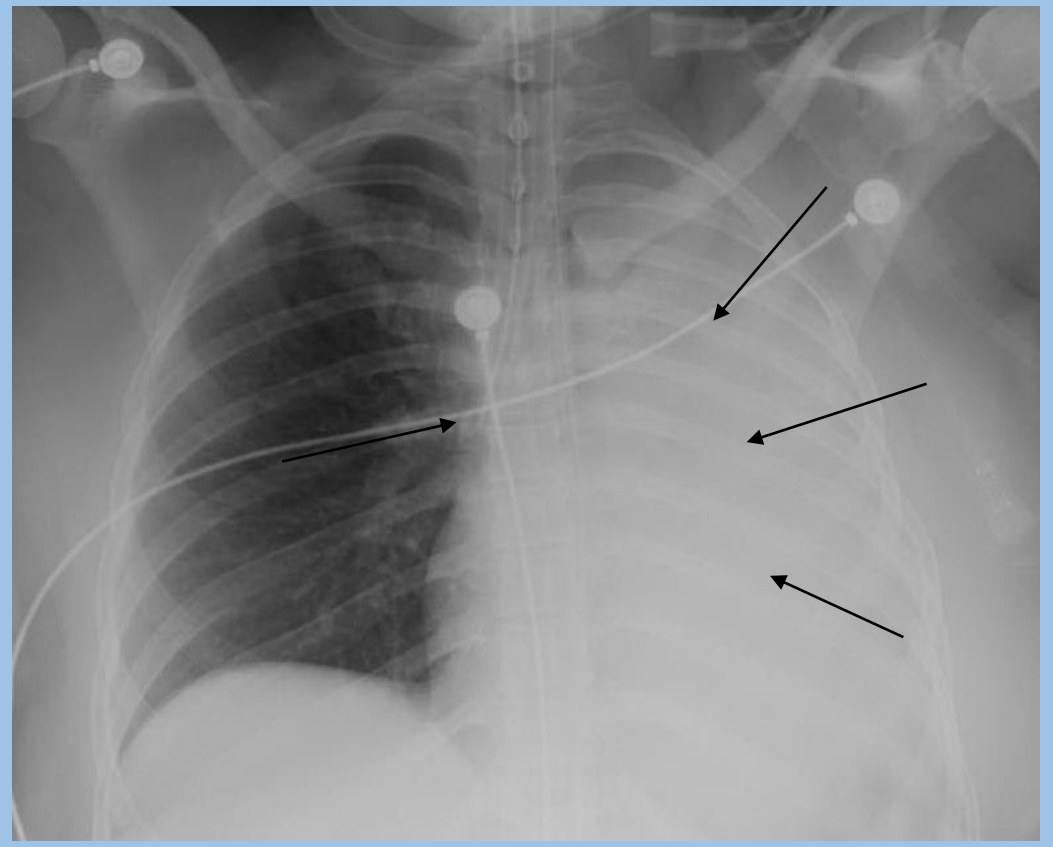

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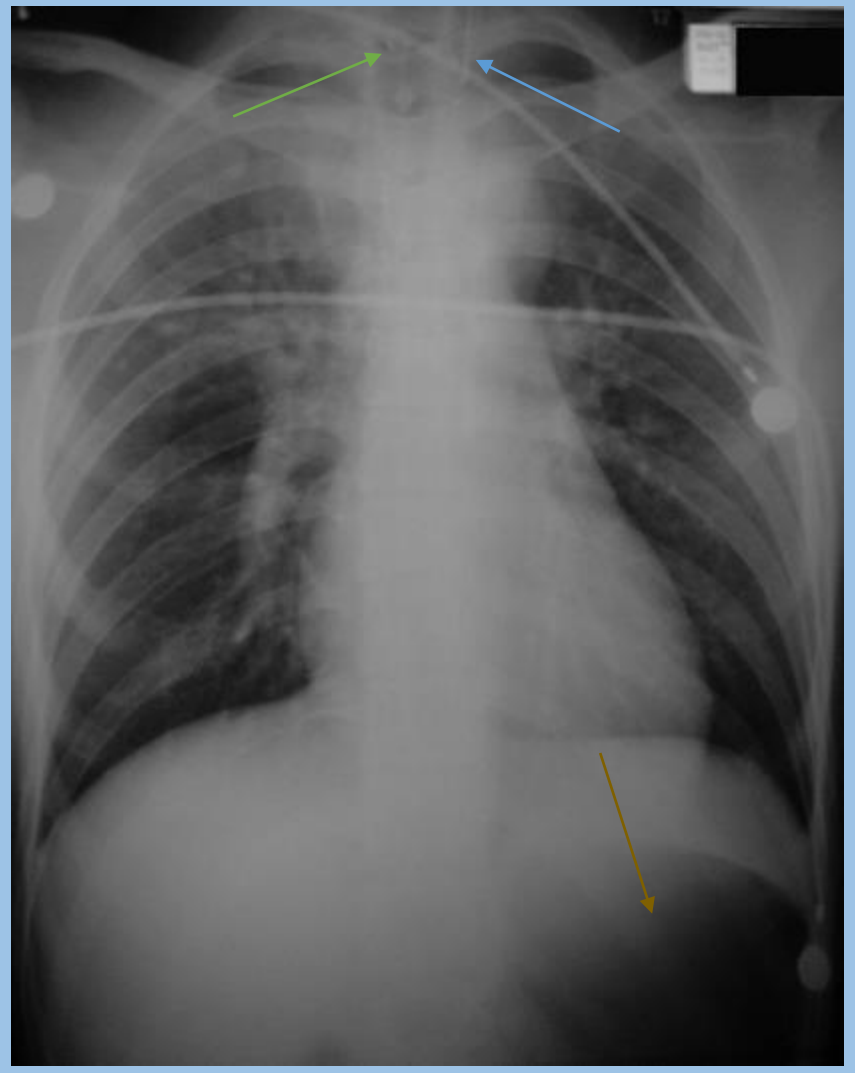
Right main stem bronchus intubation with left lung collapse (thin black arrows)

Endotracheal Tubes – Complications



Esophageal intubation with marked gastric distension

Endotracheal Tubes – Indications for Studies

- *ACR Appropriateness Criteria*

- Rating scale:
  - 1-3: Usually not appropriate
  - 4-6: May be appropriate
  - 7-9: Usually appropriate

- Takes into account clinical usefulness and potential costs/harms (i.e. radiation dose, etc.)

Endotracheal Tubes – Indications for Studies

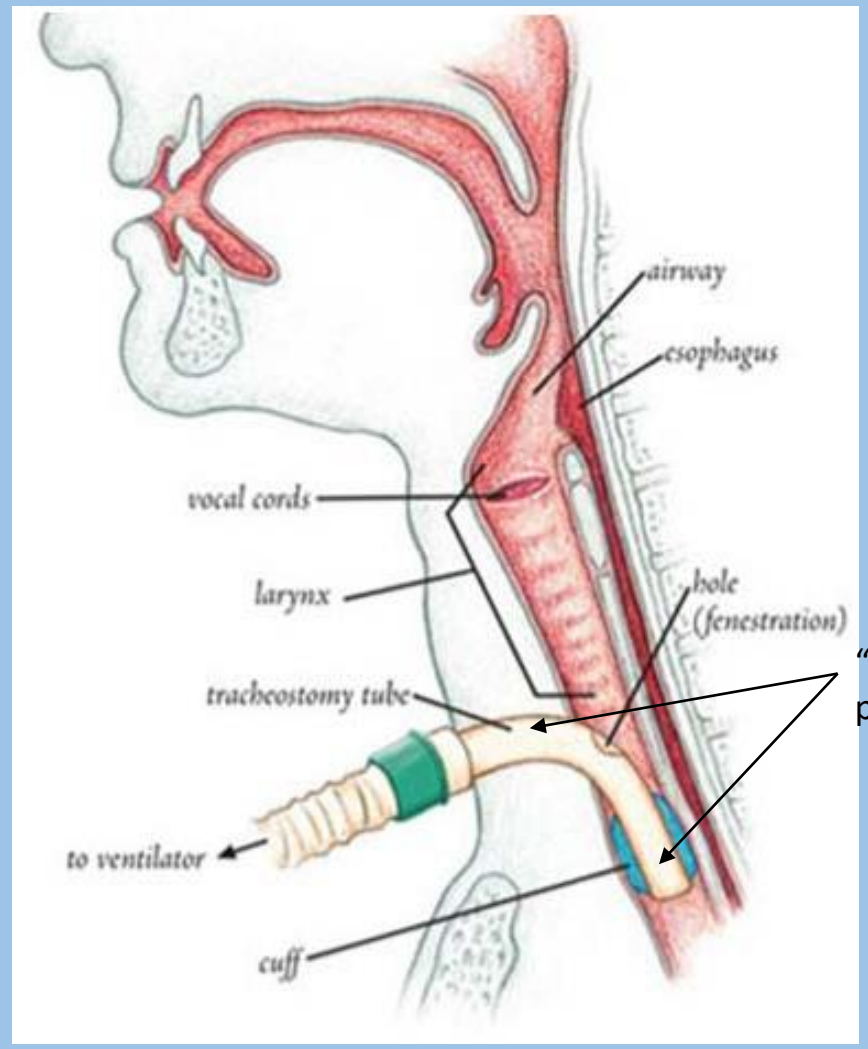
- Radiographic evaluation indicated:
  - After ETT insertion (appropriateness score = 9)
    - Higher rate of detecting malpositioned tubes with chest xrays than physical exam
  - Patient with ETT in place – clinical indications only (9)

- Radiographic evaluation NOT indicated:
  - Daily, routine follow-up (3)
    - Minimal benefit in cardiothoracic patients(?)

Legend: 1-3: usually not appropriate; 4-6: may be appropriate; 7-9: usually appropriate

Tracheostomy Tubes – Normal Position

- Similar distal tip positioning rules as ETTs
- Tip position should NOT vary with neck flexion/extension
- At least 2/3 of “smooth” portion should lie within the trachea



Tracheostomy Tubes – Normal Position

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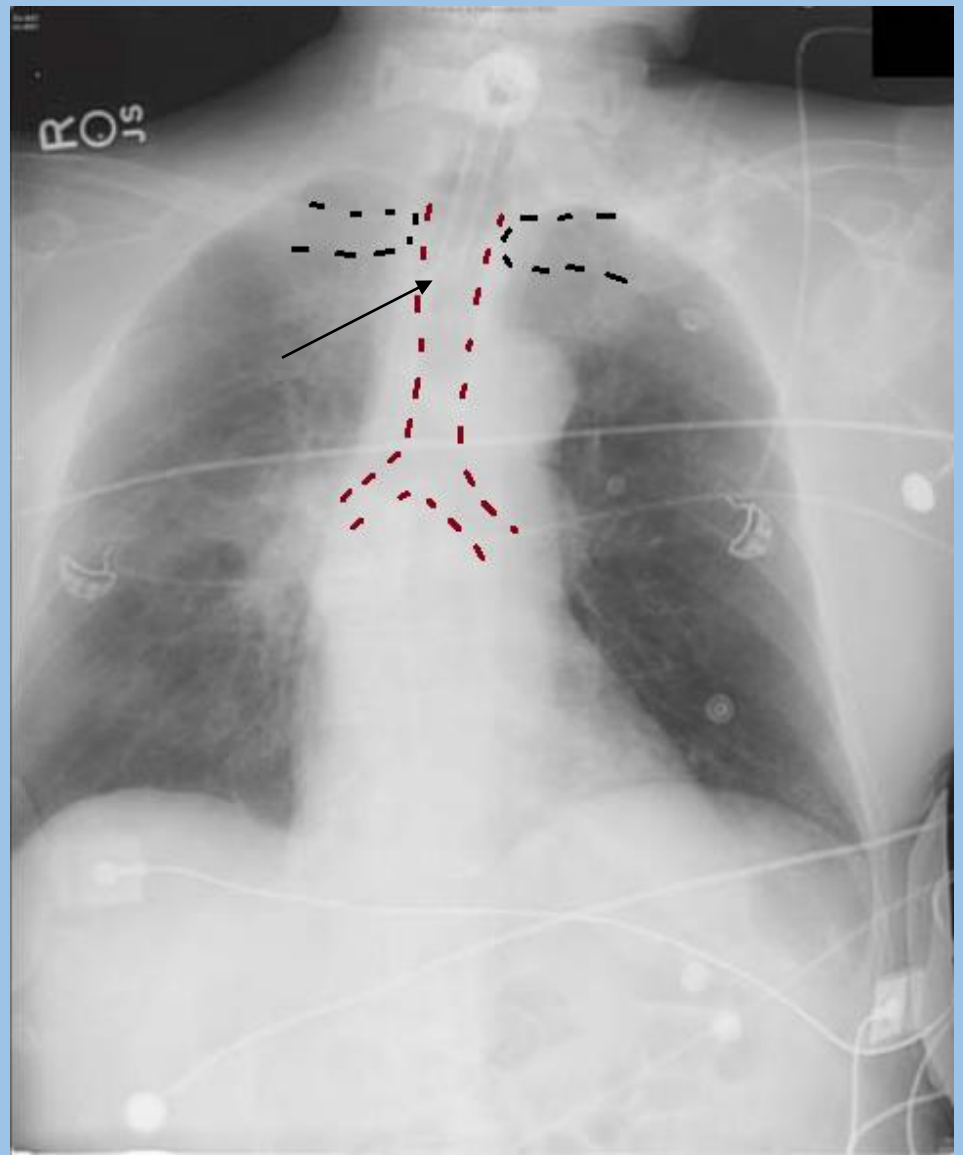
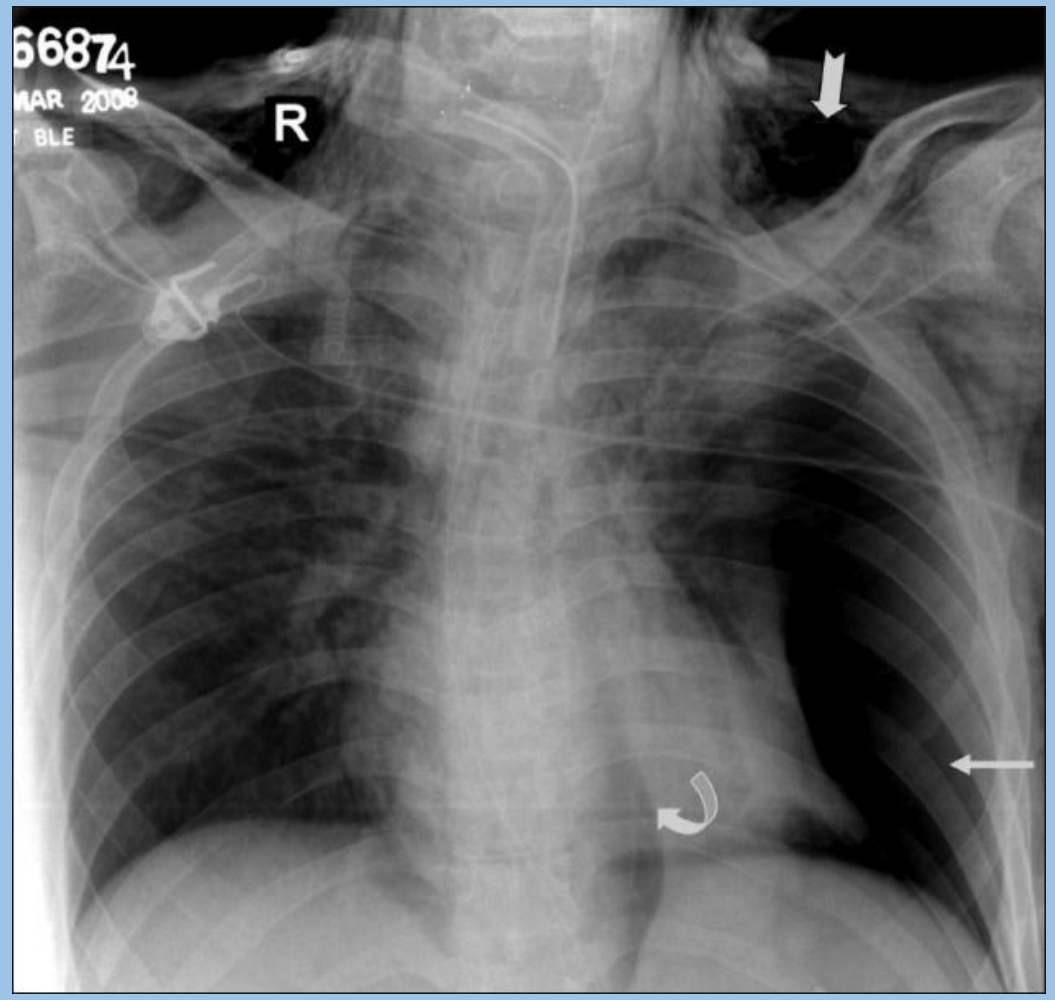


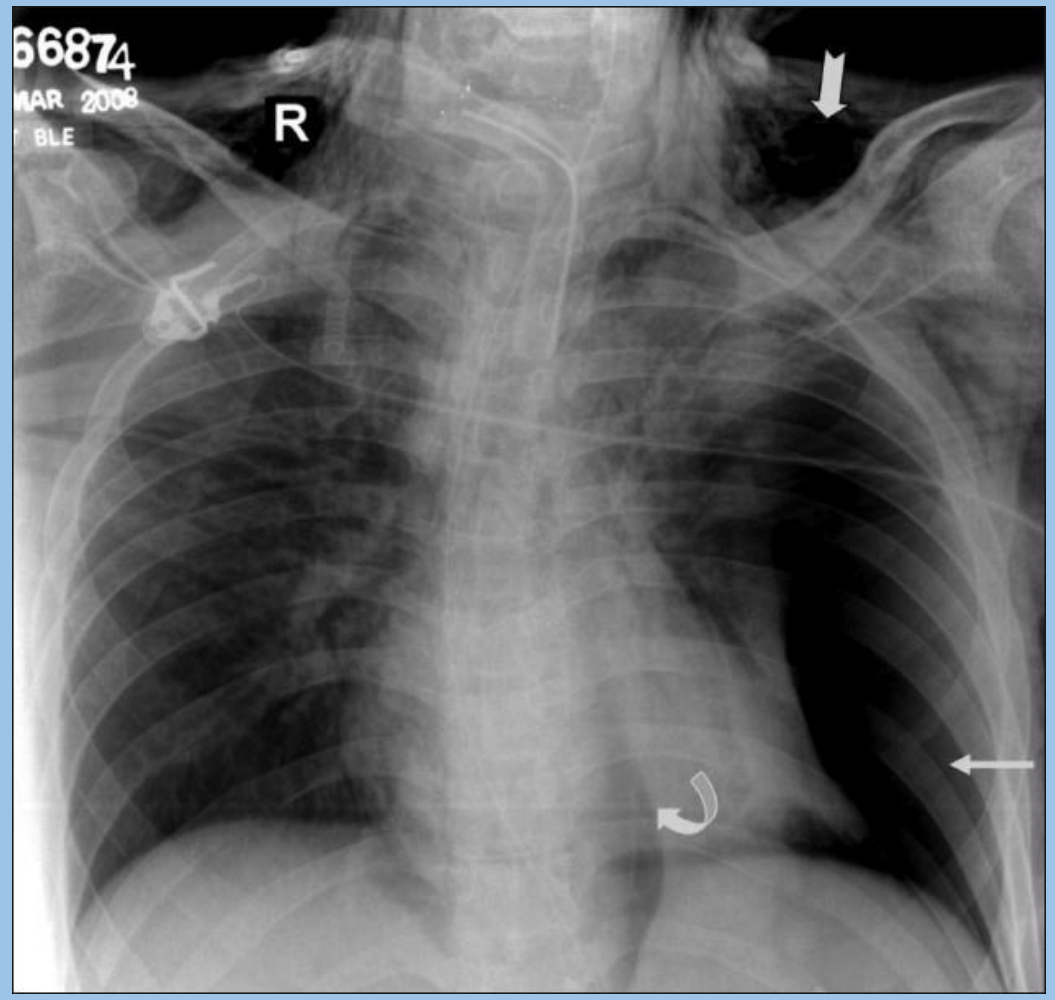
Tracheostomy Tubes – Complications



Tracheostomy Tubes – Complications

- Potential complications
  - Tracheal injury
    - Subcutaneous emphysema/pneumomediastinum*
  - Pneumothorax
  - Hemorrhage
  - Late complications:
    - Tracheal stenosis
    - Tracheomalacia
    - Vascular erosions
    - Tracheobronchial fistula

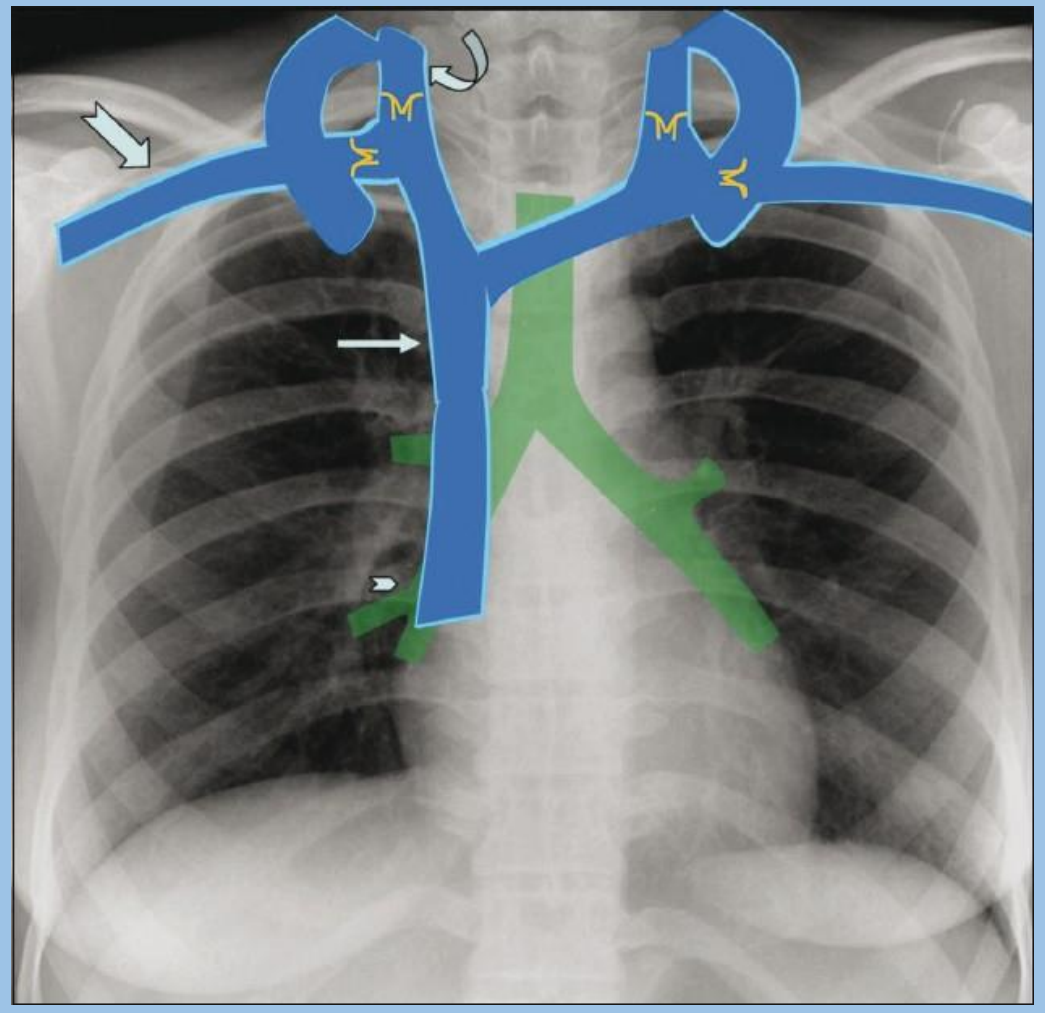
*Small amount of subcutaneous emphysema may be normal post-insertion



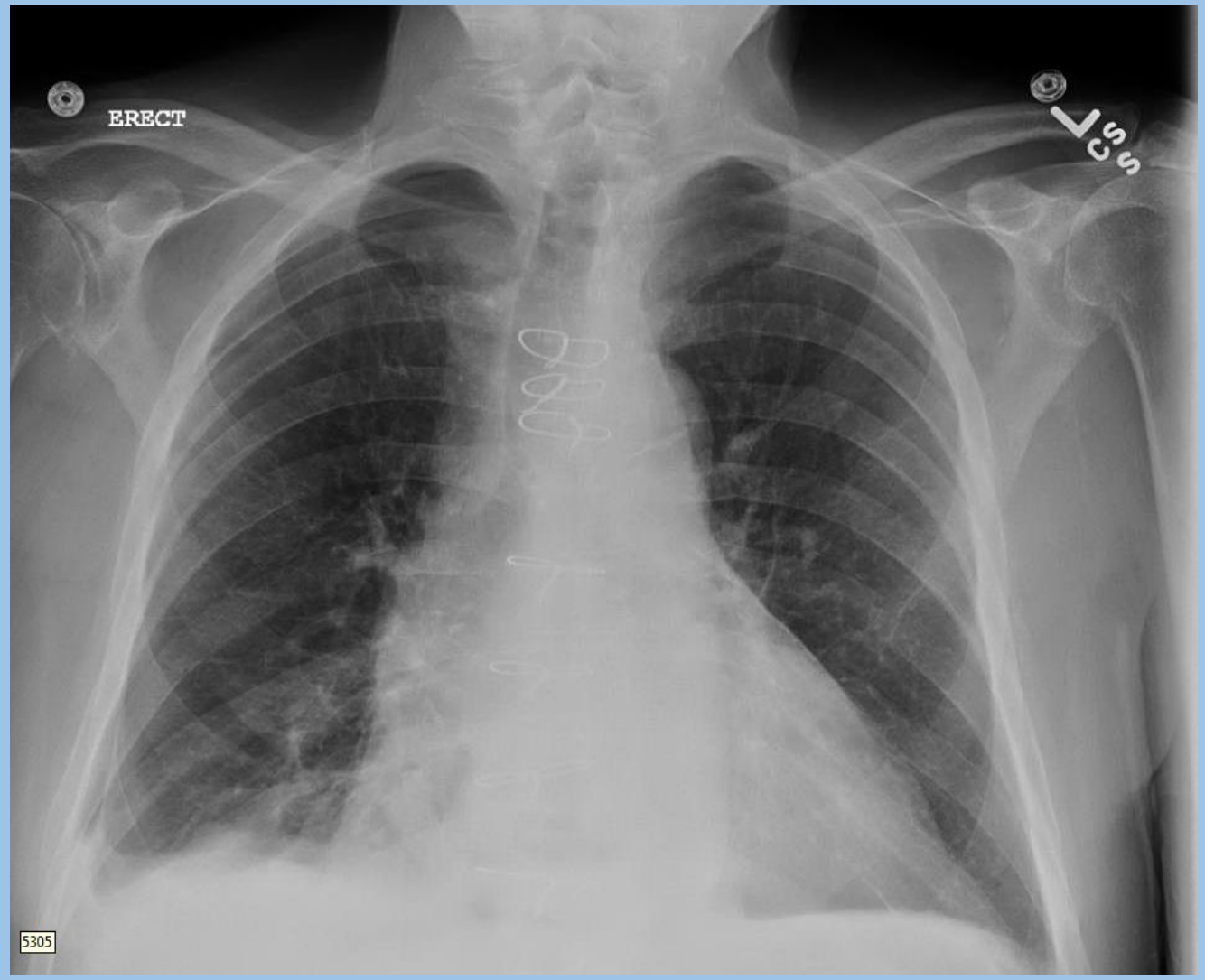
Tracheostomy tube with subcutaneous emphysema (thick arrow), pneumomediastinum (curved), and left pneumothorax (thin)

Central Venous Catheters – Normal Position

- Central venous catheter may be central (IJ, subclavian) or peripheral (PICC)
- Catheter tip should terminate in SVC or cavo-atrial junction
  - "OK to use" varies with intended function
- Placement borders:
  - Brachiocephalic/IJ junction – 1st anterior intercostal space
    - Last venous valve
  - Cavo-atrial junction – inferior border of right bronchus intermedius (+2.5 cm below)
    - Prevent cardiac chamber insertion

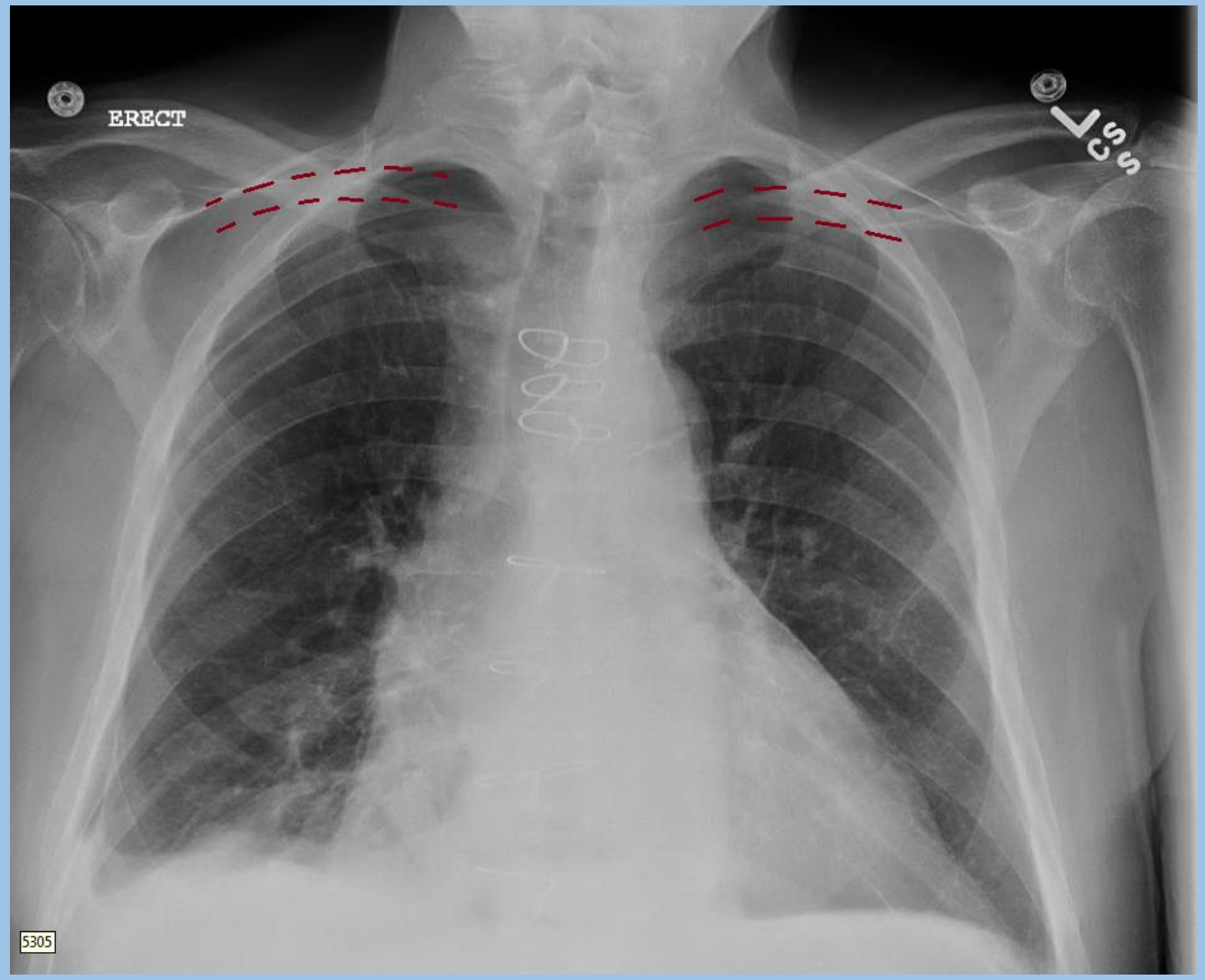


Central Venous Catheters – Normal Position



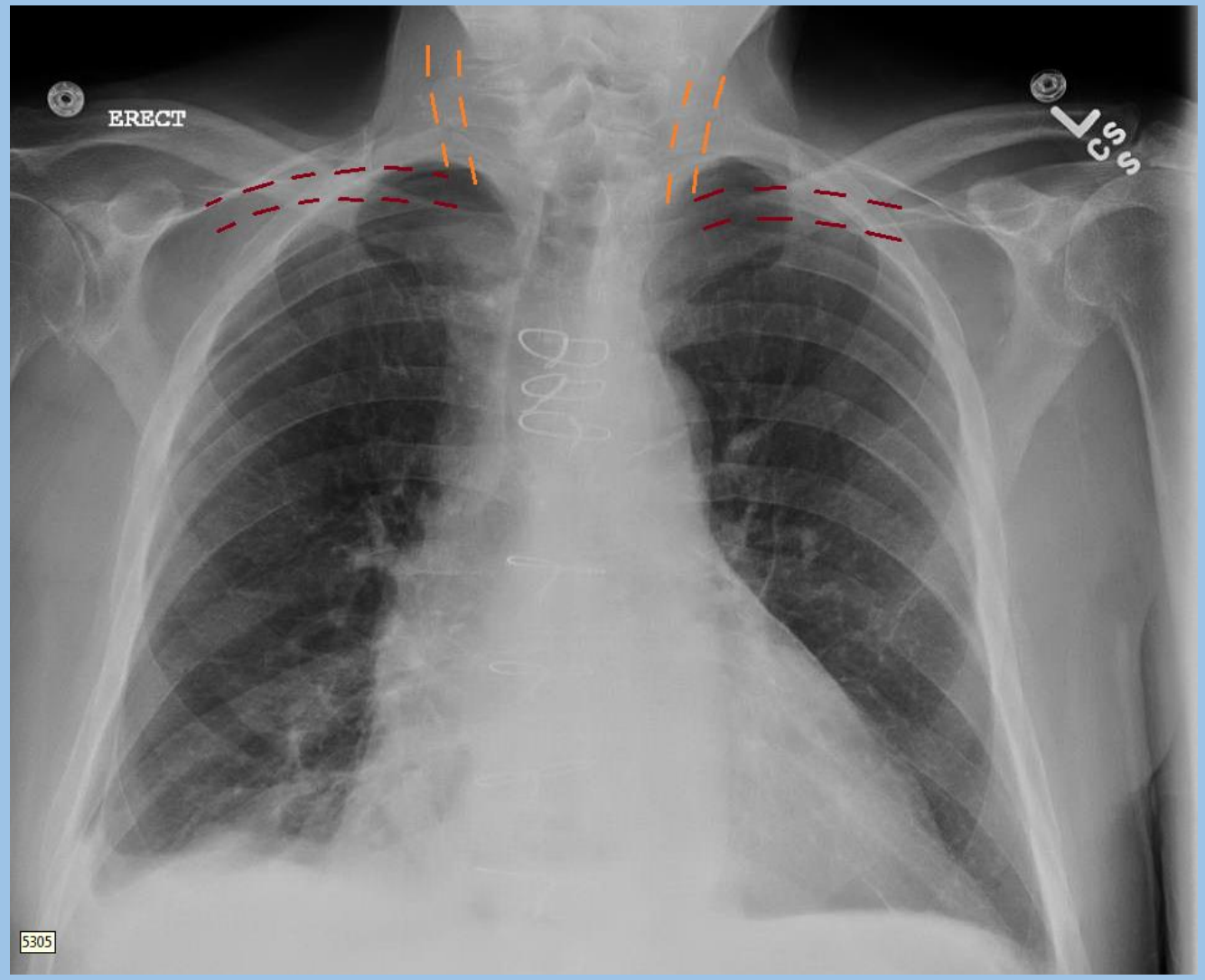
Central Venous Catheters – Normal Position

- Subclavian veins



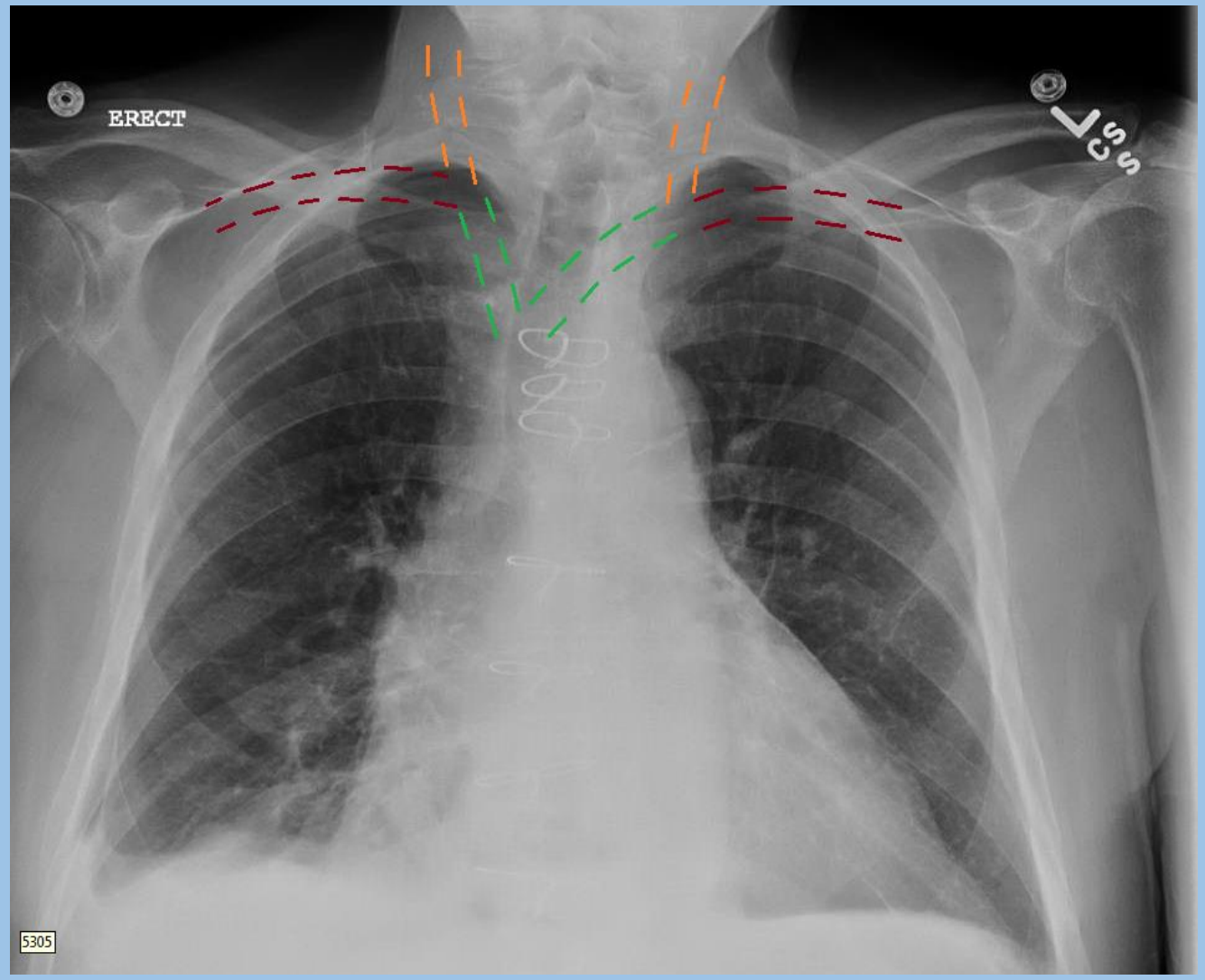
Central Venous Catheters – Normal Position

- Subclavian veins
- Internal jugular veins



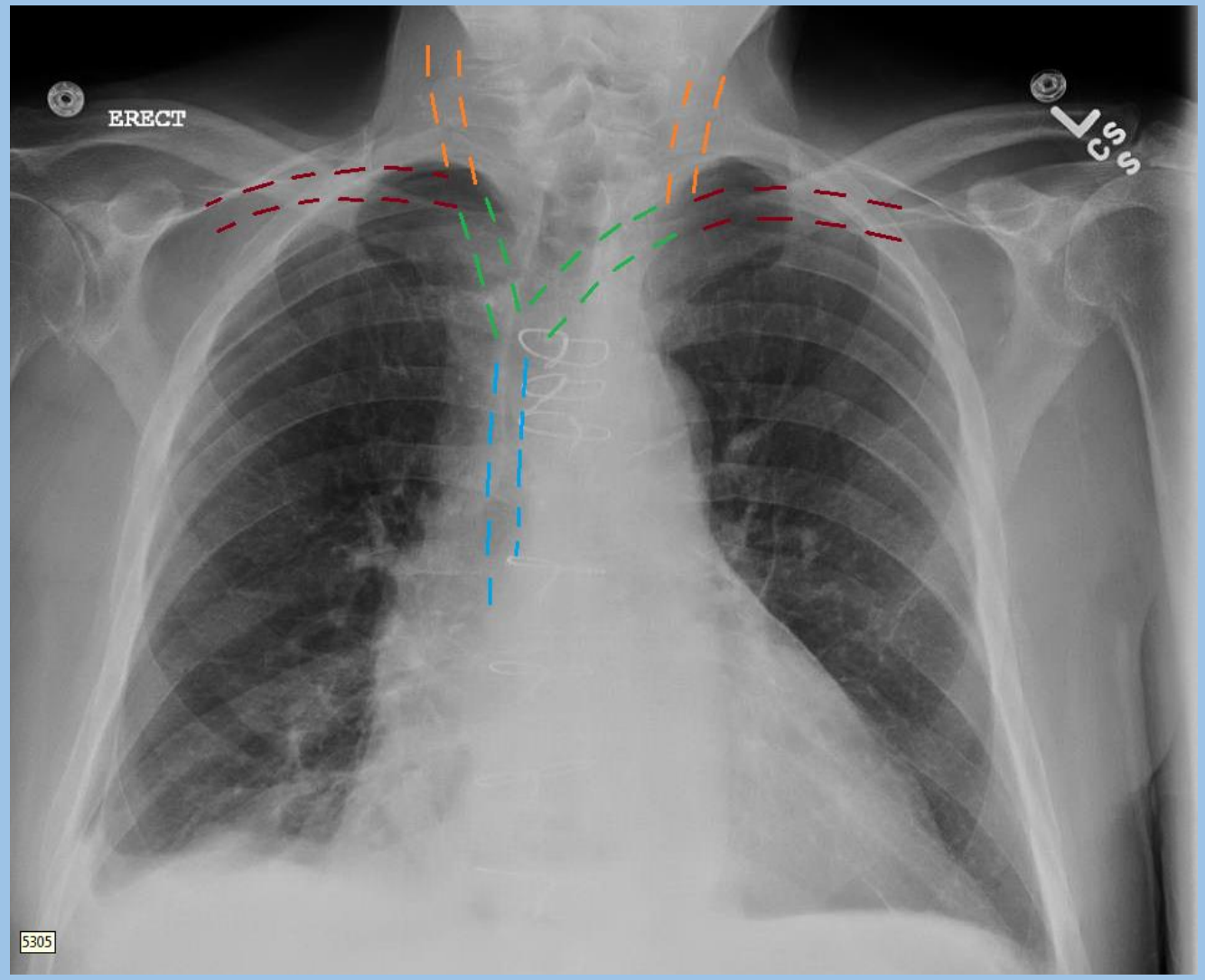
Central Venous Catheters – Normal Position

- Subclavian veins
- Internal jugular veins
- Brachiocephalic veins



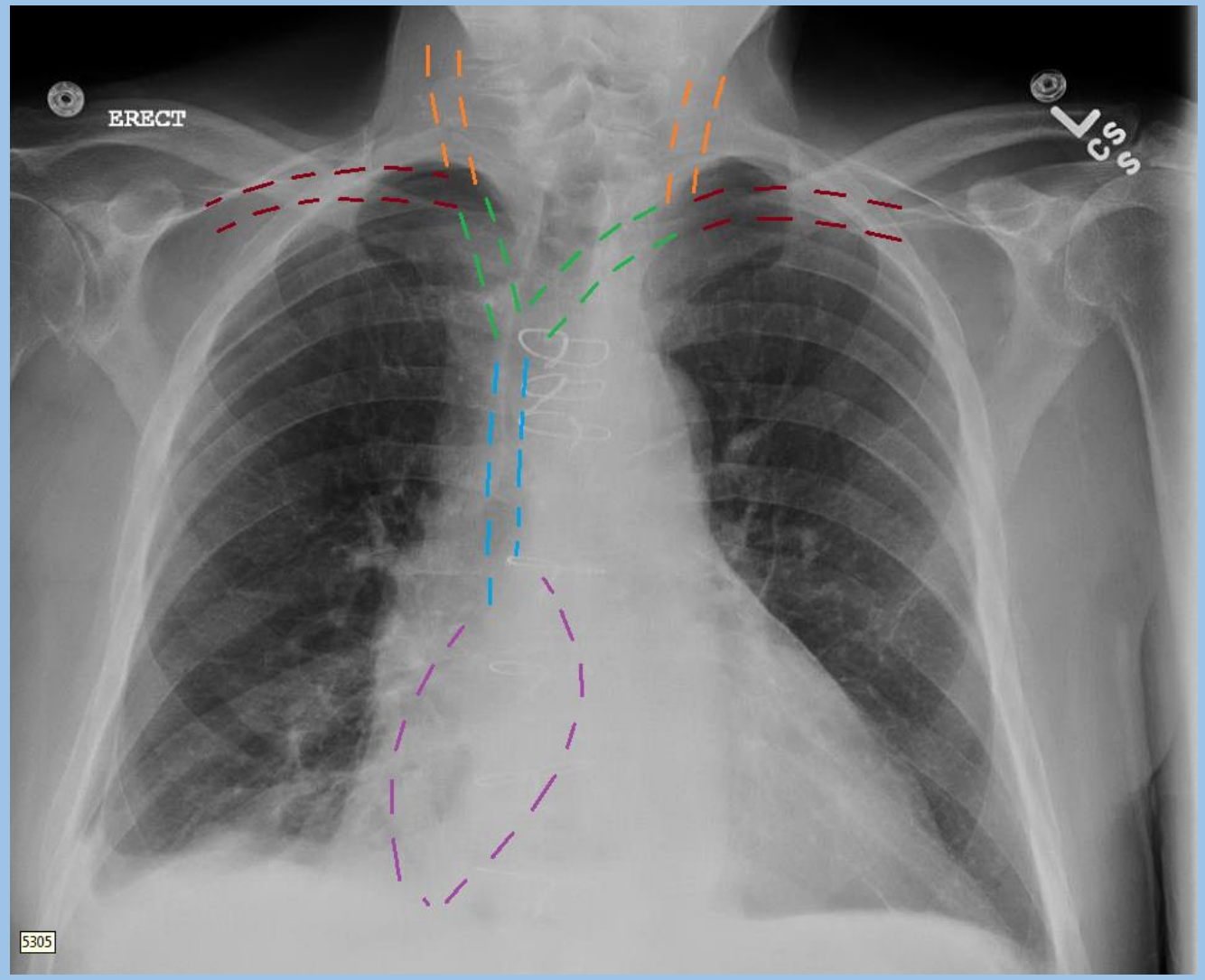
Central Venous Catheters – Normal Position

- Subclavian veins
- Internal jugular veins
- Brachiocephalic veins
- Superior vena cava



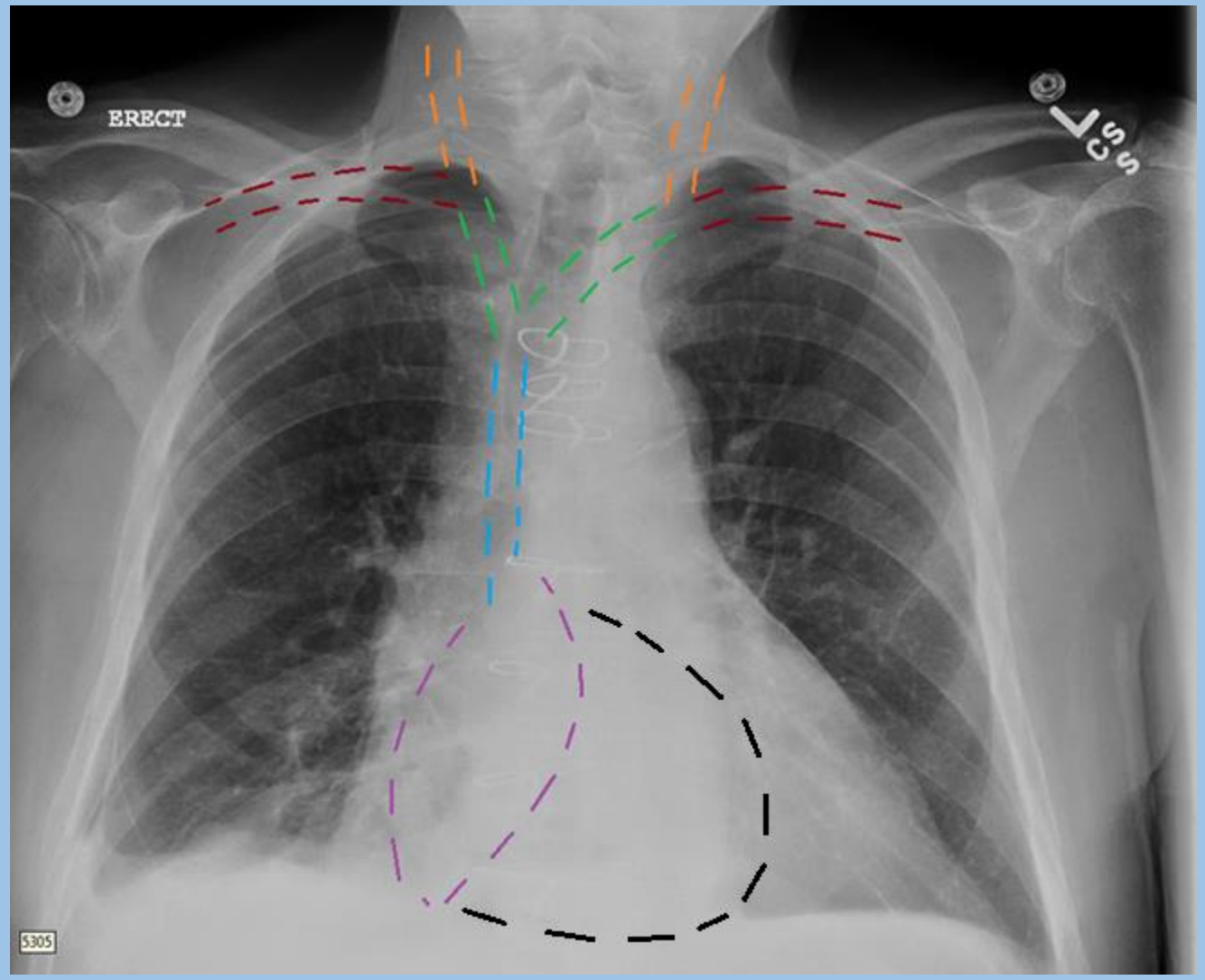
Central Venous Catheters – Normal Position

- Subclavian veins
- Internal jugular veins
- Brachiocephalic veins
- Superior vena cava
- Right atrium

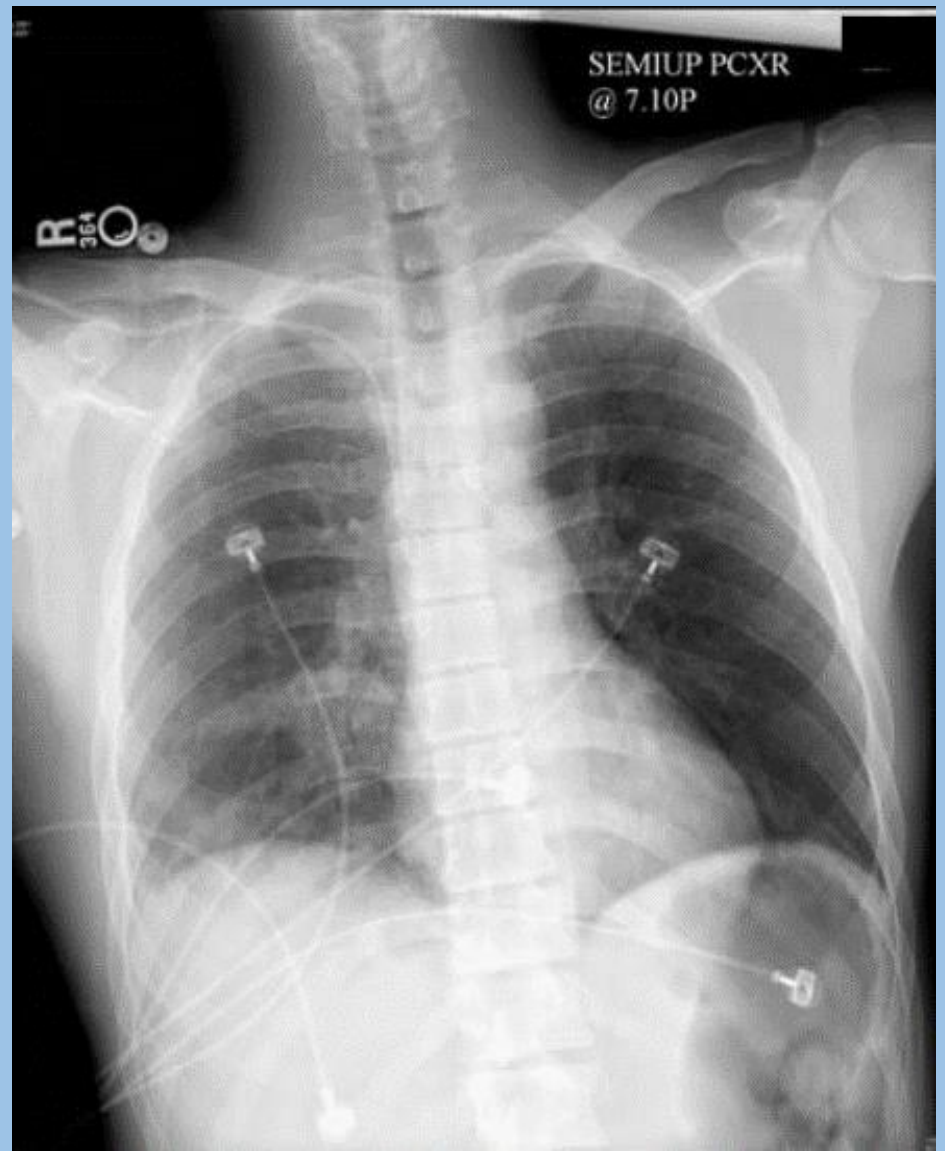


Central Venous Catheters – Normal Position

- Subclavian veins
- Internal jugular veins
- Brachiocephalic veins
- Superior vena cava
- Right atrium
- Right ventricle



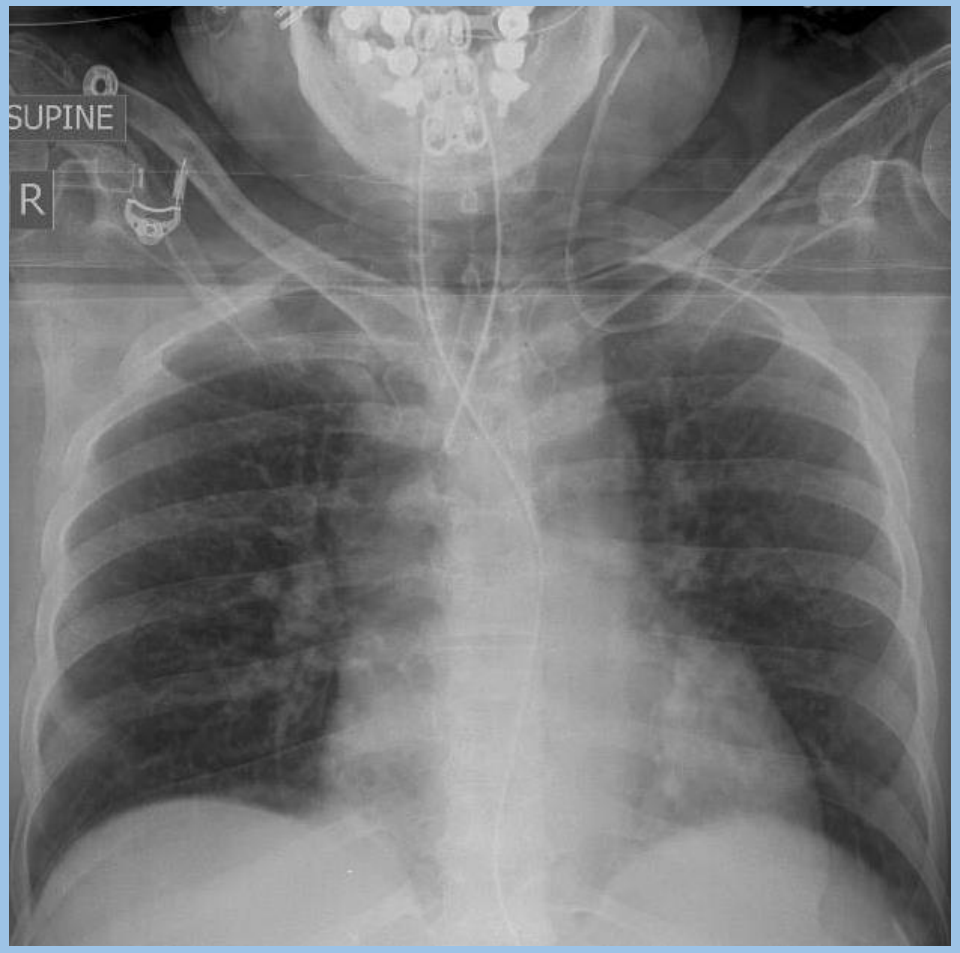
Central Venous Catheters – Normal Position



Central Venous Catheters – Normal Position

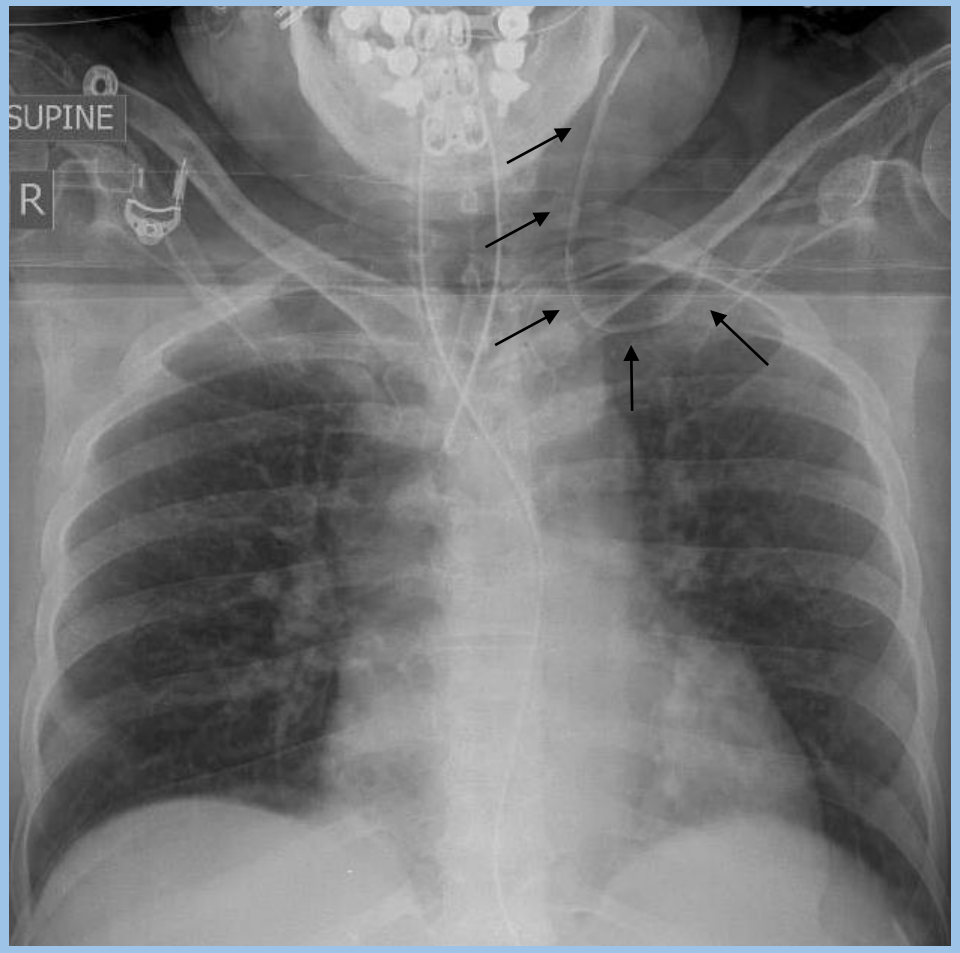
Central Venous Catheters – Abnormal Position

- Positioning errors:



Central Venous Catheters – Abnormal Position

- Positioning errors:
  - Ipsilateral IJ vein



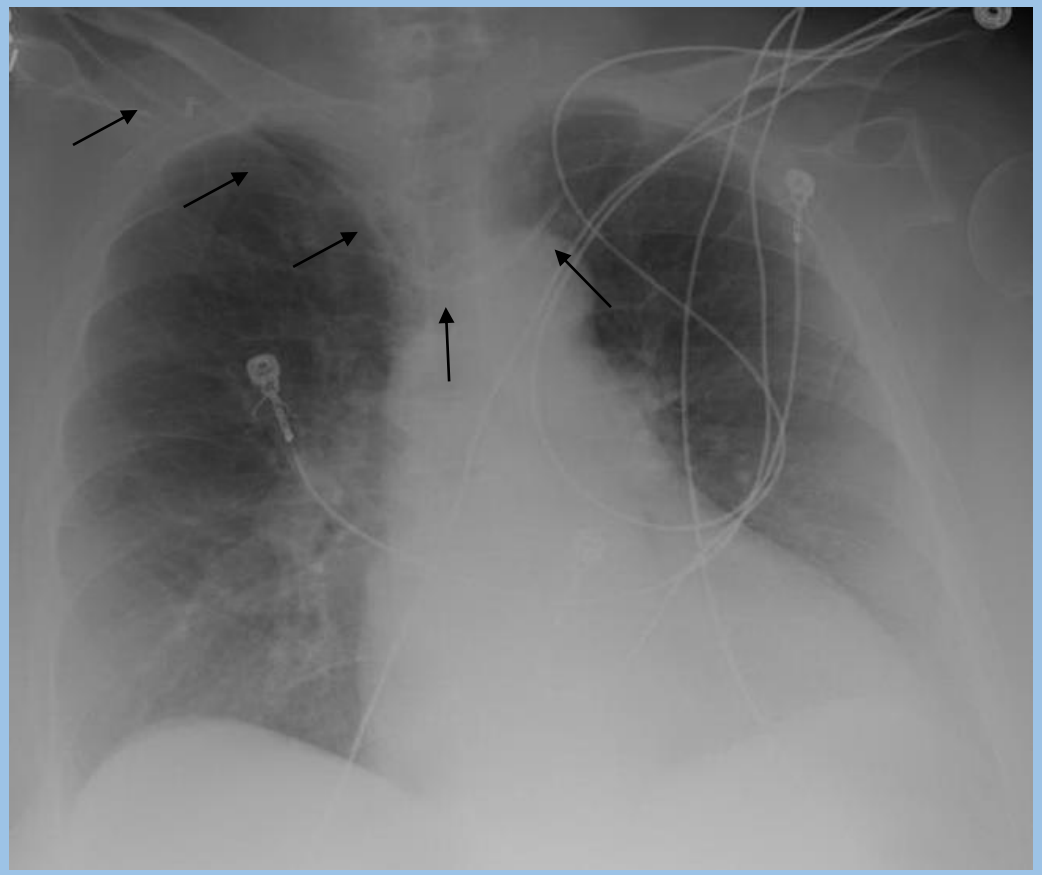
Left subclavian line terminating in left IJ

Central Venous Catheters – Abnormal Position

- Positioning errors:
  - Ipsilateral IJ vein

Central Venous Catheters – Abnormal Position

- Positioning errors:
  - Ipsilateral IJ vein
  - Contralateral brachiocephalic vein

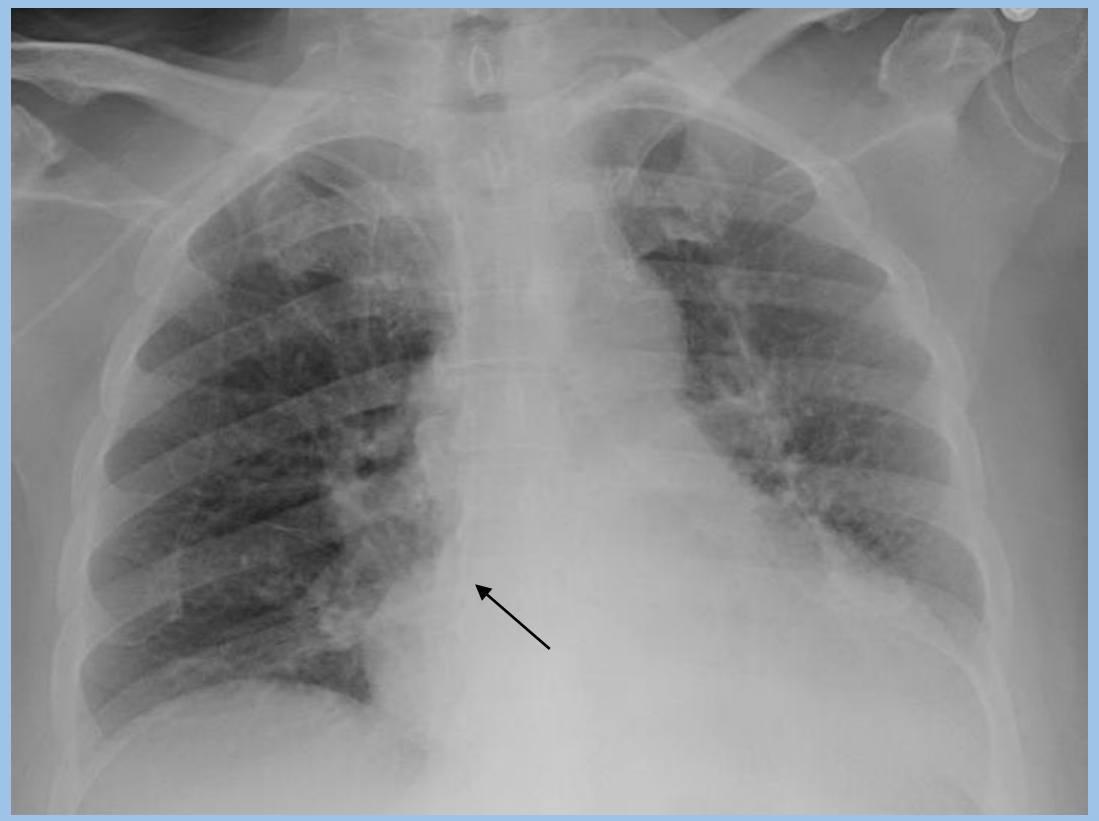


Right subclavian line terminating in left brachiocephalic

Central Venous Catheters – Abnormal Position

- Positioning errors:
  - Ipsilateral IJ
  - Contralateral brachiocephalic vein
  - Right atrium/ventricle
    - Increased risk of arrhythmias
    - Reduced dilution of administered medications

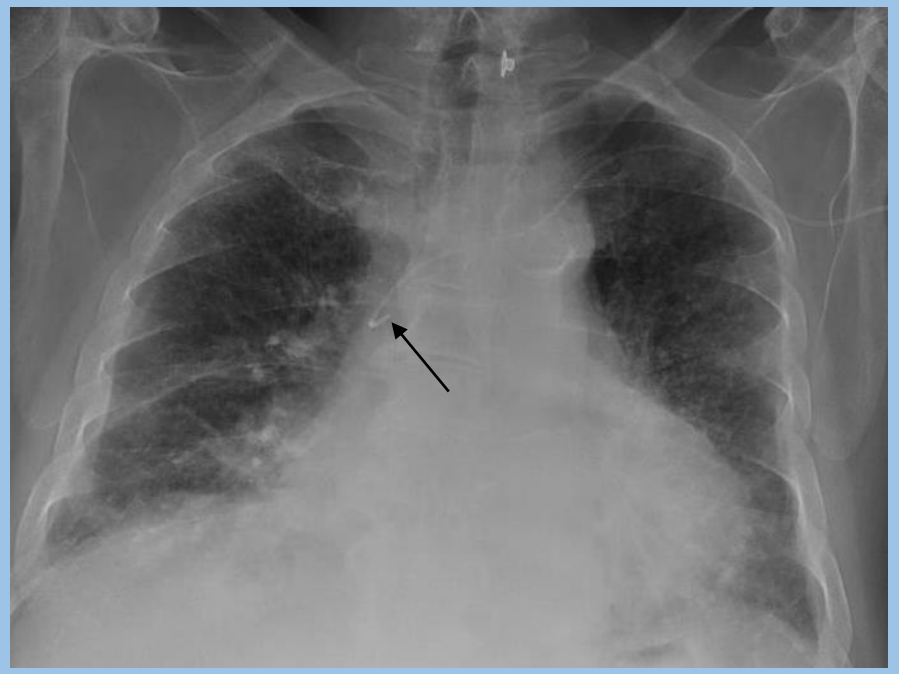
*Difficult to detect on routine AP imaging – may require lateral imaging if suspicious; more common in SVC thrombus and/or volume overload

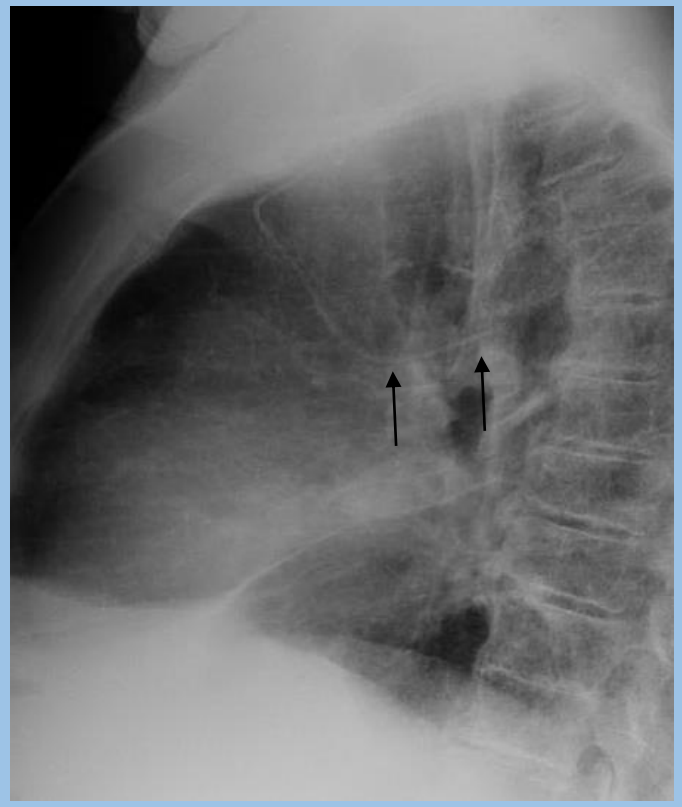


Right arm PICC terminating in right atrium

Central Venous Catheters – Abnormal Position

- Positioning errors:
  - Ipsilateral IJ
  - Contralateral brachiocephalic vein
  - Right atrium/ventricle
    - Increased risk of arrhythmias
    - Reduced dilution of administered medications
  - Azygous vein*





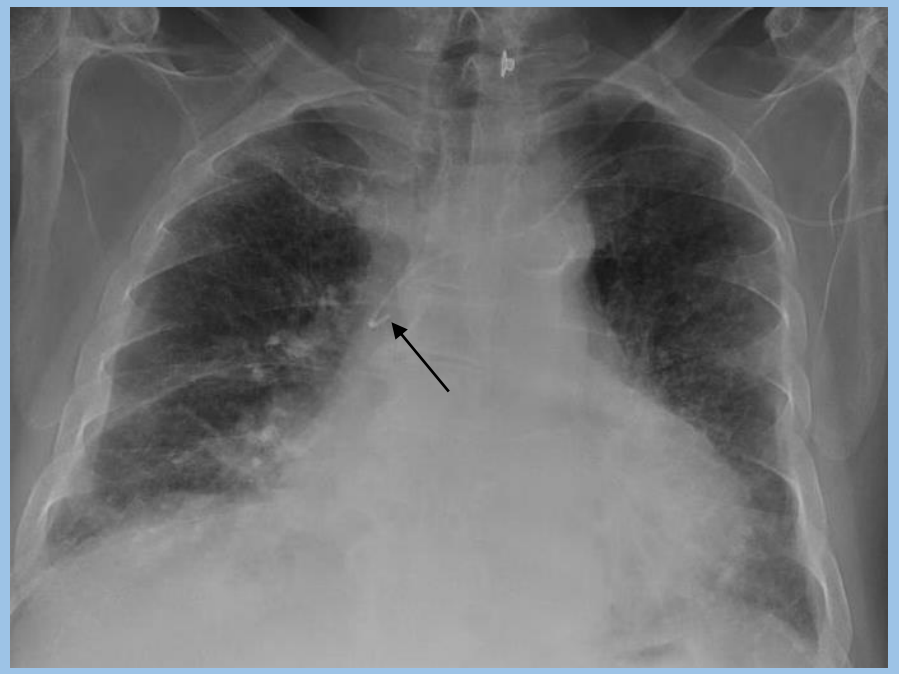
Left arm PICC terminating in azygos vein

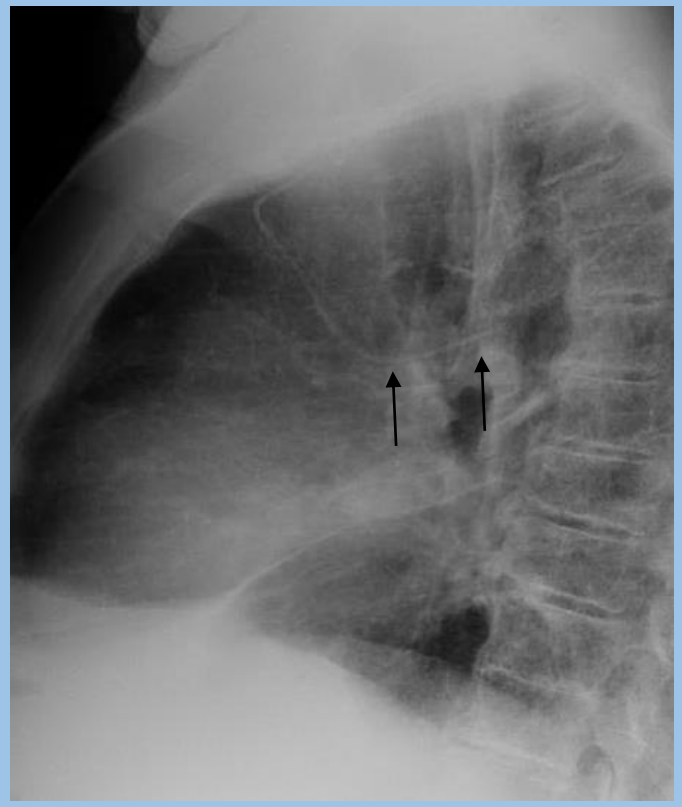
*Difficult to detect on routine AP imaging – may require lateral imaging if suspicious; more common in SVC thrombus and/or volume overload

Central Venous Catheters – Abnormal Position

- Positioning errors:
  - Ipsilateral IJ
  - Contralateral brachiocephalic vein
  - Right atrium/ventricle
    - Increased risk of arrhythmias
    - Reduced dilution of administered medications
  - Azygous vein*
  - Internal thoracic vein*

*Difficult to detect on routine AP imaging – may require lateral imaging if suspicious; more common in SVC thrombus and/or volume overload

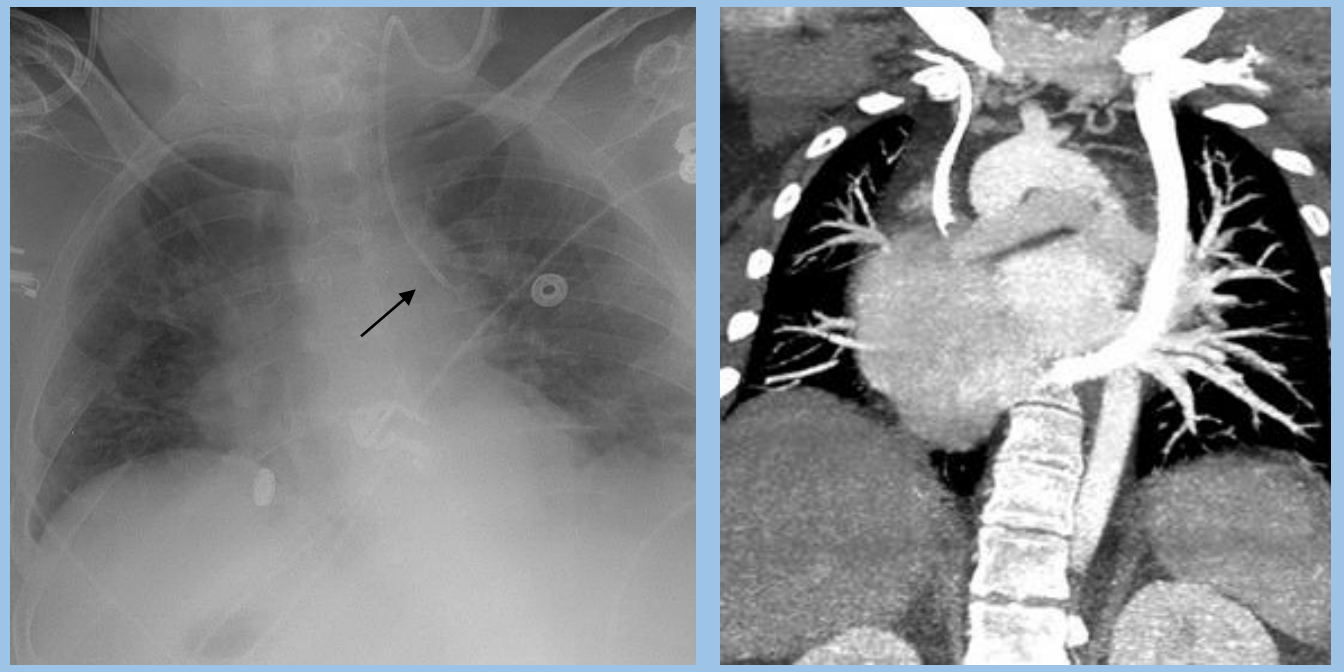




Left arm PICC terminating in azygos vein

Central Venous Catheters – Anatomic Variants

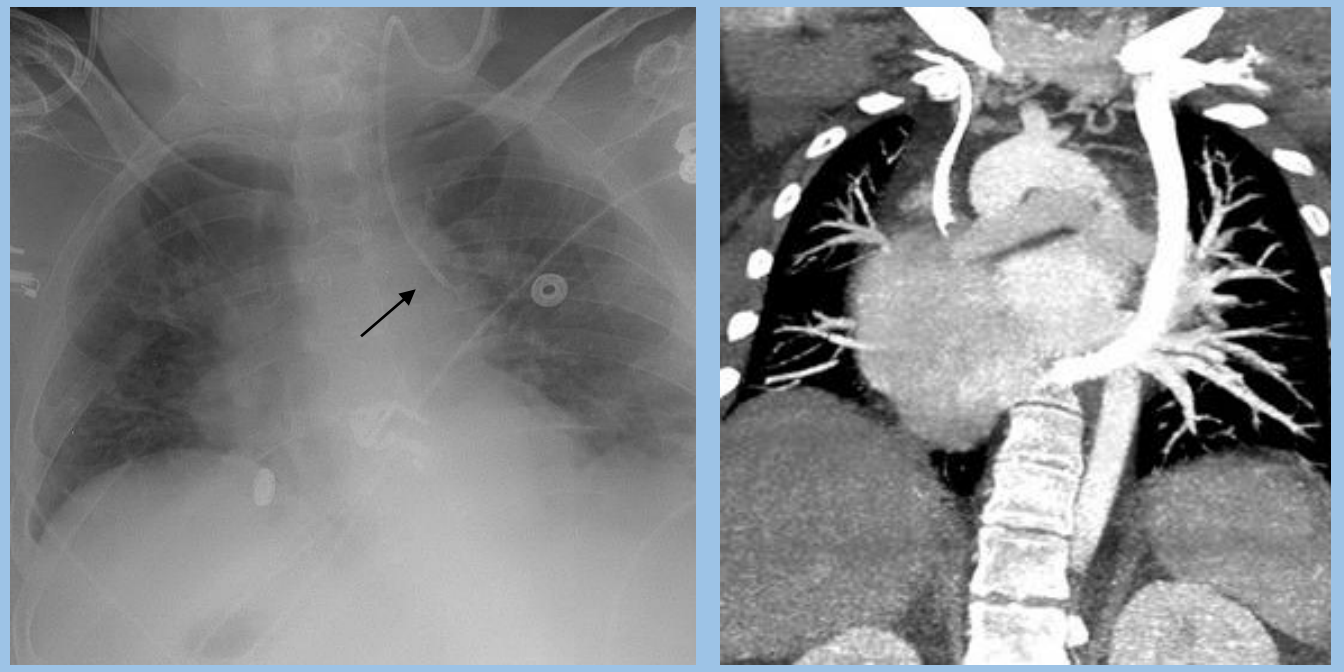
- Anatomic variants :
  - Persistent left SVC (0.3% of population)
    - Left SVC → coronary sinus → RA
    - More common in CHD



Left IJ catheter terminating within proximal left-sided SVC

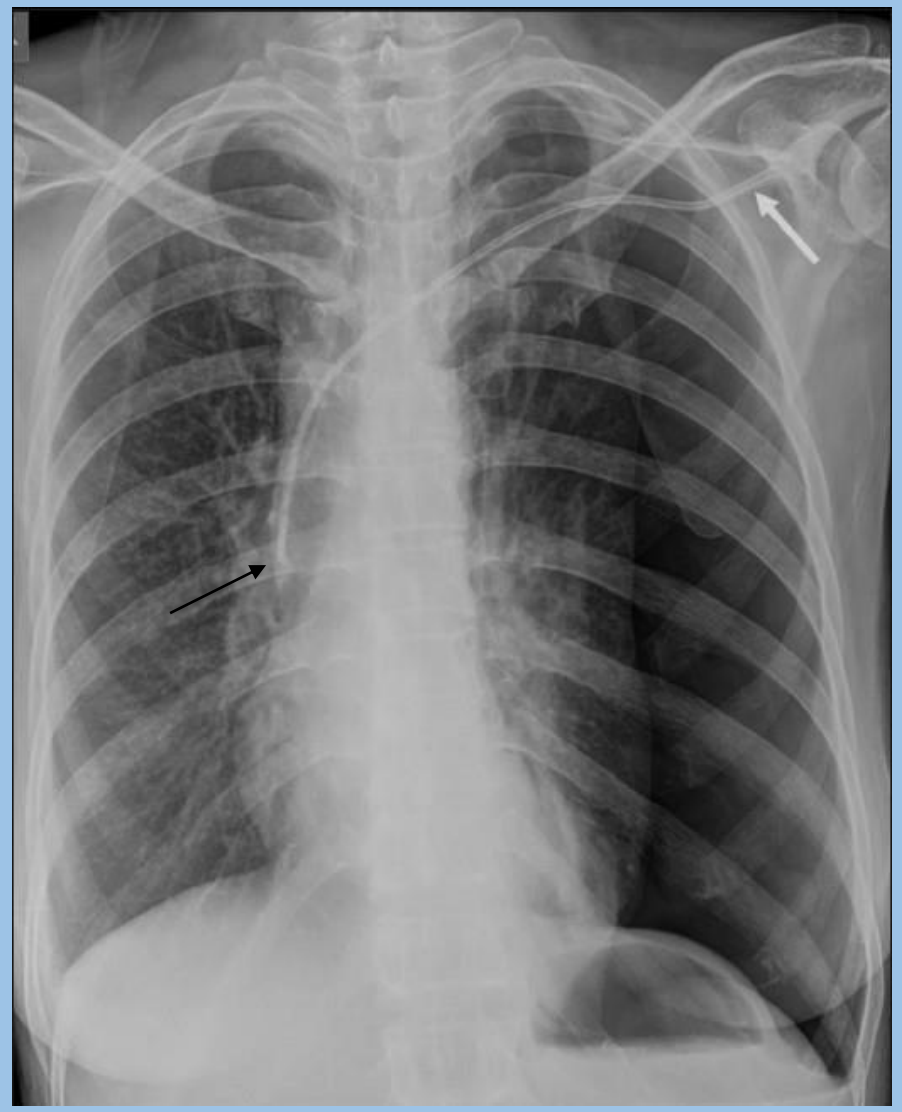
Central Venous Catheters – Anatomic Variants

- Anatomic variants :
  - Persistent left SVC (0.3% of population)
    - Left SVC → coronary sinus → RA
    - More common in CHD
  - Ventricular septal defect
  - Atrial septal defect
  - Anomalous pulmonary vein

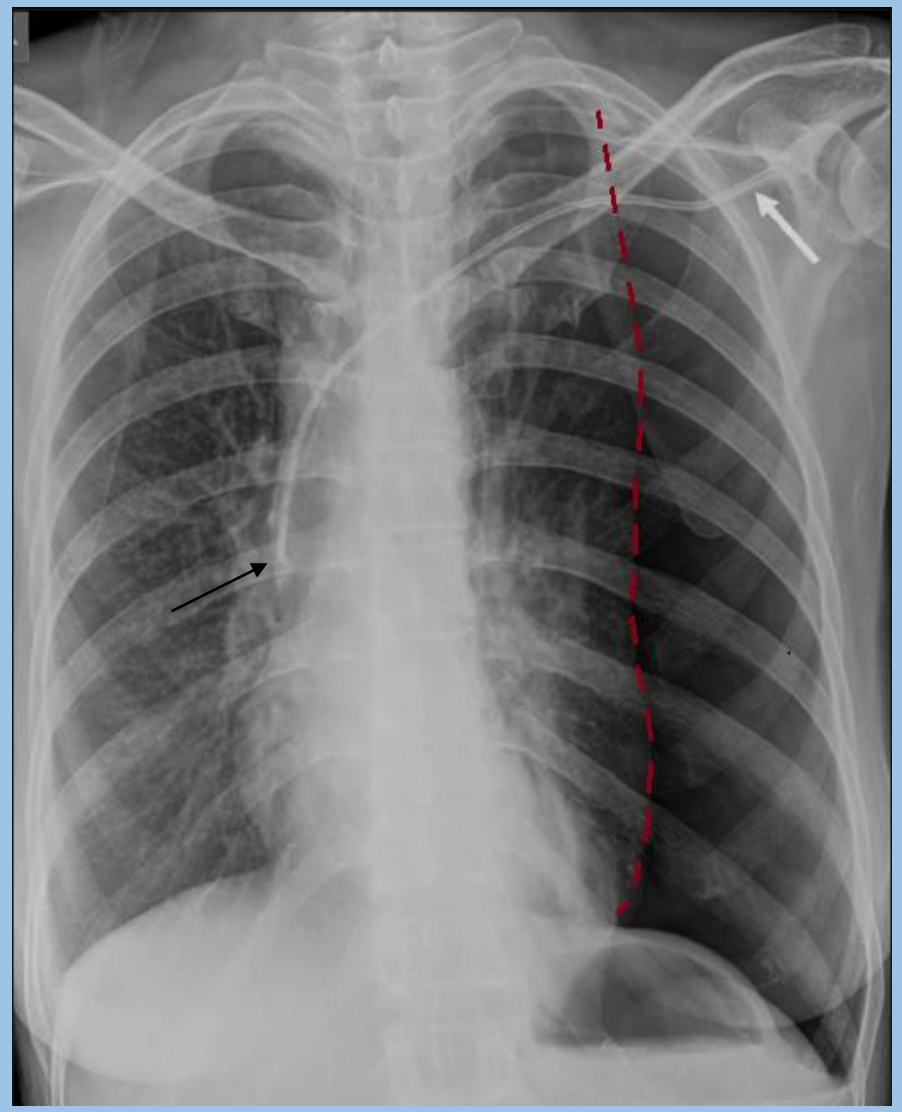


Left IJ catheter terminating within proximal left-sided SVC

Central Venous Catheters – Complications

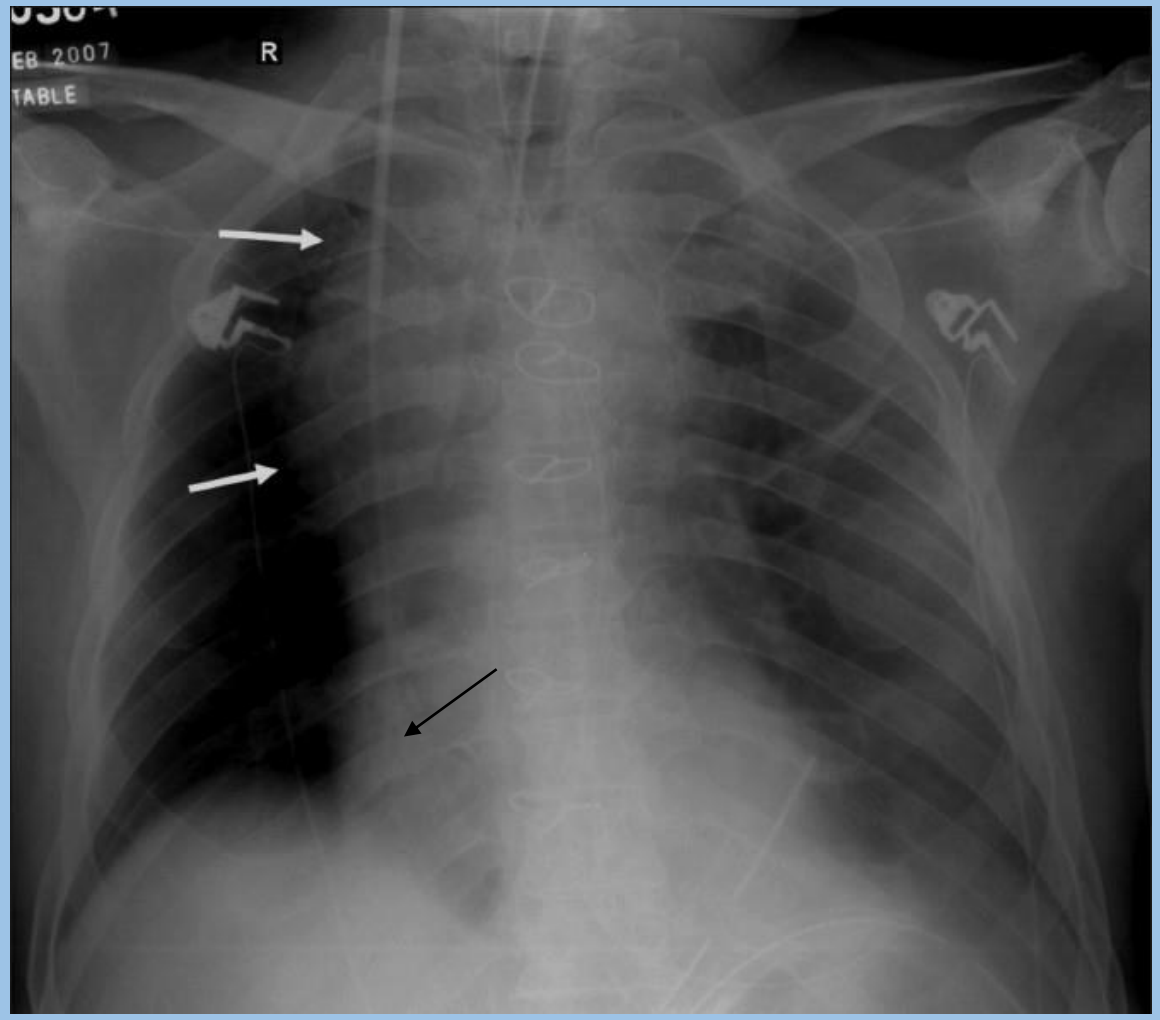


Central Venous Catheters – Complications



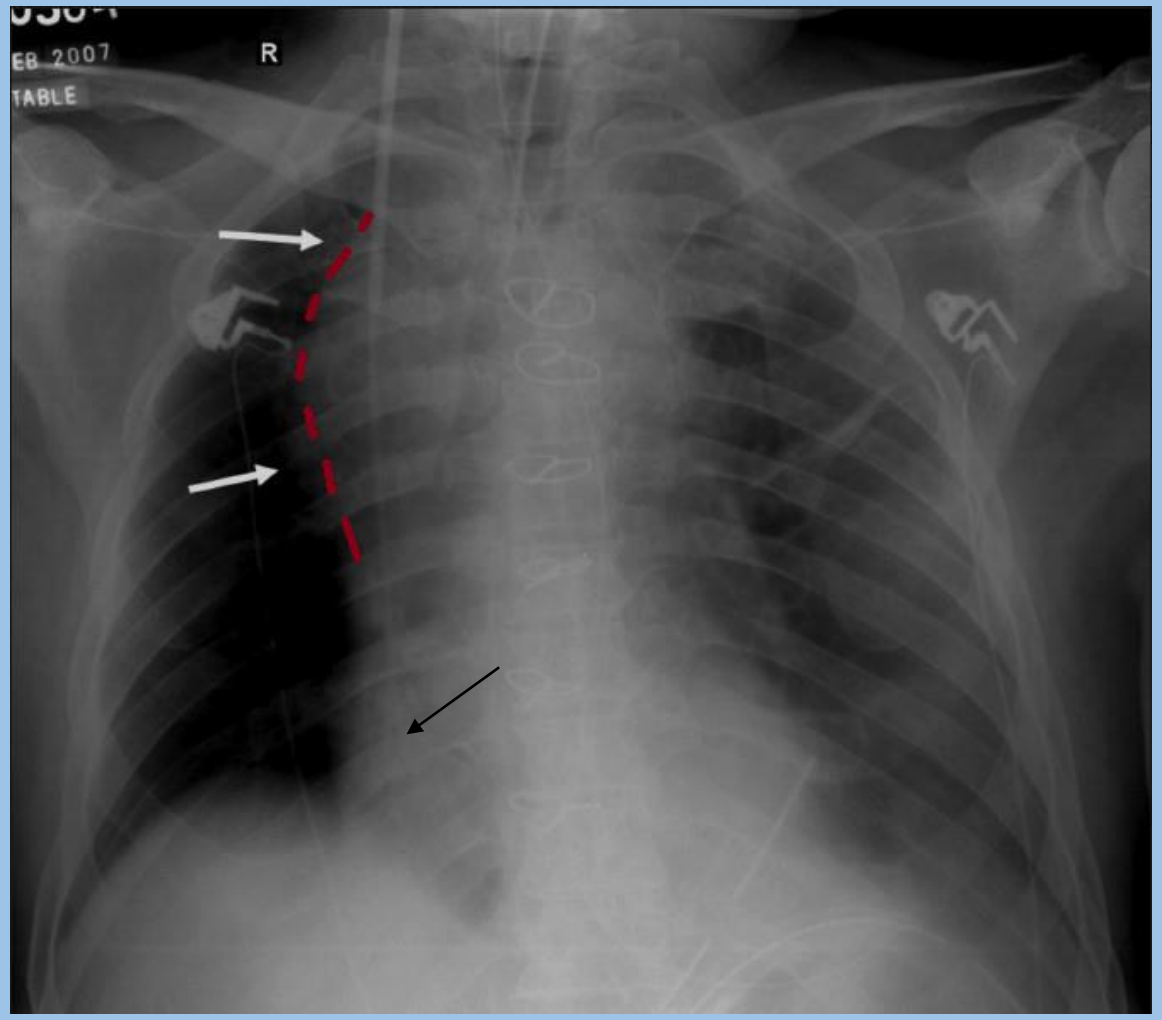
Left subclavian line with tip in SVC; Left pneumothorax

Central Venous Catheters – Complications



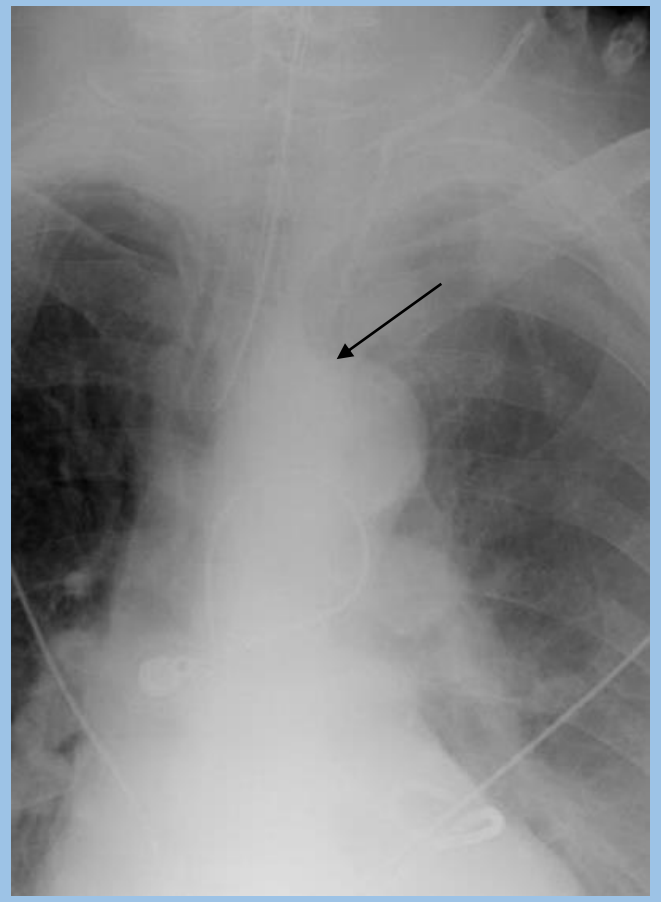
Central Venous Catheters – Complications

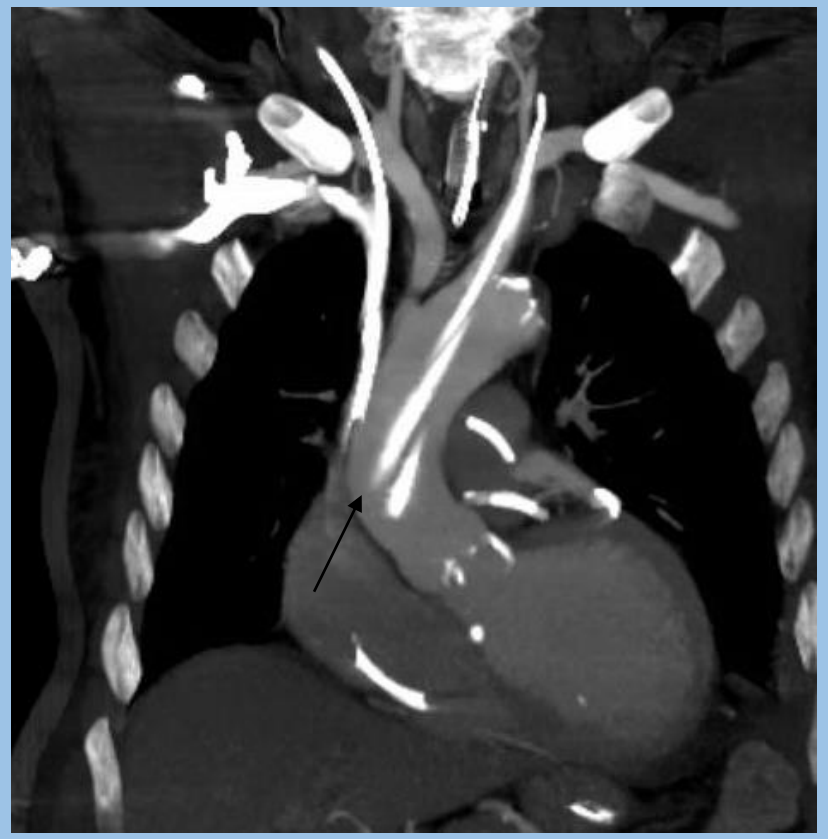
- Signs of perforation:
  - Unusual catheter trajectory
  - New apical density (“apical cap”)
    - Extrapleural hematoma
  - New pleural effusion
    - Hemothorax
  - Mediastinal widening
    - Mediastinal hematoma



Right IJ catheter with venous perforation and right mediastinal hematoma

Central Venous Catheters – Complications





Central line placement into left common carotid artery

Central Venous Catheters– Indications for Studies

- Radiographic evaluation indicated:
  - After CVC insertion (appropriateness score = 9)
  - Patient with CVC in place – clinical indications only (9)

- Radiographic evaluation NOT indicated:
  - Daily, routine follow-up (1)

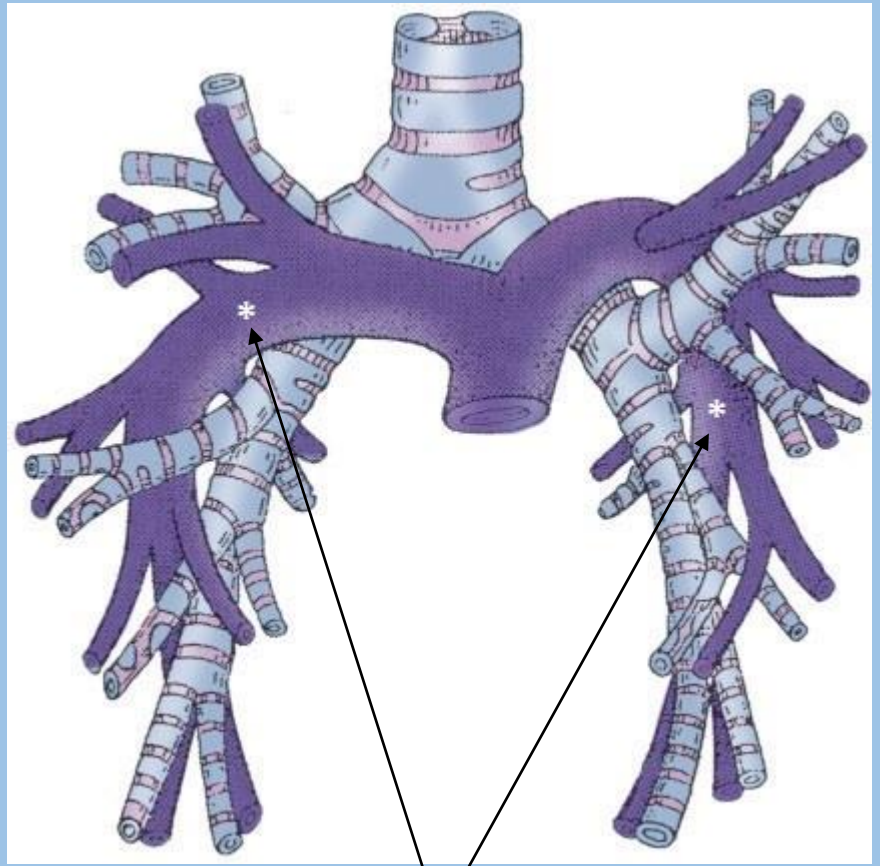
- Radiographic evaluation after failed CVC insertion?
  - Insertion site hematoma, pneumothorax
  - No clear evidence or guidelines

Legend: 1-3: usually not appropriate; 4-6: may be appropriate; 7-9: usually appropriate

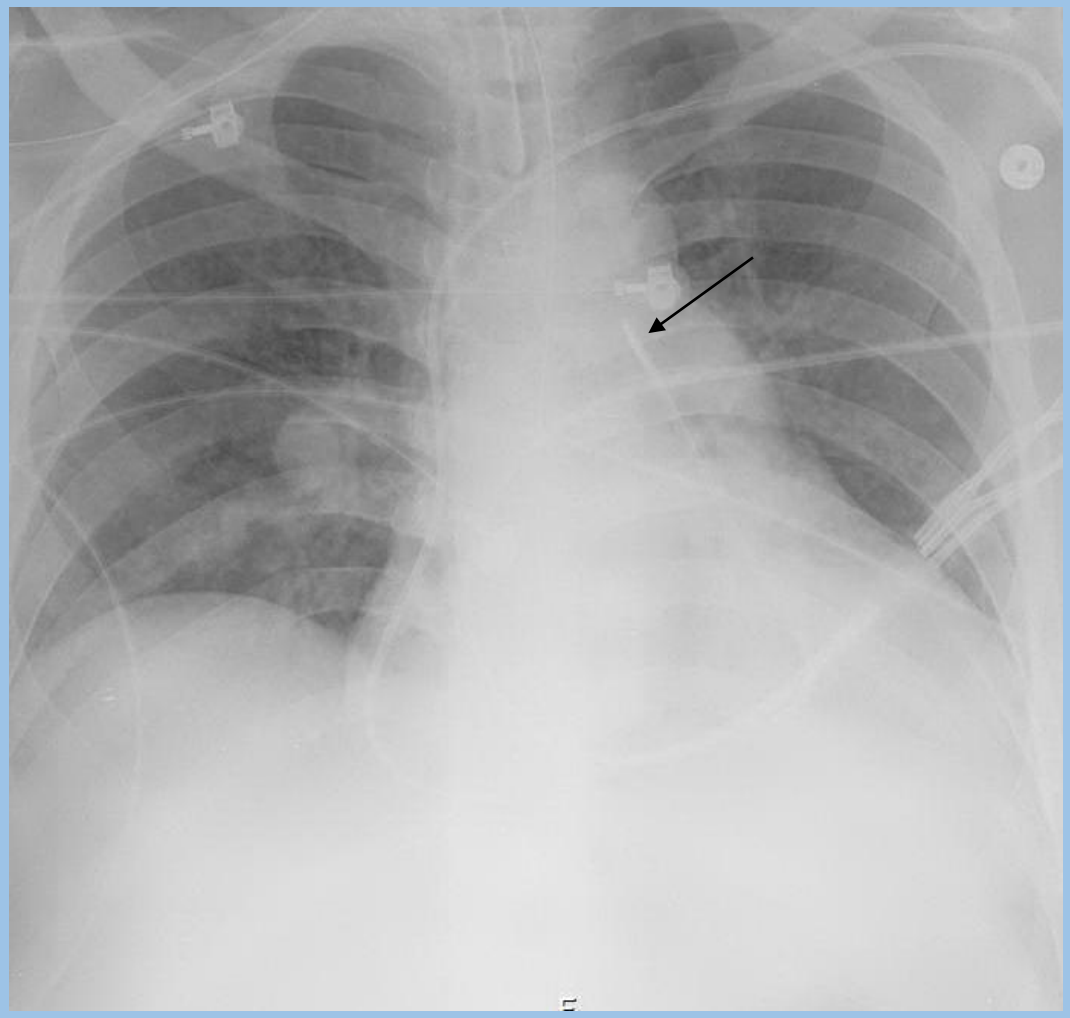
Pulmonary Artery Catheters – Normal Position

- Inserted via subclavian, jugular, or femoral veins
- "Resting" position dependent on its intended function
  - RV, pulmonary trunk, right/left PA, etc
- Ideal catheter tip position no farther than proximal interlobar pulmonary arteries
  - Within 1-2 cm of hilum/mediastinal shadow

*Catheter balloon tip should only be inflated during pressure measurements!

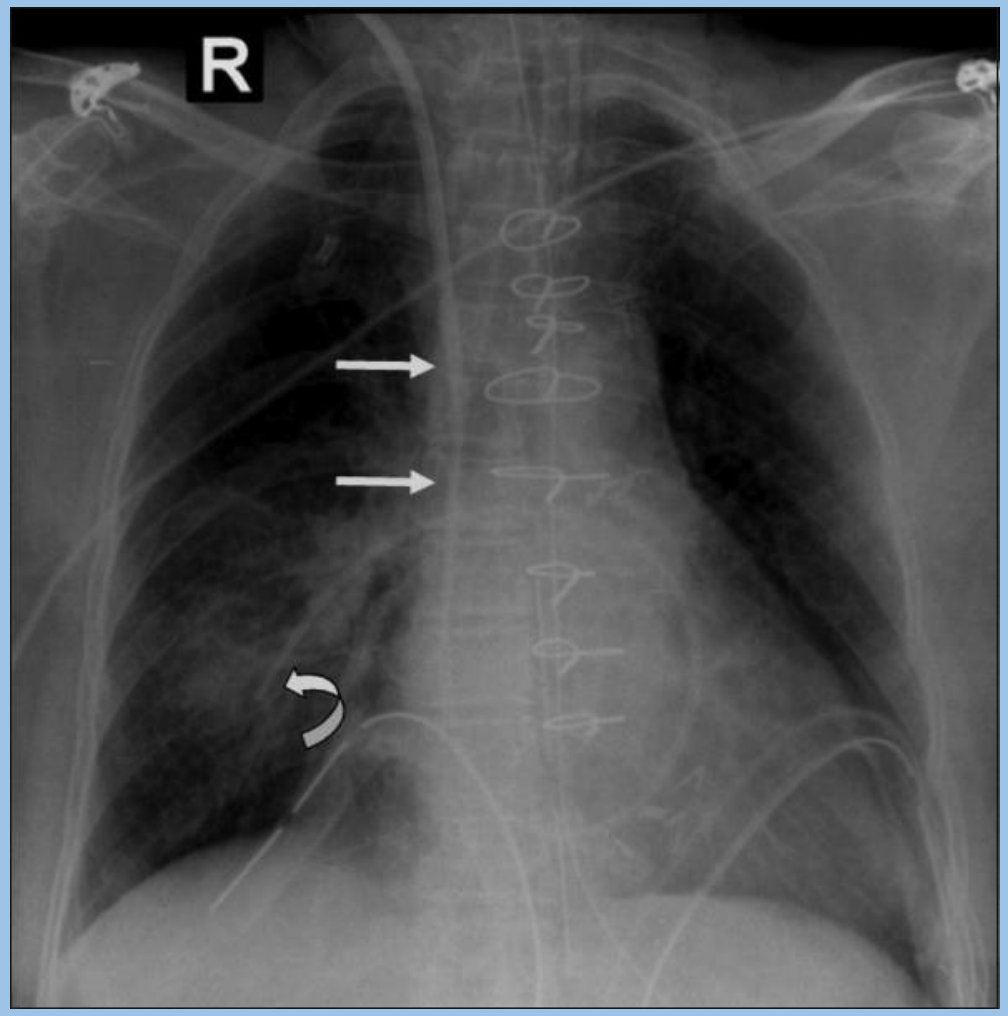


Pulmonary Artery Catheters – Normal Position



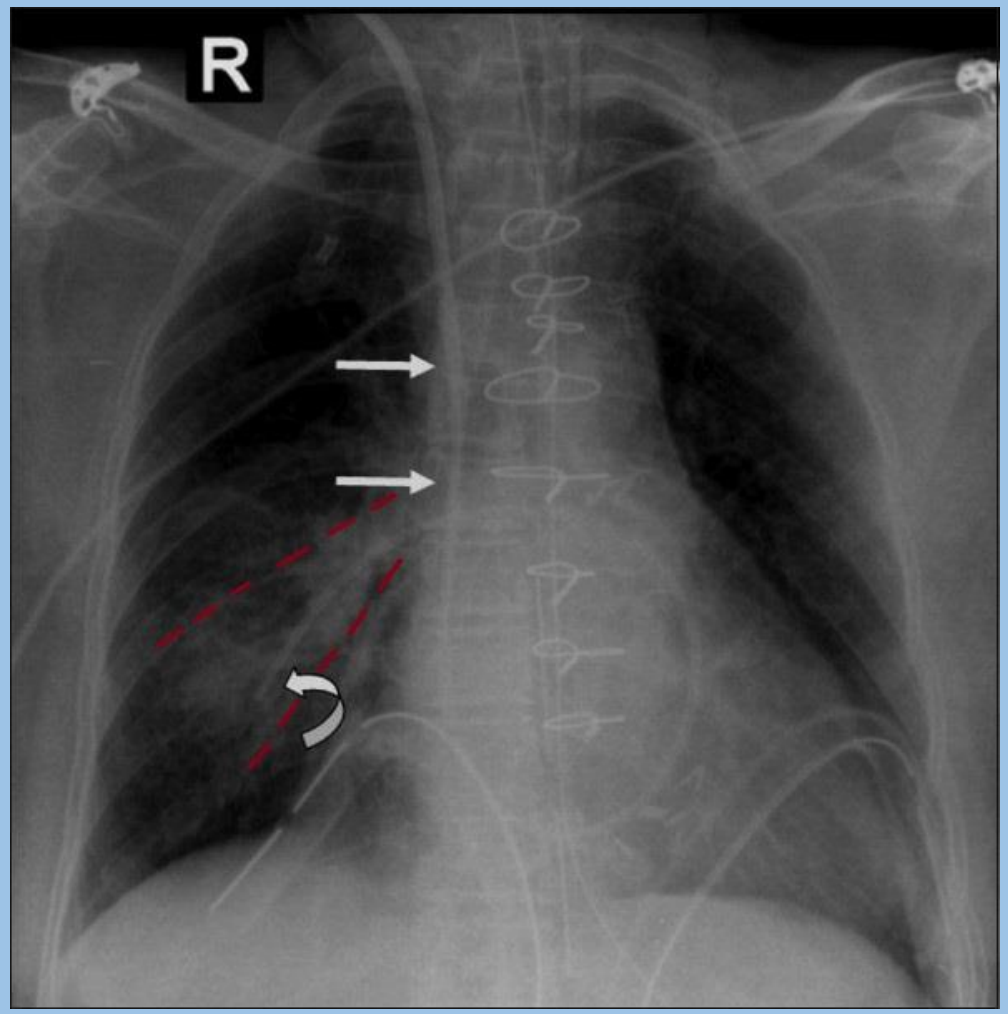
Left subclavian PA catheter terminating in main pulmonary artery

Pulmonary Artery Catheters – Complications



Pulmonary Artery Catheters – Complications

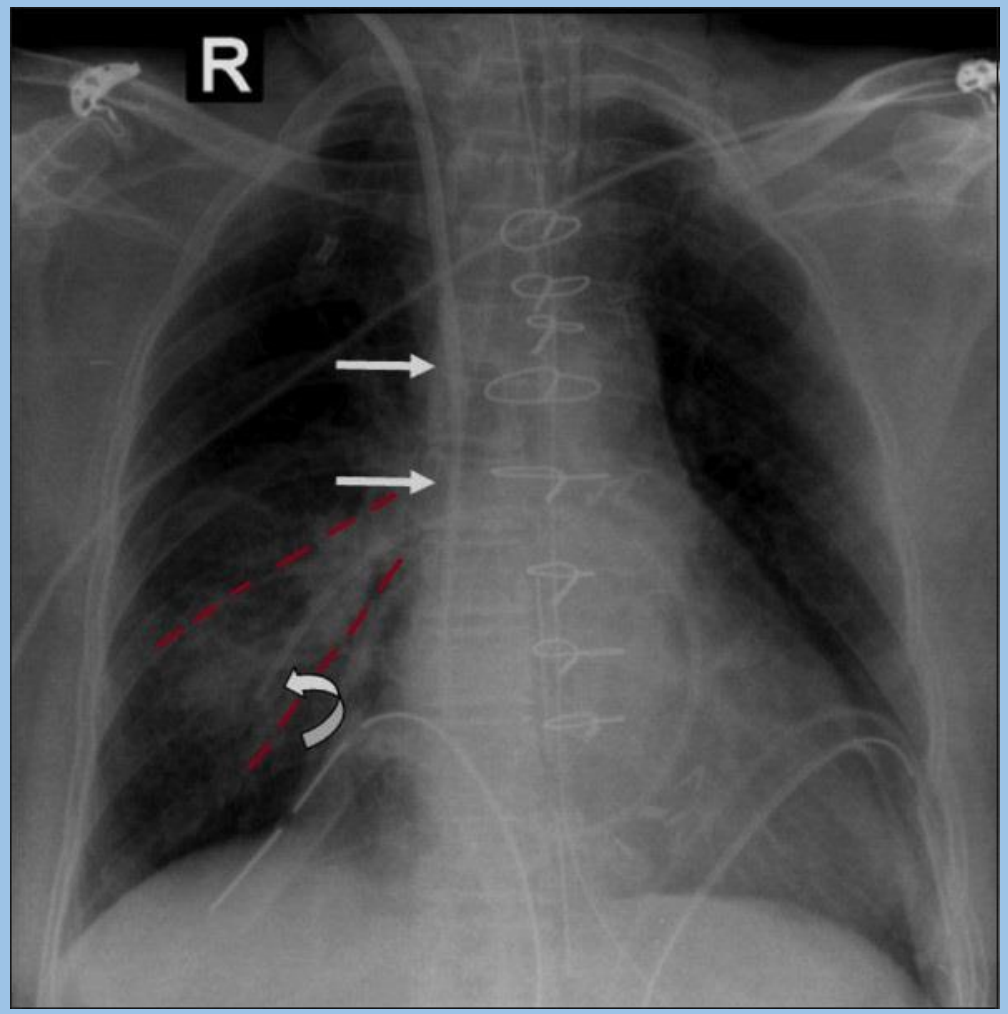
- Potential Complications:
  - Pulmonary artery infarction
    - Tip too distal
    - Persistent balloon inflation
    - Clot around distal catheter tip



Right IJ PA catheter (straight arrows) distally placed with pulmonary infarction (curved)

Pulmonary Artery Catheters – Complications

- Potential Complications:
  - Pulmonary artery infarction
    - Tip too distal
    - Persistent balloon inflation
    - Clot around distal catheter tip
  - Pulmonary artery rupture
  - Pulmonary artery dissection
  - Complications of CVCs
    - Looping/coiling
    - Pneumothorax
    - Hematoma
    - Perforation



Right IJ PA catheter (straight arrows) distally placed with pulmonary infarction (curved)

Pulmonary Artery Catheters– Indications for Studies

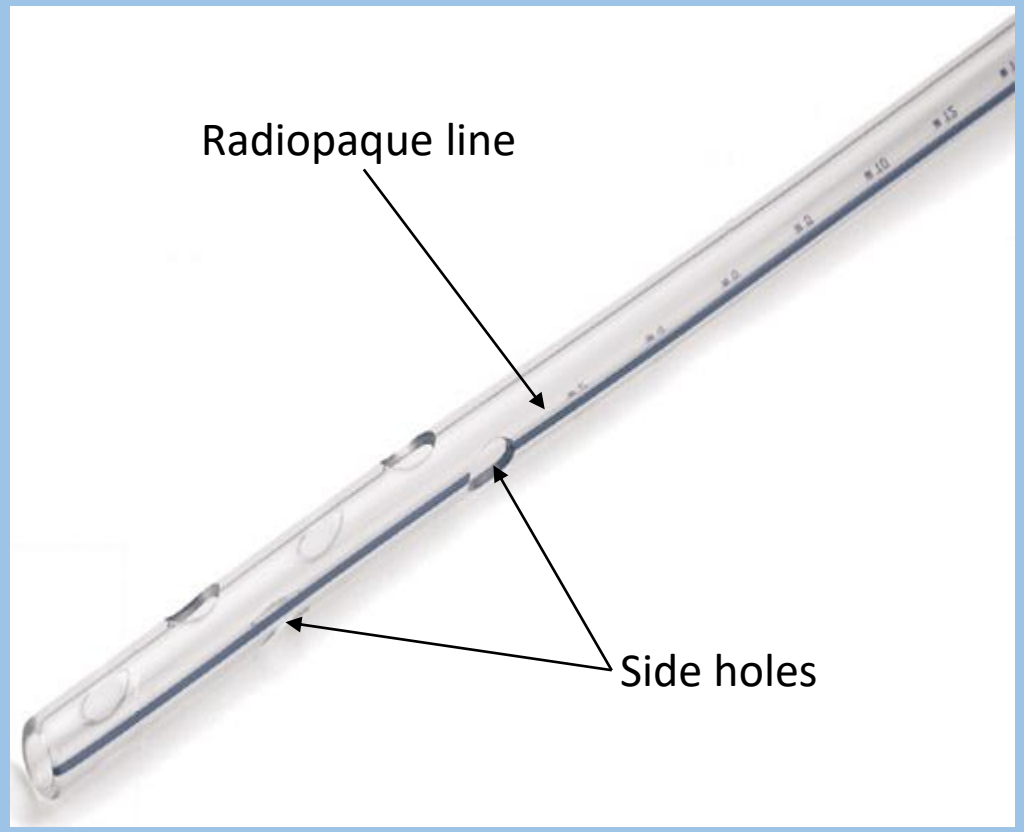
- Radiographic evaluation indicated:
  - After PAC insertion (appropriateness score = 9)
    - Characteristic pressure tracings alone are NOT sufficient to verify position
  - Patient with PAC in place – clinical indications only (9)

- Radiographic evaluation NOT indicated:
  - Daily, routine follow-up (1)

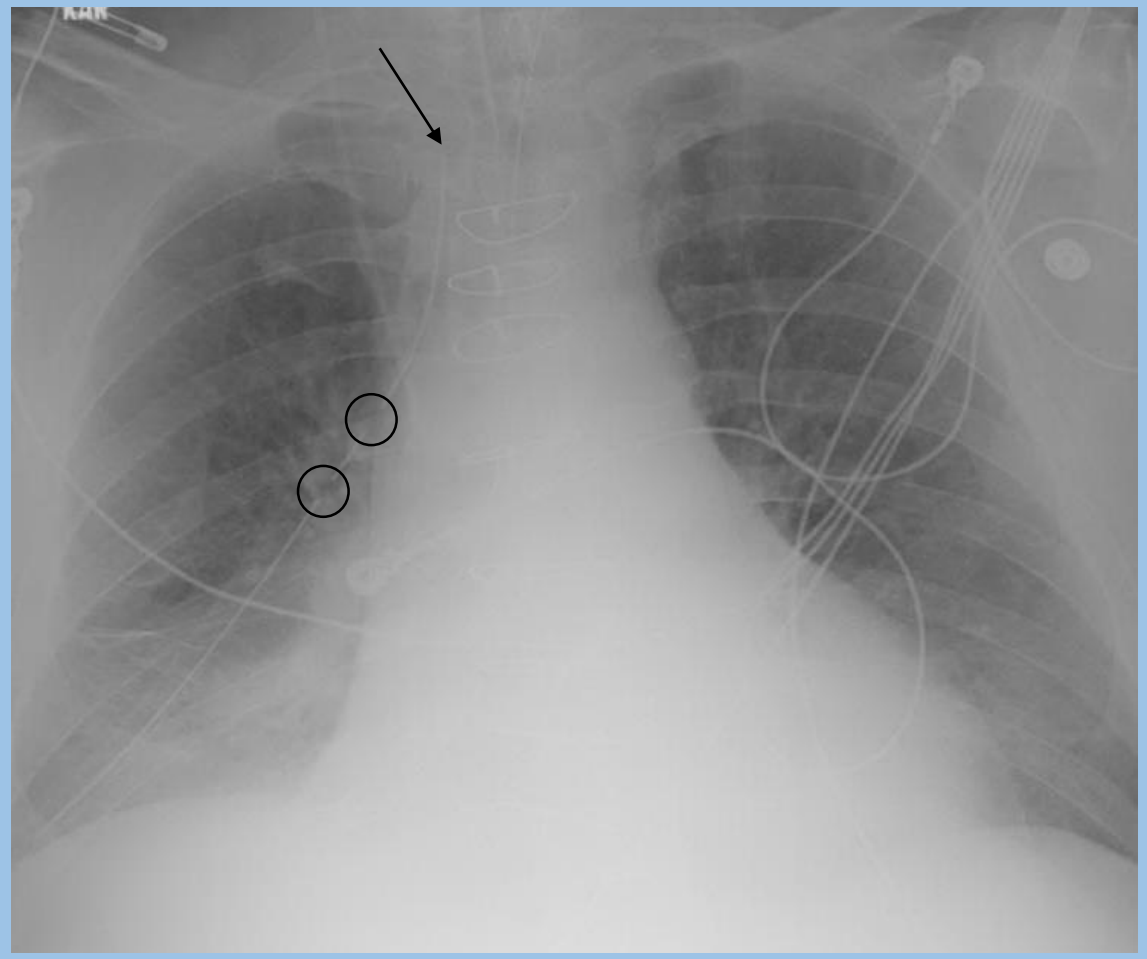
Legend: 1-3: usually not appropriate; 4-6: may be appropriate; 7-9: usually appropriate

Chest Tubes – Normal Position

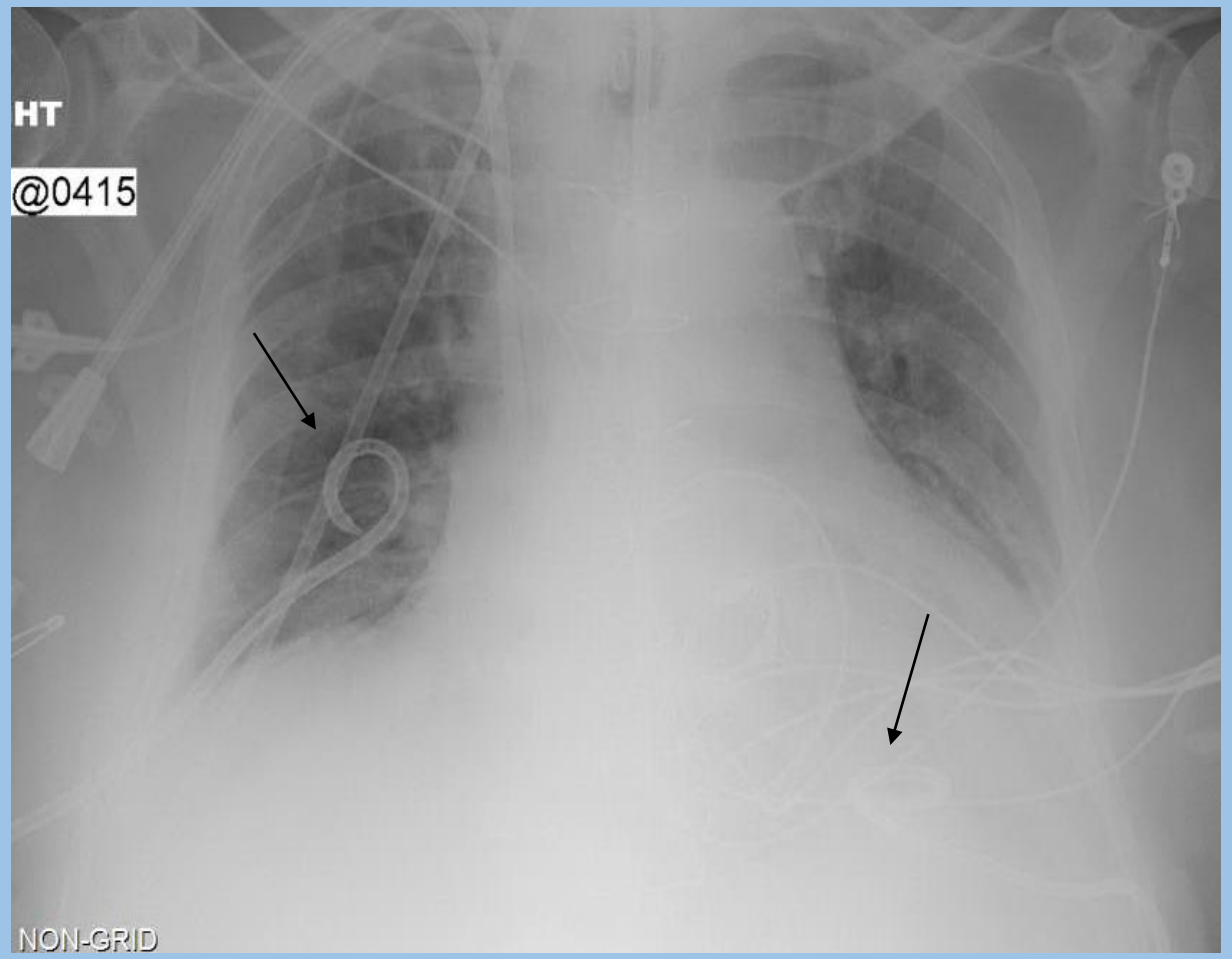
- Assessment based on identification of radiopaque lines and side holes
- All side holes must be within pleural space and completely visualized
  - Side holes = interruption of radiopaque line
  - Position medial to inner margin of ribs
- Tube direction depends on indication:
  - Air removal (PTX) – anterior and superior
  - Fluid removal (effusion)– posterior and inferior
    - Tube should not “float” on top of effusion
- Lateral films also helpful in confirming position (i.e. anterior-posterior)
  - Non-contrast CT scan if still uncertain



Chest Tubes – Normal Position



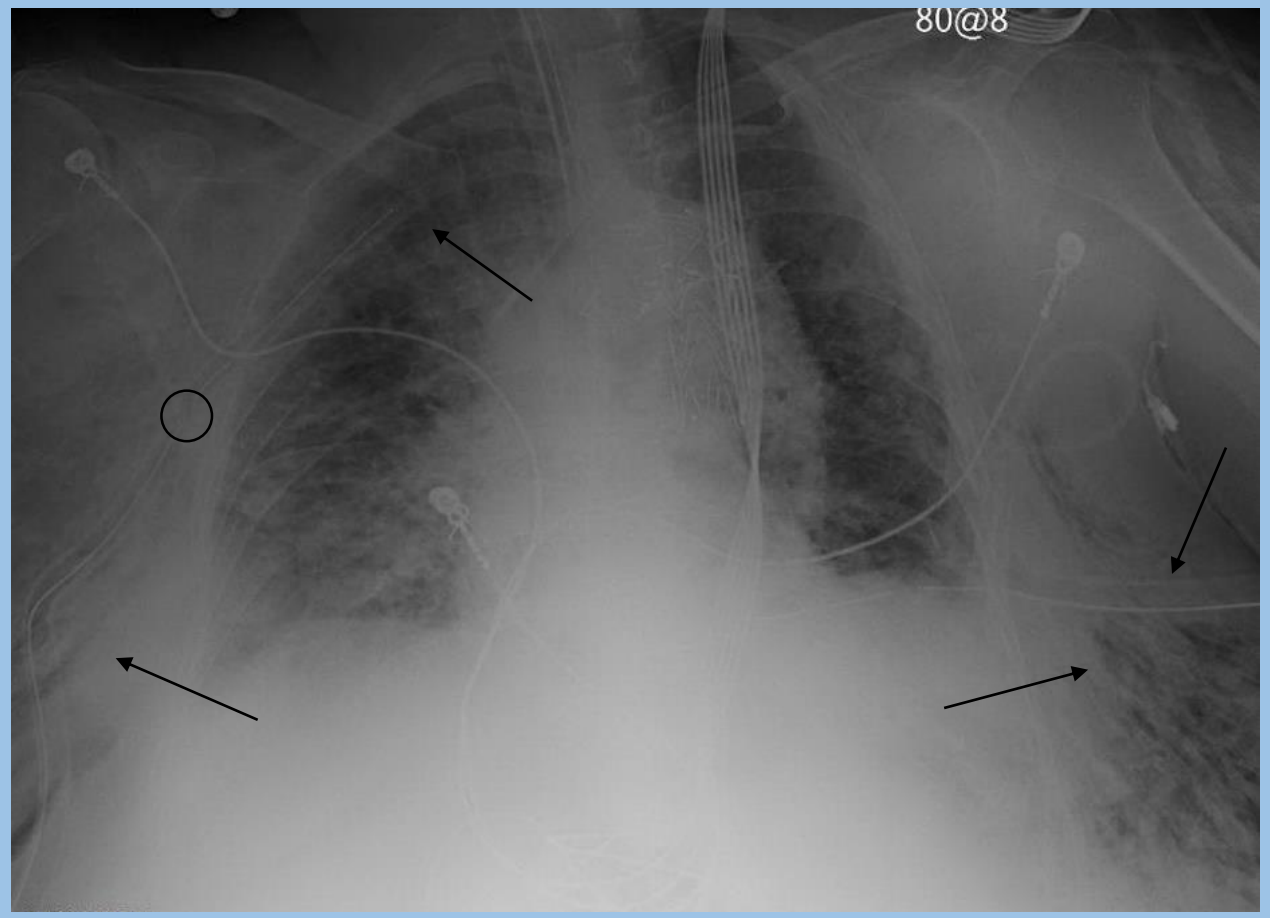
Right apical chest tube



Bilateral pigtail chest tubes

Chest Tubes – Abnormal Position

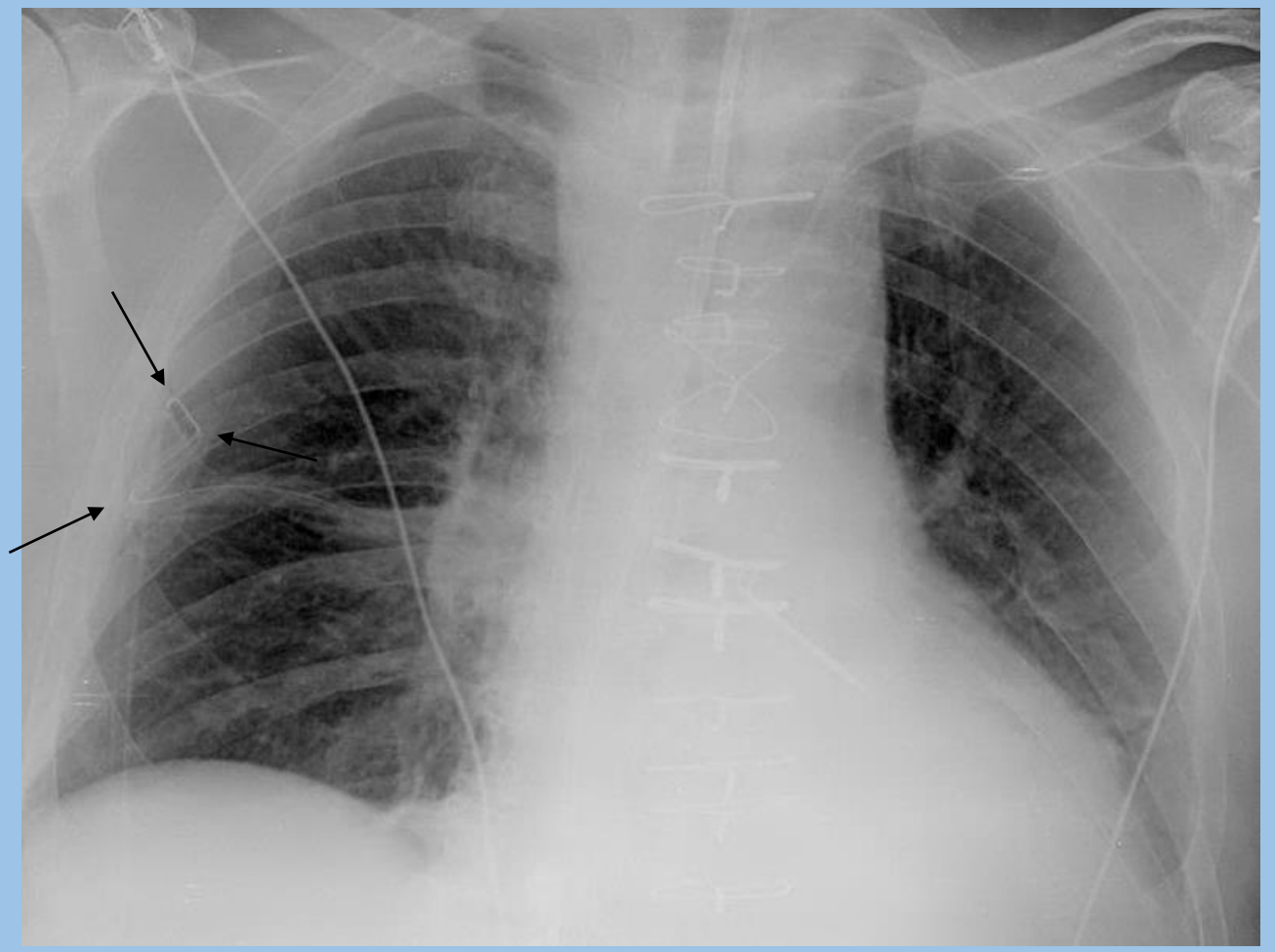
- Positioning errors:
  - Incomplete insertion
    - Side hole outside of pleural cavity



Incomplete tube placement with subcutaneous emphysema

Chest Tubes – Abnormal Position

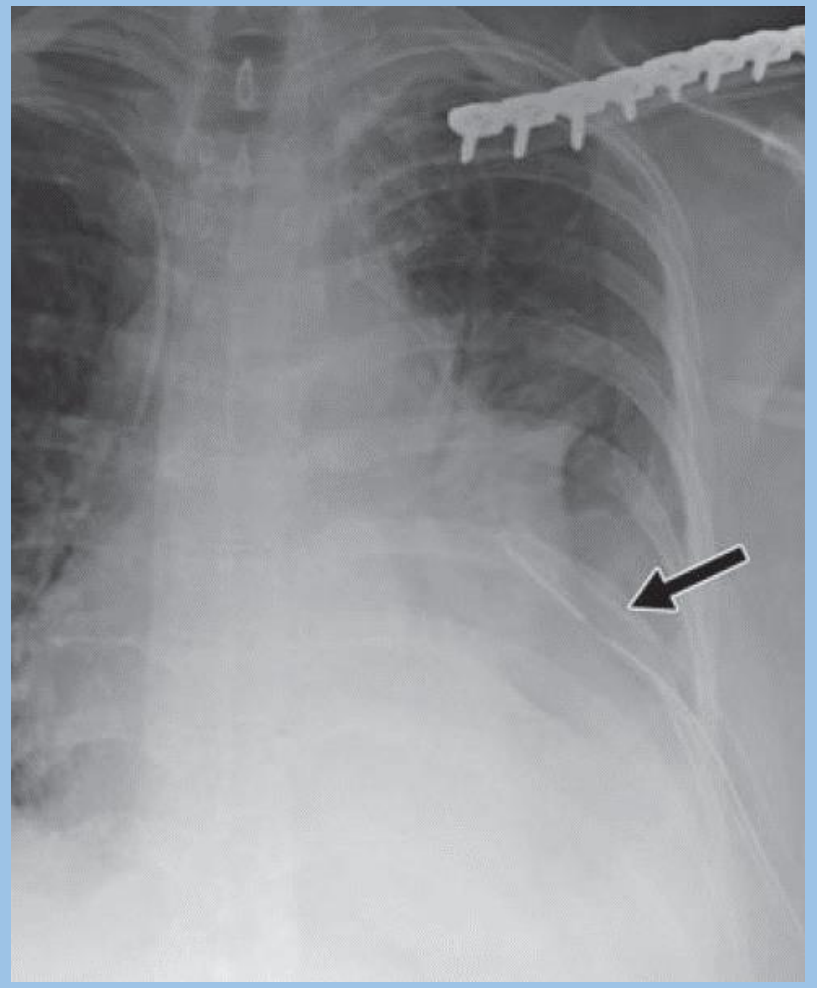
- Positioning errors:
  - Incomplete insertion
    - Side hole outside of pleural cavity
  - Tube kinking
    - Tube angulations



Multiple chest tube kinks

Chest Tubes – Abnormal Position

- Positioning errors:
  - Incomplete insertion
    - Side hole outside of pleural cavity
  - Tube kinking
    - Tube angulations
  - Soft tissue/chest wall

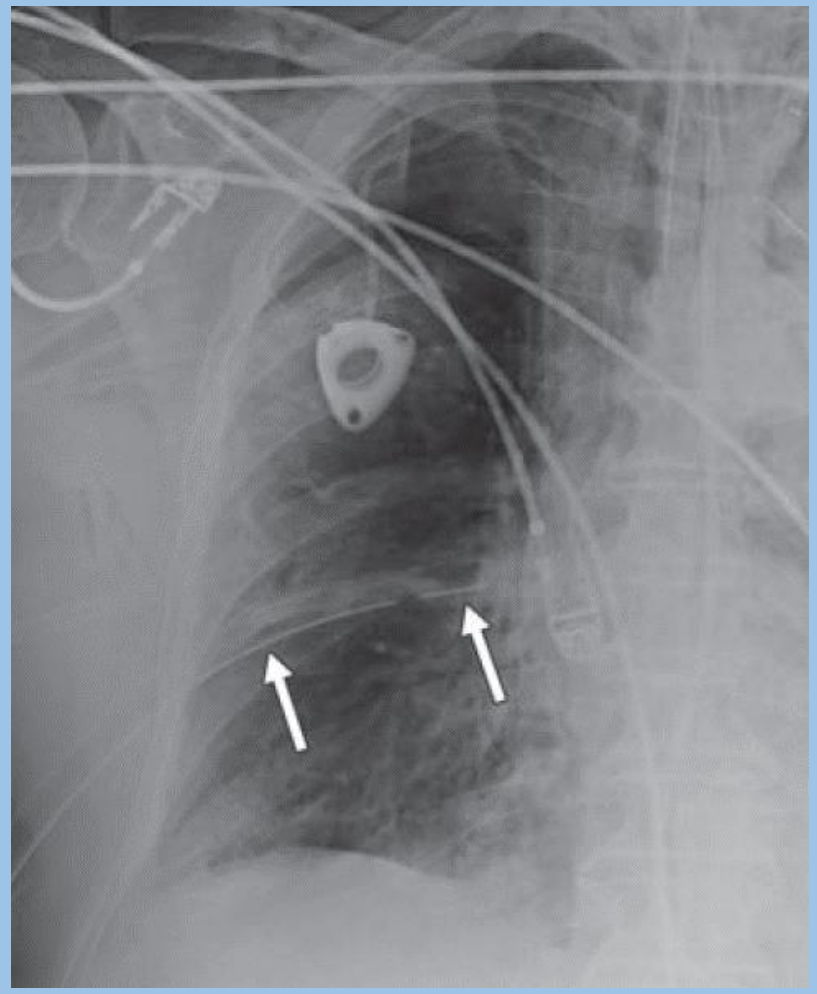


Left chest tube appears in proper position

CT demonstrating chest tube within chest wall

Chest Tubes – Abnormal Position

- Positioning errors:
  - Incomplete insertion
    - Side hole outside of pleural cavity
  - Tube kinking
    - Tube angulations
  - Soft tissue/chest wall
  - Lung fissures*
    - Poor drainage
    - Horizontal projection
    - Herniation into tube → infarction



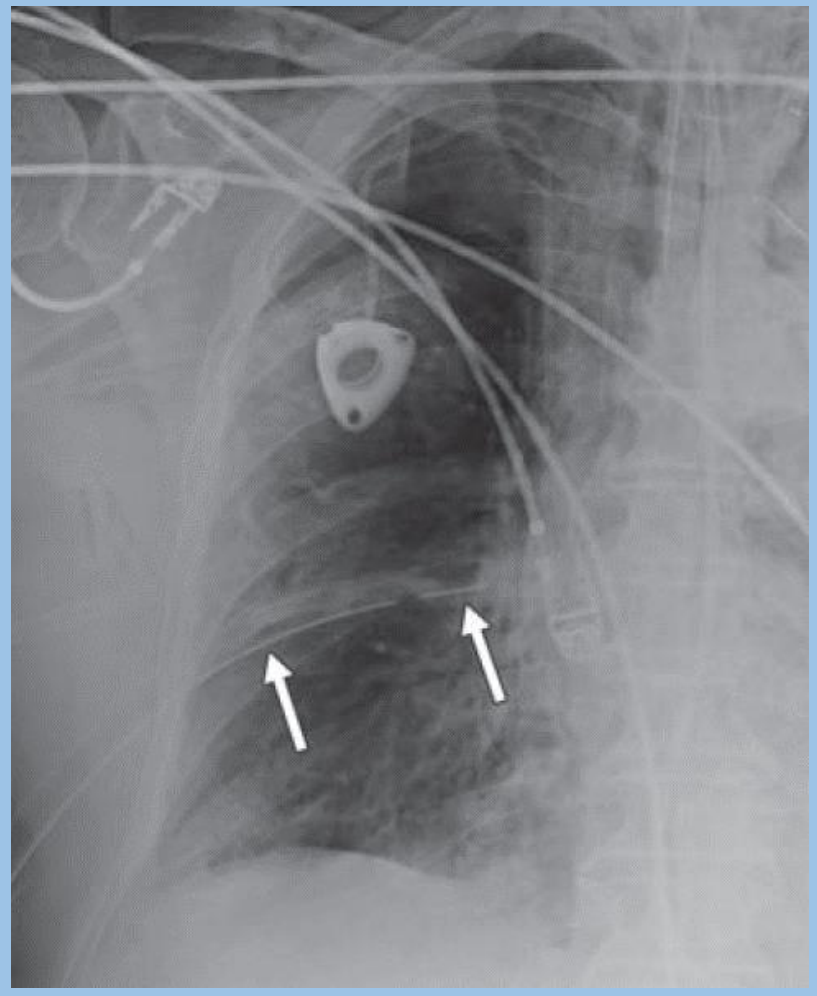
Right chest tube projecting horizontally

Right chest tube (axial) within right minor fissure

Chest Tubes – Abnormal Position

- Positioning errors:
  - Incomplete insertion
    - Side hole outside of pleural cavity
  - Tube kinking
    - Tube angulations
  - Soft tissue/chest wall
  - Lung fissures*
    - Poor drainage
    - Horizontal projection
    - Herniation into tube → infarction

*May appear normal on frontal chest X ray

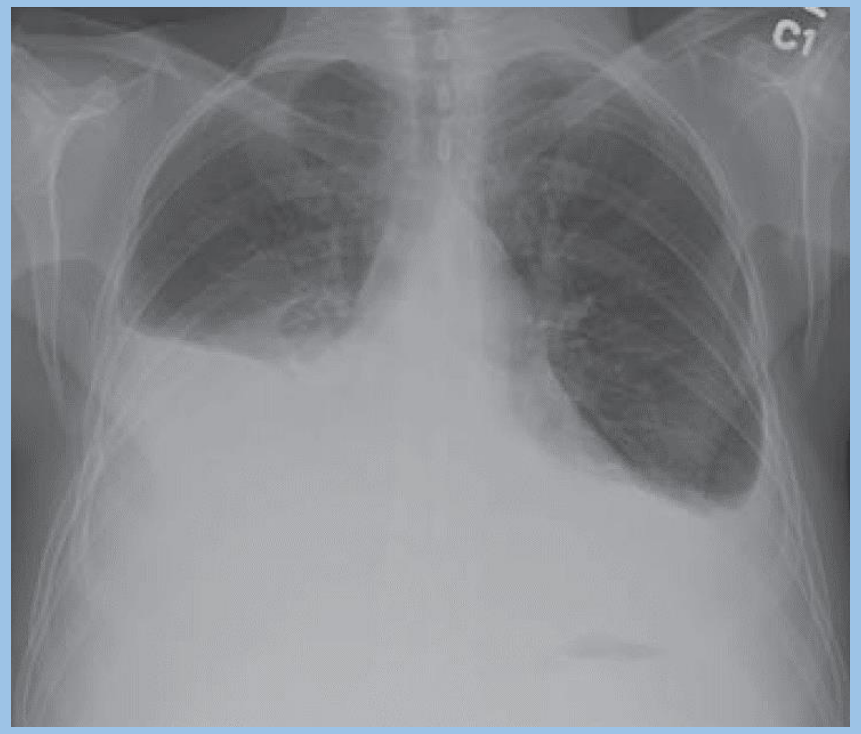


Right chest tube projecting horizontally

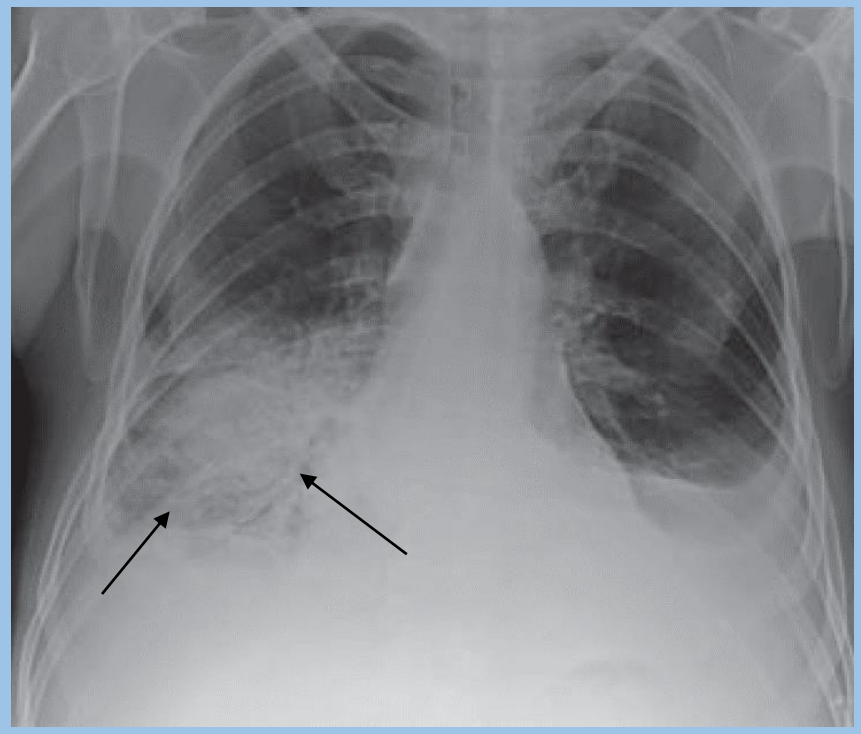
Right chest tube (axial) within right minor fissure

Chest Tubes – Complications

- Reexpansion pulmonary edema
  - Rapid removal of air/fluid from pleural space
    - Prolonged atelectasis
  - Also: s/p thoracentesis
  - Clinical manifestations:
    - <2 hours after lung reexpansion
    - Hypoxia → respiratory distress
    - Lasts 1-2 days
  - Unilateral airspace opacity



Right pleural effusion prior to drainage



Interval resolution of right pleural effusion; new airspace opacity in RLL

Chest Tubes– Indications for Studies

- Radiographic evaluation indicated:
  - After chest tube insertion (appropriateness score = 9)
  - Patient with chest tube in place – clinical indications only (9)
    - Also: newly malfunctioning chest tubes

- Radiographic evaluation NOT indicated:
  - Daily, routine follow-up (1)

Legend: 1-3: usually not appropriate; 4-6: may be appropriate; 7-9: usually appropriate

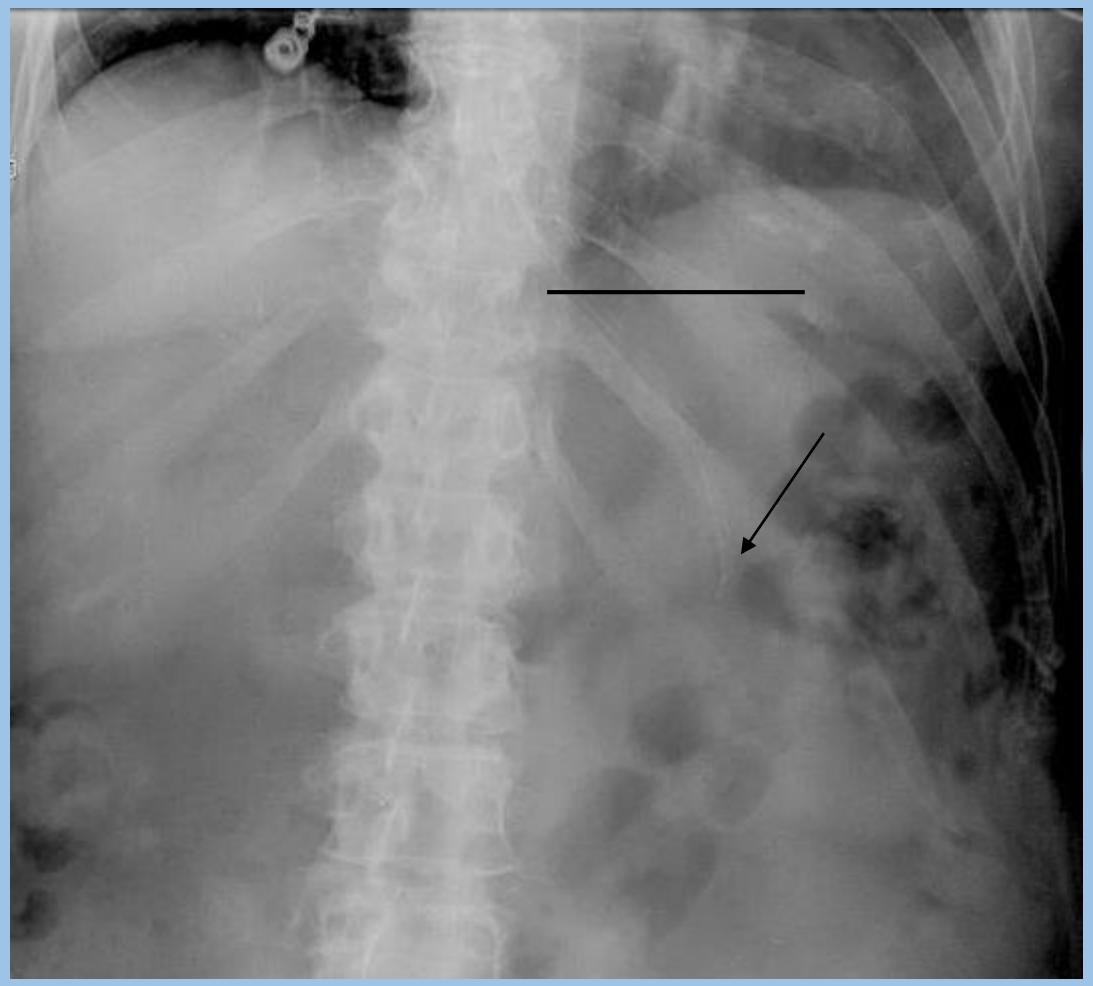
Enteric Tubes – Normal Position

- NGT/OGT
  - Larger diameter
  - Stiffer
  - Used for feeding or suction
  - More easily placed
  - Increased aspiration risk
    - Large feeding volumes
    - Impaired gastric motility
  - May measure gastric residuals
  - May contain side holes
- Flexible/Dobhoff tube (DHT)
  - Small diameter
  - More flexible
  - Used for feeding only (no suction)
  - More difficult to place
    - Weight (radiopaque) tip
  - Decreased aspiration risk
    - Antral/post-pyloric placement
  - May contain side holes

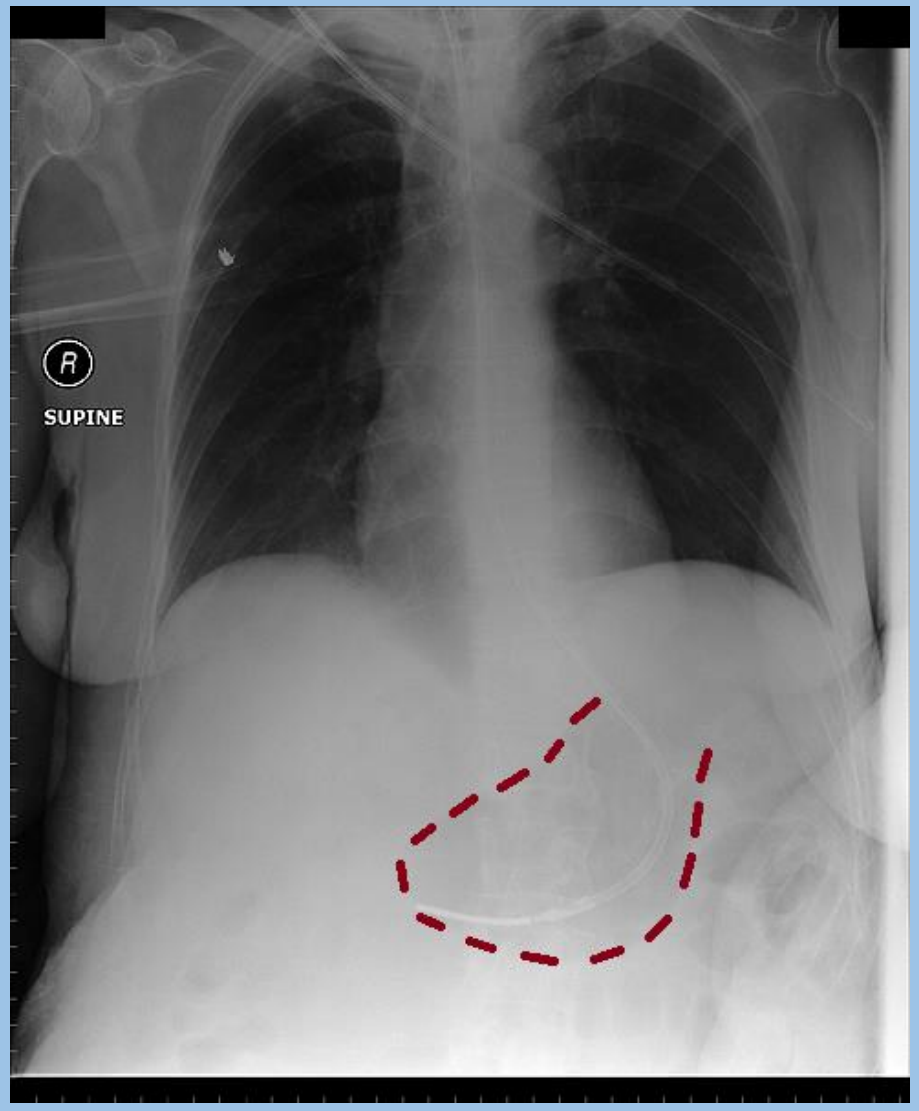
Enteric Tubes – Normal Position

- Optimal position depends on tube type
  - NGT/OGT:
    - Feeding – distal/antral stomach placement
      - Tip directed towards midline
      - Tip at least 10cm distal to GE junction
        - GE junction - just below level of the left cardiophrenic angle
    - Decompression – gastric placement
      - Tip distal to GE junction
  - Dobhoff:
    - Feeding – 2nd portion of duodenum
      - Tip crosses midline; tip oriented caudally
- "Optimal" position ≠ "acceptable" position
- "OK to use" criteria:
  - Tube follows midline course down the chest without coils
  - Tip and all side holes are below GE junction

Enteric Tubes – Normal Position



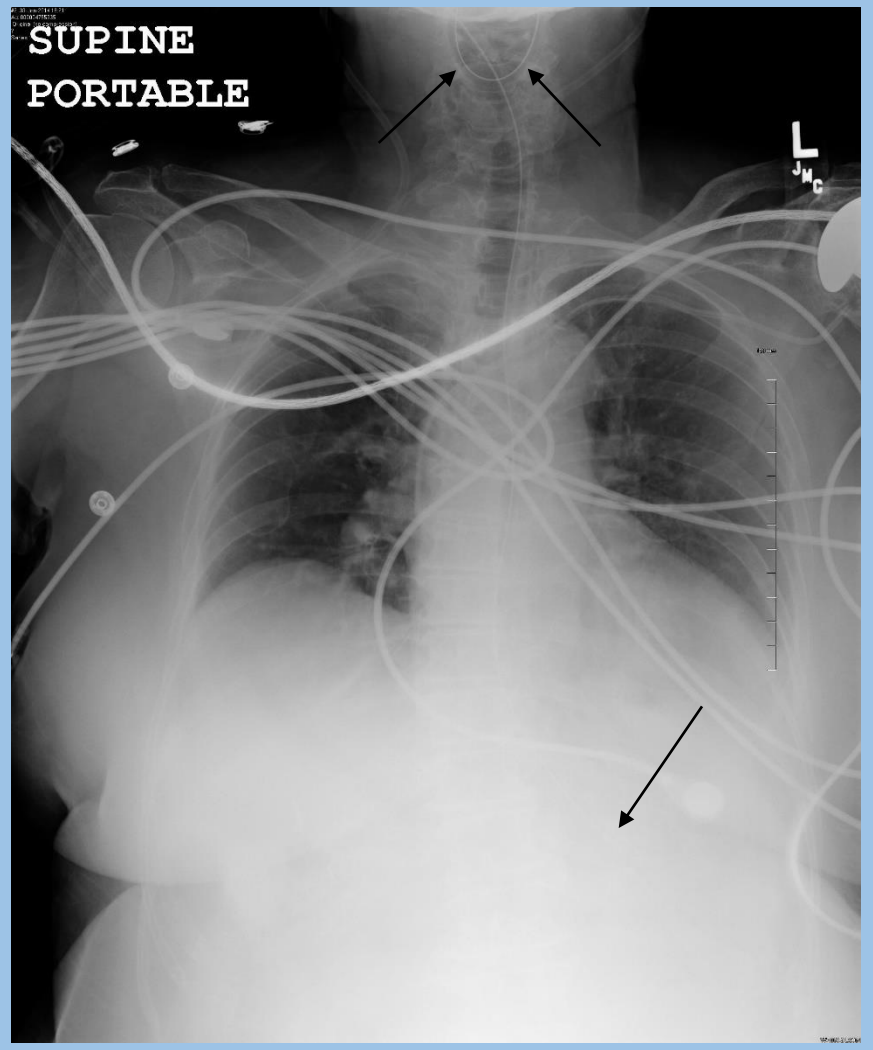
NGT terminating in gastric body



DHT terminating in gastric antrum

Enteric Tubes – Abnormal Position

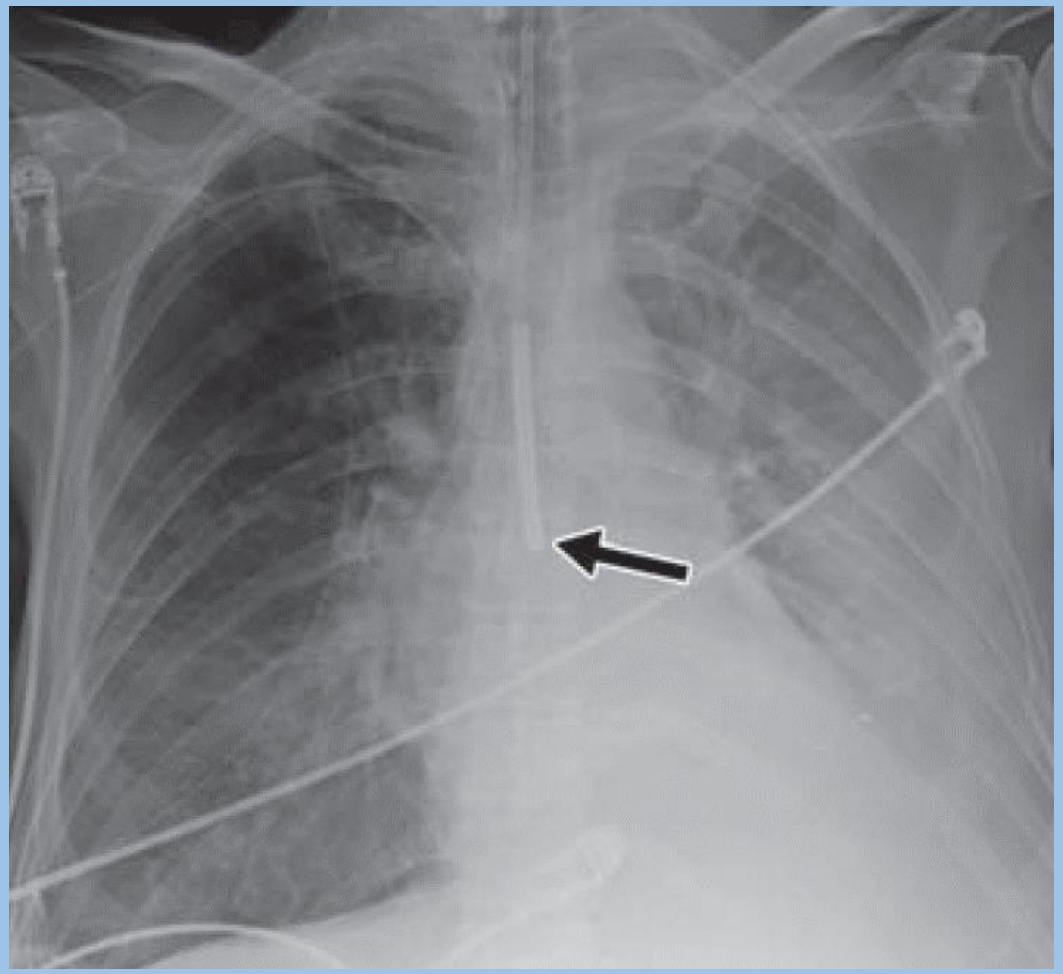
- Positioning errors:
  - Coiled tube



Tube terminating in gastric body; coiled in larynx

Enteric Tubes – Abnormal Position

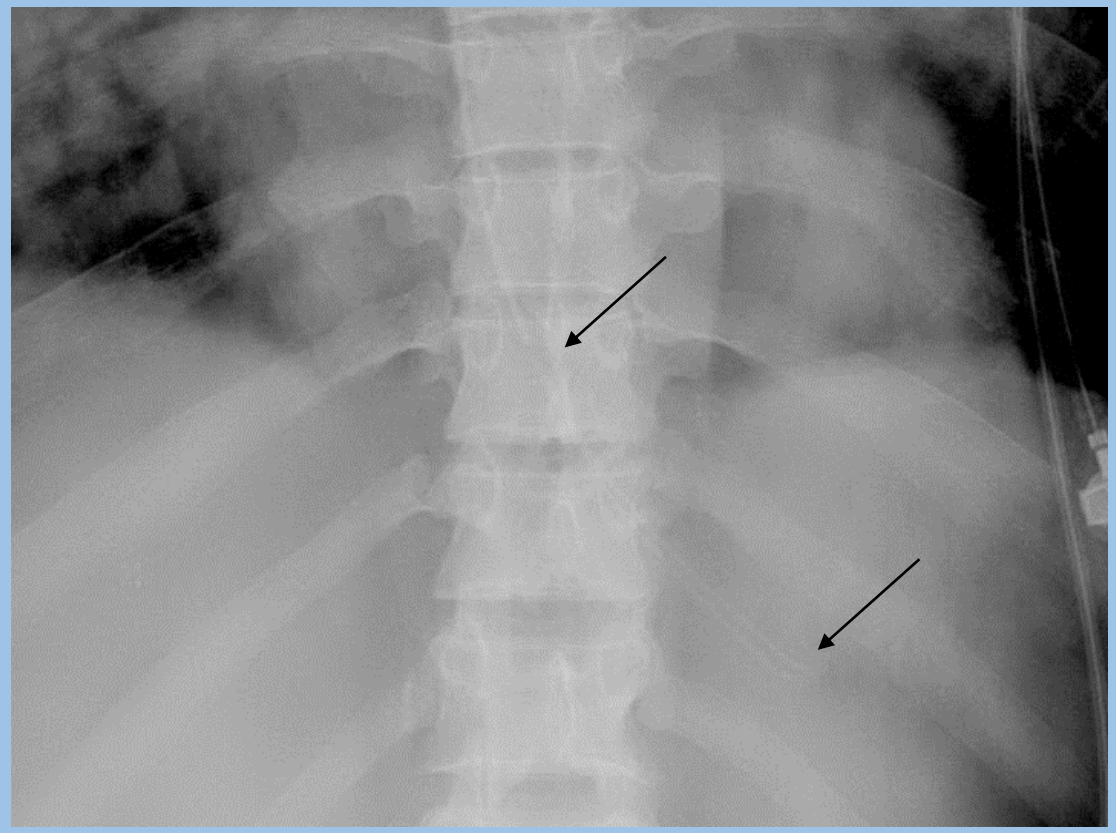
- Positioning errors:
  - Coiled tube
  - Proximal/“marginal” placement
    - Aspiration risk



Tube terminating proximal to the GE junction

Enteric Tubes – Abnormal Position

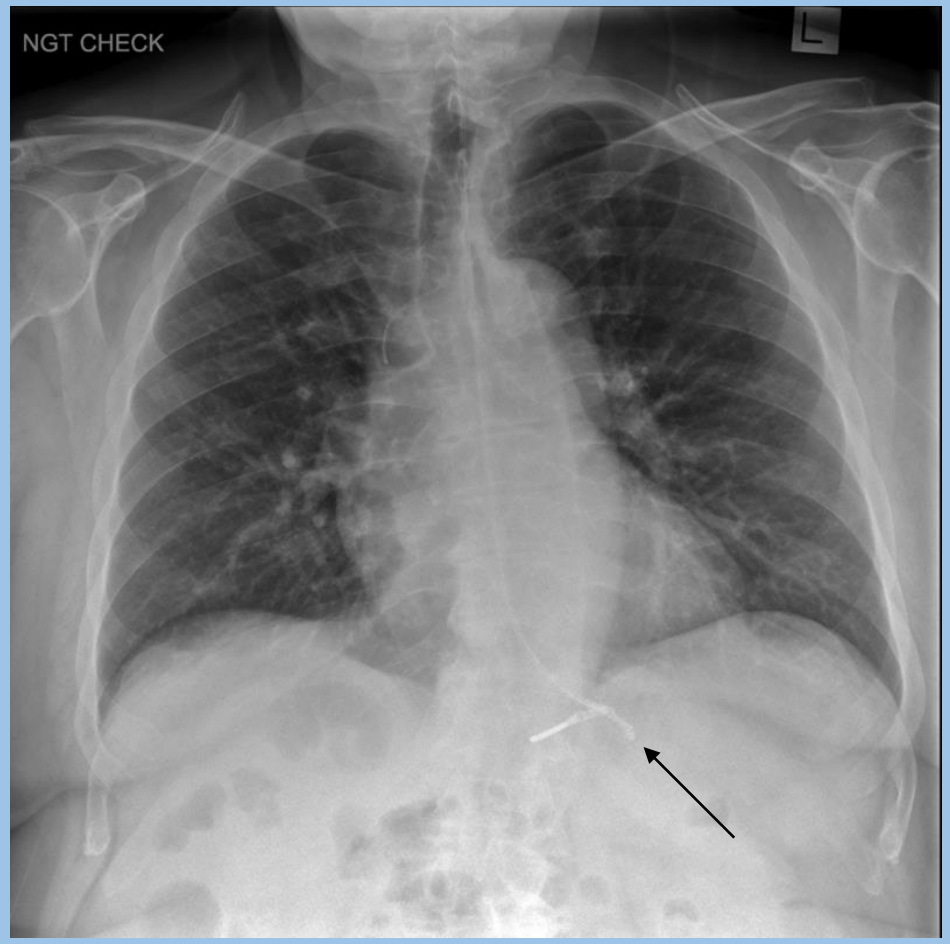
- Positioning errors:
  - Coiled tube
  - Proximal/“marginal” placement
    - Aspiration risk



Tube tip below GE junction; side hole within distal esophagus

Enteric Tubes – Abnormal Position

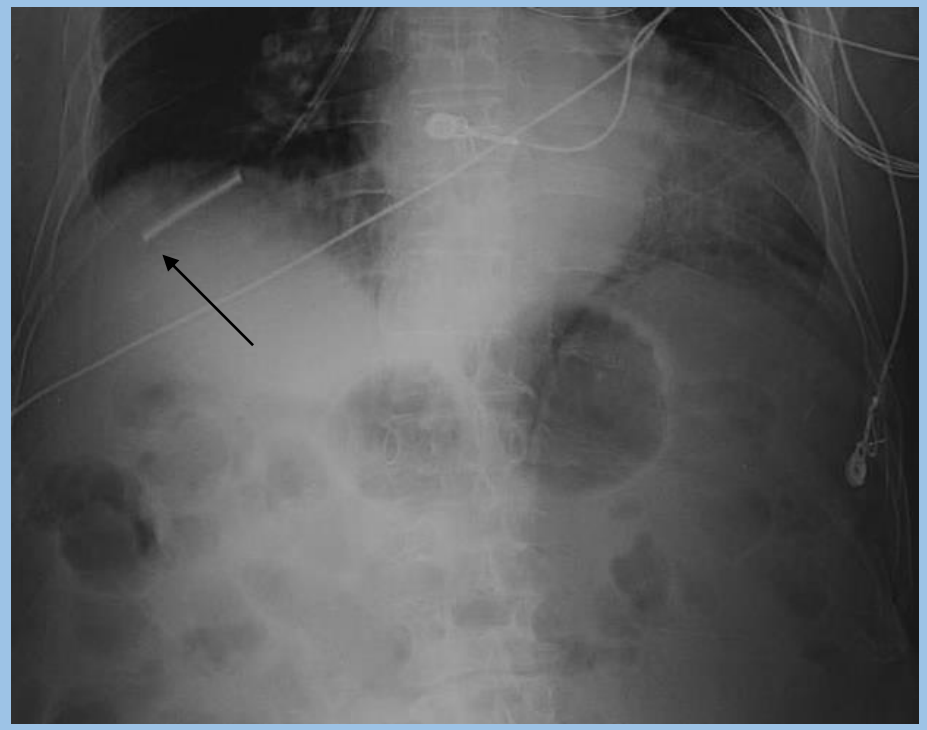
- Positioning errors:
  - Coiled tube
  - Proximal/“marginal” placement
    - Aspiration risk
  - Kinked tube



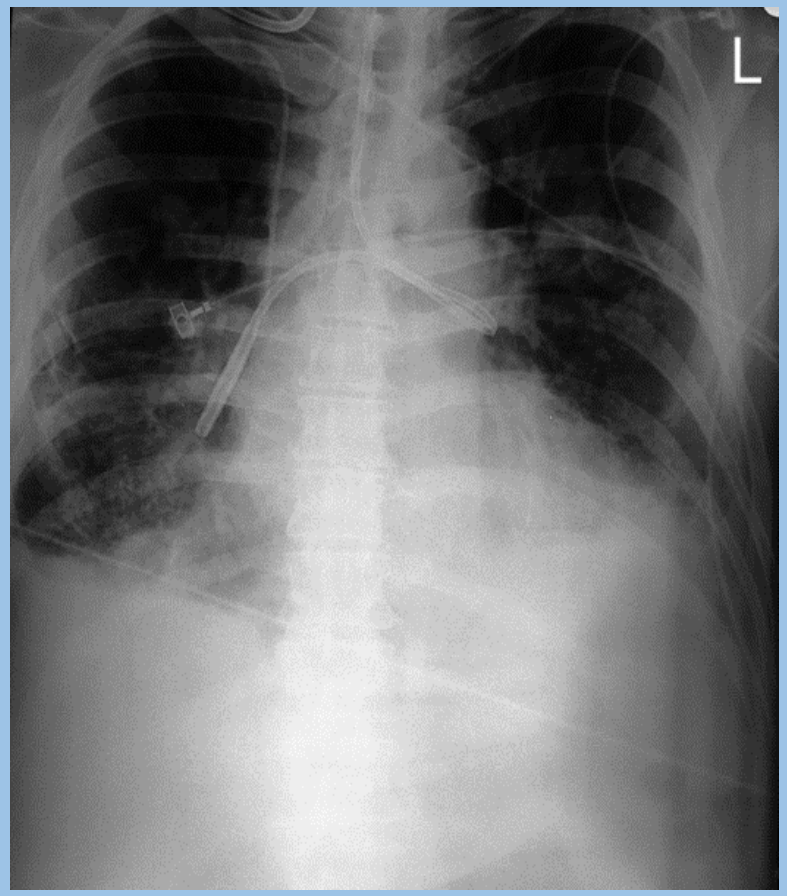
Tube kinked within proximal stomach

Enteric Tubes – Abnormal Position

- Positioning errors:
  - Coiled tube
  - Proximal/“marginal” placement
    - Aspiration risk
  - Kinked tube
  - Pulmonary placement



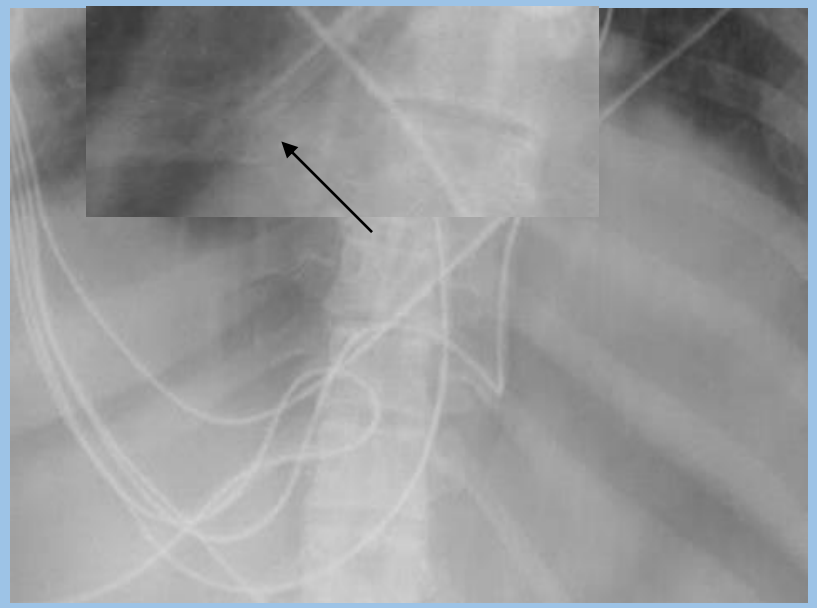
Tube inserted through right bronchus into RLL



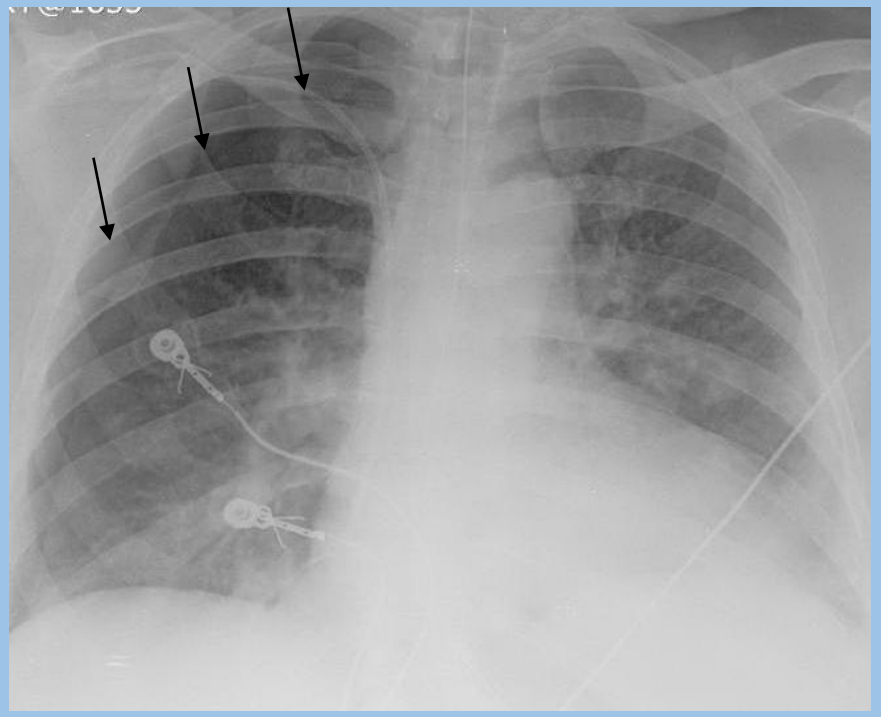
Tube inserted through left bronchus and deflected into right bronchus

Enteric Tubes – Abnormal Position

- Positioning errors:
  - Coiled tube
  - Proximal/“marginal” placement
    - Aspiration risk
  - Kinked tube
  - Pulmonary placement



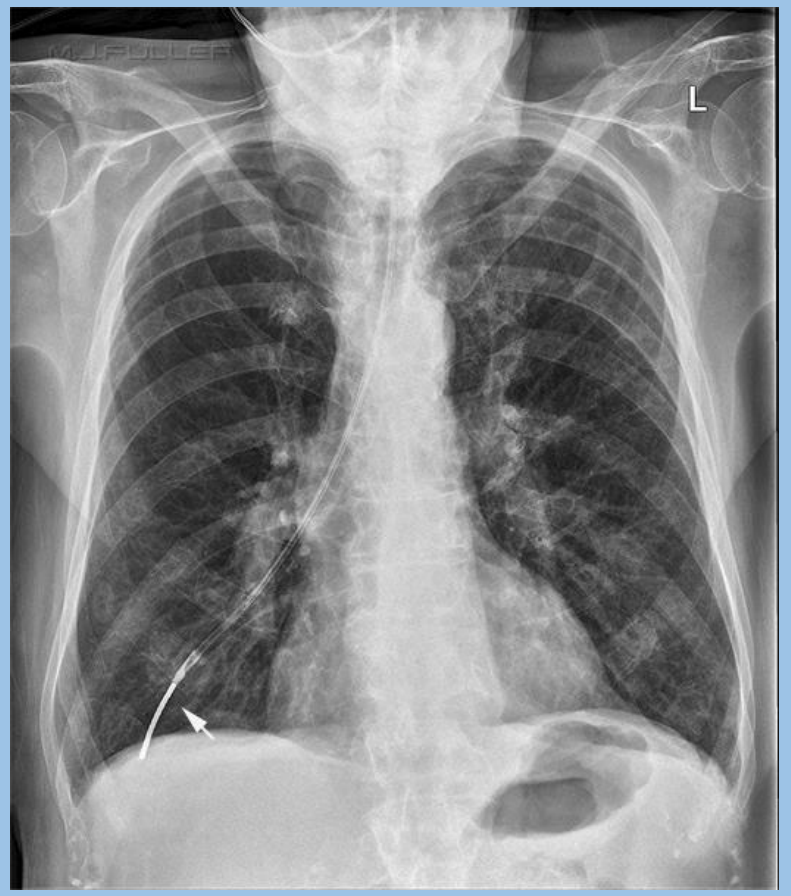
Tube inserted through right bronchus into RLL



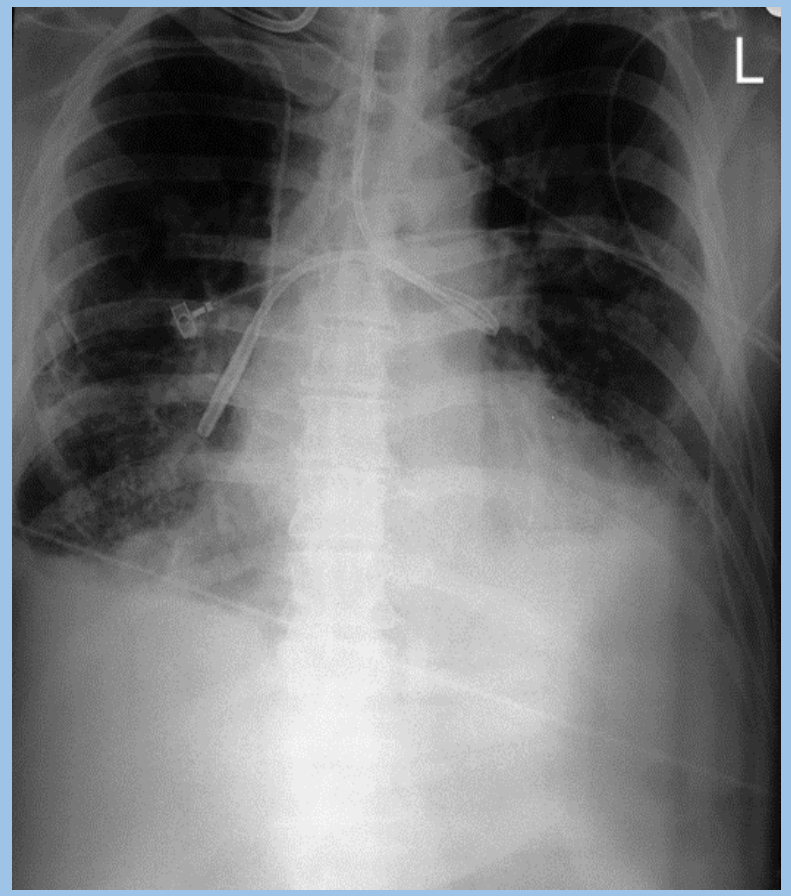
Follow up chest X ray with right sided pneumothorax

Enteric Tubes – Abnormal Position

- Positioning errors:
  - Coiled tube
  - Proximal/“marginal” placement
    - Aspiration risk
  - Kinked tube
  - Pulmonary placement



Tube inserted through right bronchus into RLL

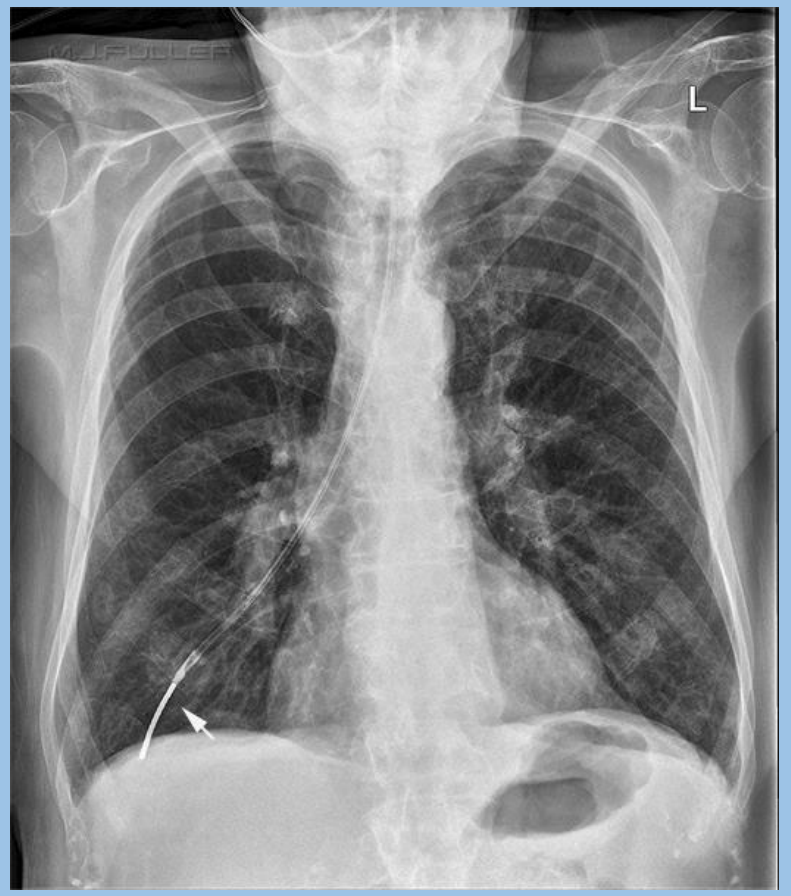


Tube inserted through left bronchus and deflected into right bronchus

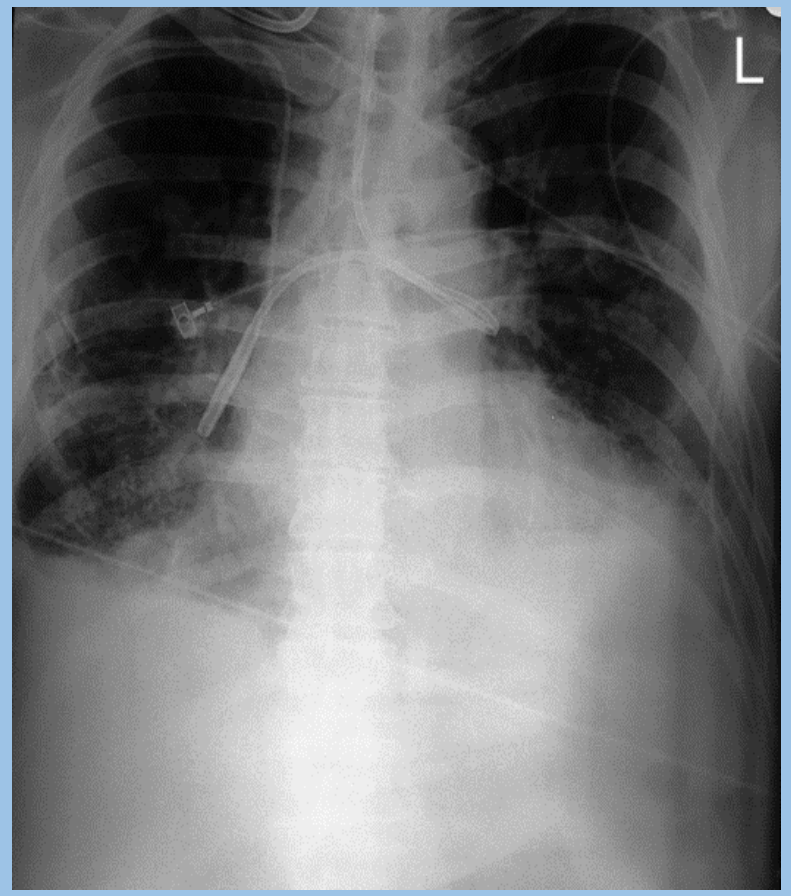
Enteric Tubes – Abnormal Position

- Positioning errors:
  - Coiled tube
  - Proximal/“marginal” placement
    - Aspiration risk
  - Kinked tube
  - Pulmonary placement
  - Intracranial placement*

*Extremely rare (case reports); usually post-trauma



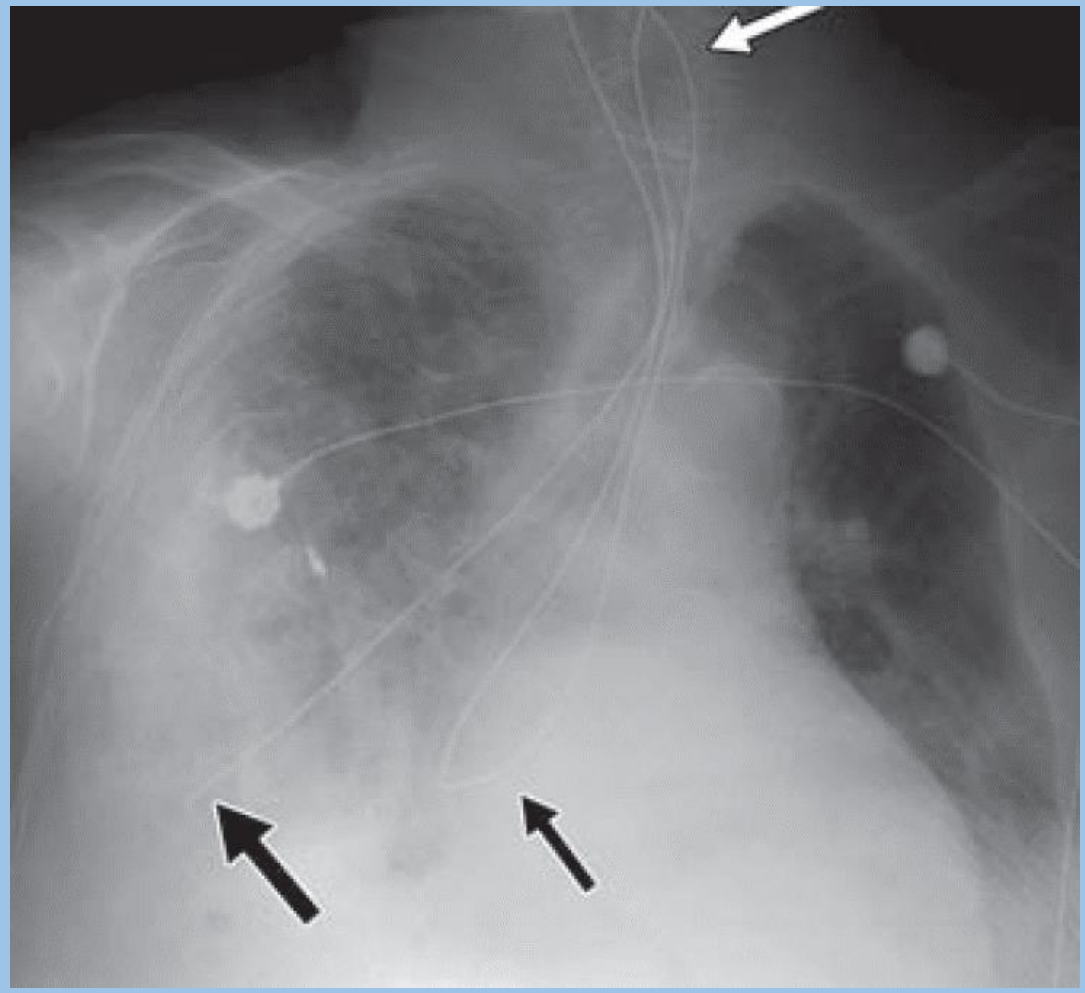
Tube inserted through right bronchus into RLL



Tube inserted through left bronchus and deflected into right bronchus

Enteric Tubes – Complications

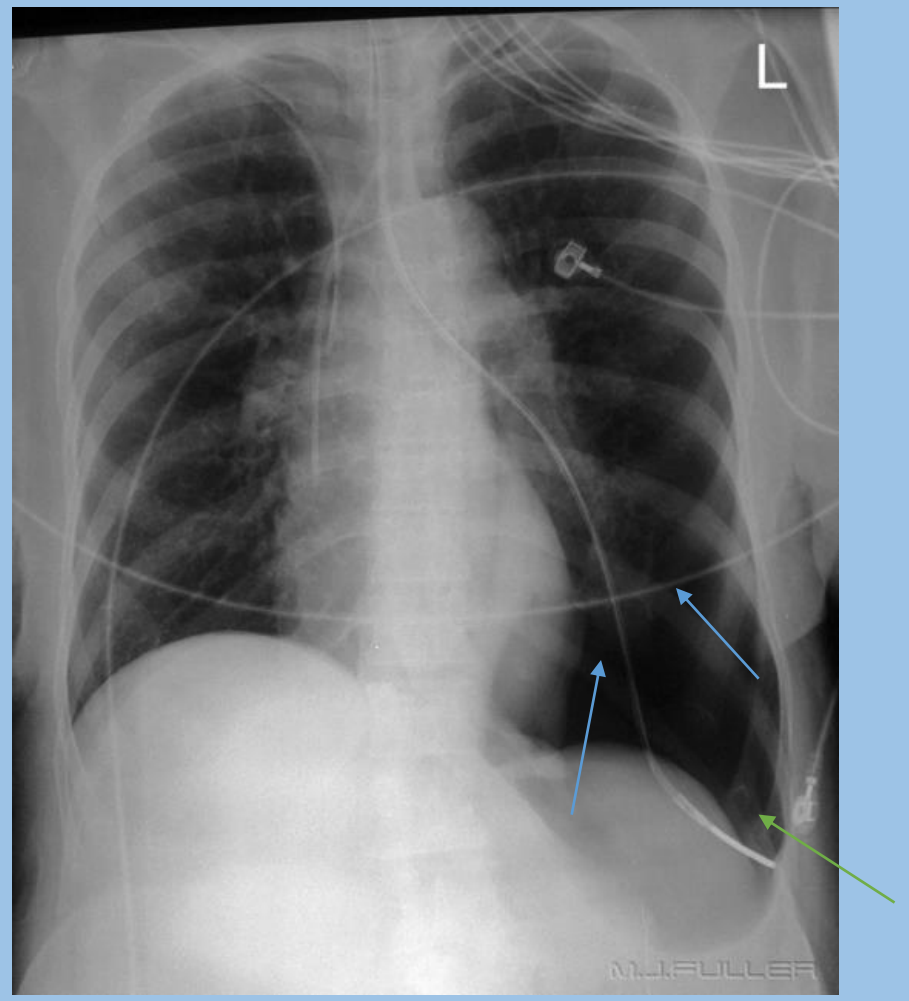
- Complications:
  - Pulmonary contusion/laceration



Tube coiled within esophagus; second loop entering right bronchus with right airspace opacity

Enteric Tubes – Complications

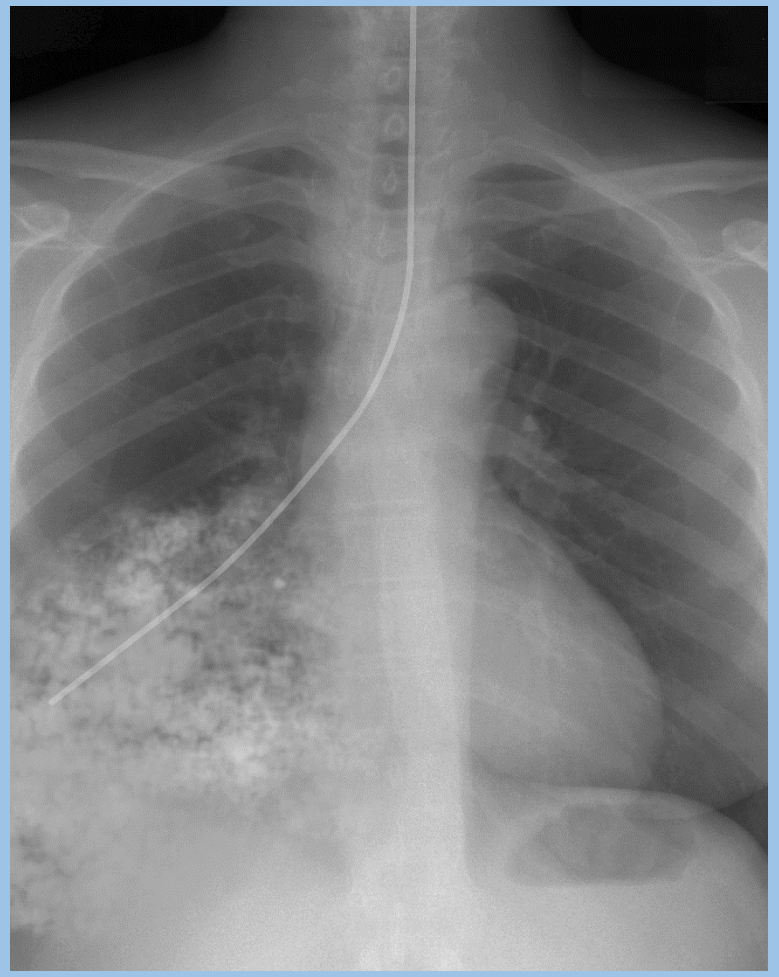
- Complications:
  - Pulmonary contusion/laceration
  - Pneumothorax



Tube entering left bronchus with left basilar pneumothorax (deep sulcus-green arrow)

Enteric Tubes – Complications

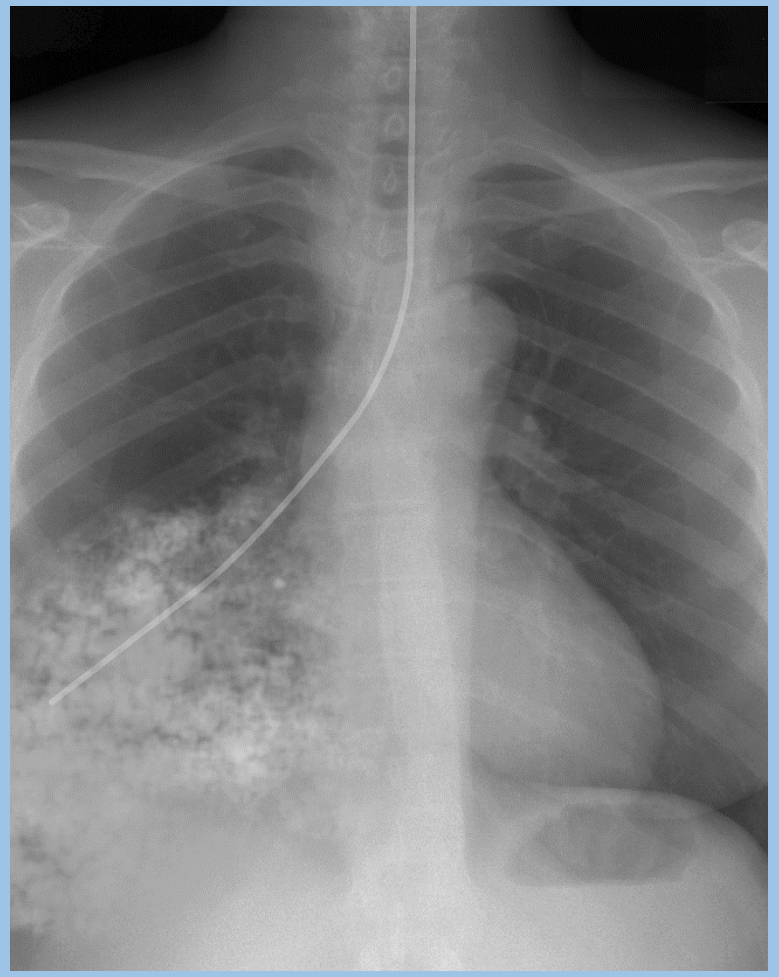
- Complications:
  - Pulmonary contusion/laceration
  - Pneumothorax
  - Aspiration of feedings
    - Pneumonia
    - Abscess
    - Empyema



Tube entering right bronchus; RLL infiltrate after initiation of feeds

Enteric Tubes – Complications

- Complications:
  - Pulmonary contusion/laceration
  - Pneumothorax
  - Aspiration of feedings
    - Pneumonia
    - Abscess
    - Empyema
  - Diaphragmatic perforation
  - Esophageal perforation
    - Widened mediastinum, pneumomediastinum
  - Gastric perforation
    - Pneumoperitoneum



Tube entering right bronchus; RLL infiltrate after initiation of feeds

Enteric Tubes– Indications for Studies

- Radiographic evaluation indicated:
  - After enteric tube insertion (appropriateness score = 9)
  - Patient with enteric tube in place – clinical indications only (9)

- Radiographic evaluation NOT indicated:
  - Daily, routine follow-up (1)

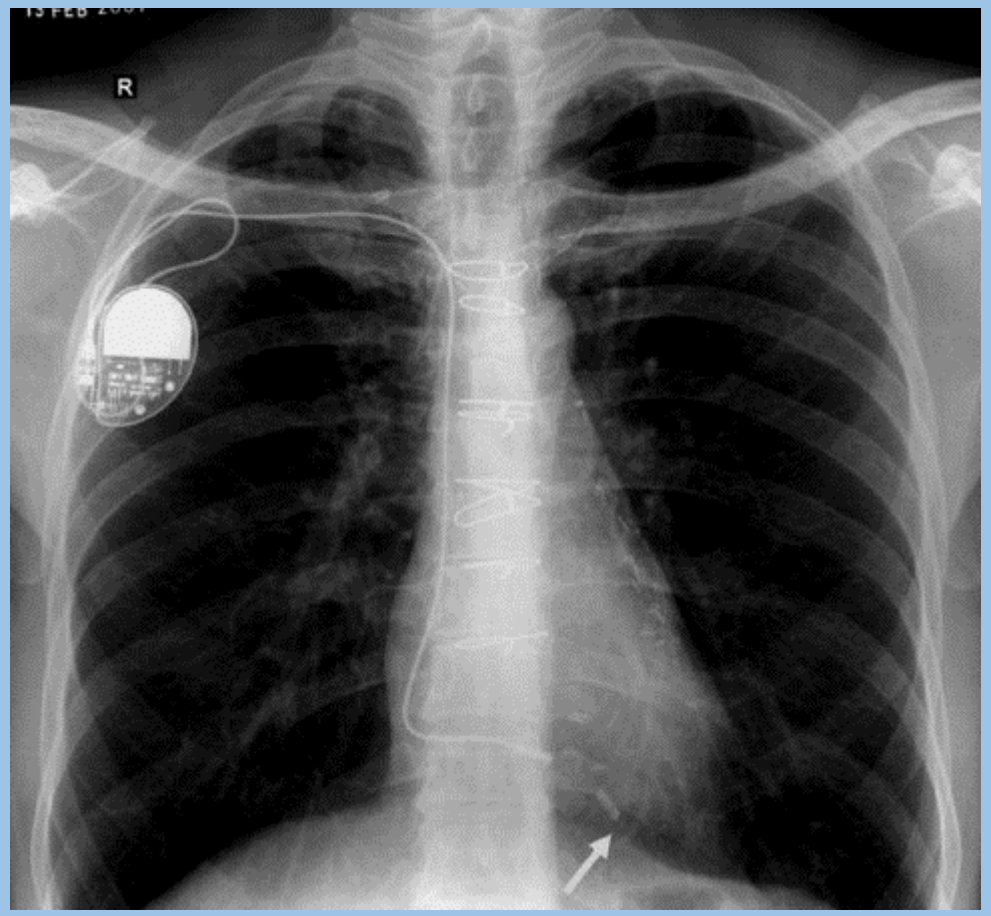
- Imaging technique pearls:
  - Images should attempt to include pharynx → stomach
    - Maximize visualization of tube course
  - Higher penetration may allow better stripe/tip visualization

Legend: 1-3: usually not appropriate; 4-6: may be appropriate; 7-9: usually appropriate

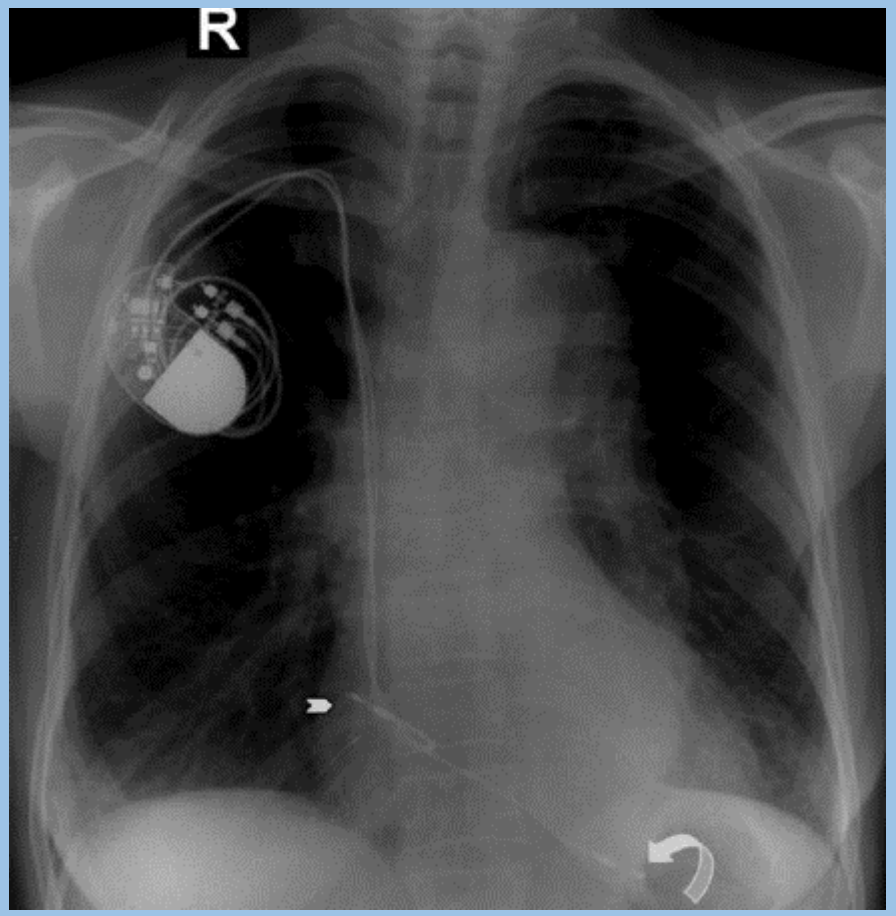
Cardiac Devices – Normal Position

- Pacemakers
  - Pulse generator and lead wire with electrodes
  - Single lead: lead tip in RV apex (rarely RA)
  - Two lead: leads tips in RA and RV
  - Three lead (biventricular pacing/CRT): leads tips in RA, RV, and coronary sinus/cardiac vein
    - RV lead: stimulates septum
    - Coronary sinus: stimulates lateral LV wall
      - Postero-superior to RV lead
    - No leads in left heart (elevated pressures)
  - All leads should have gentle curves

Cardiac Devices – Normal Position

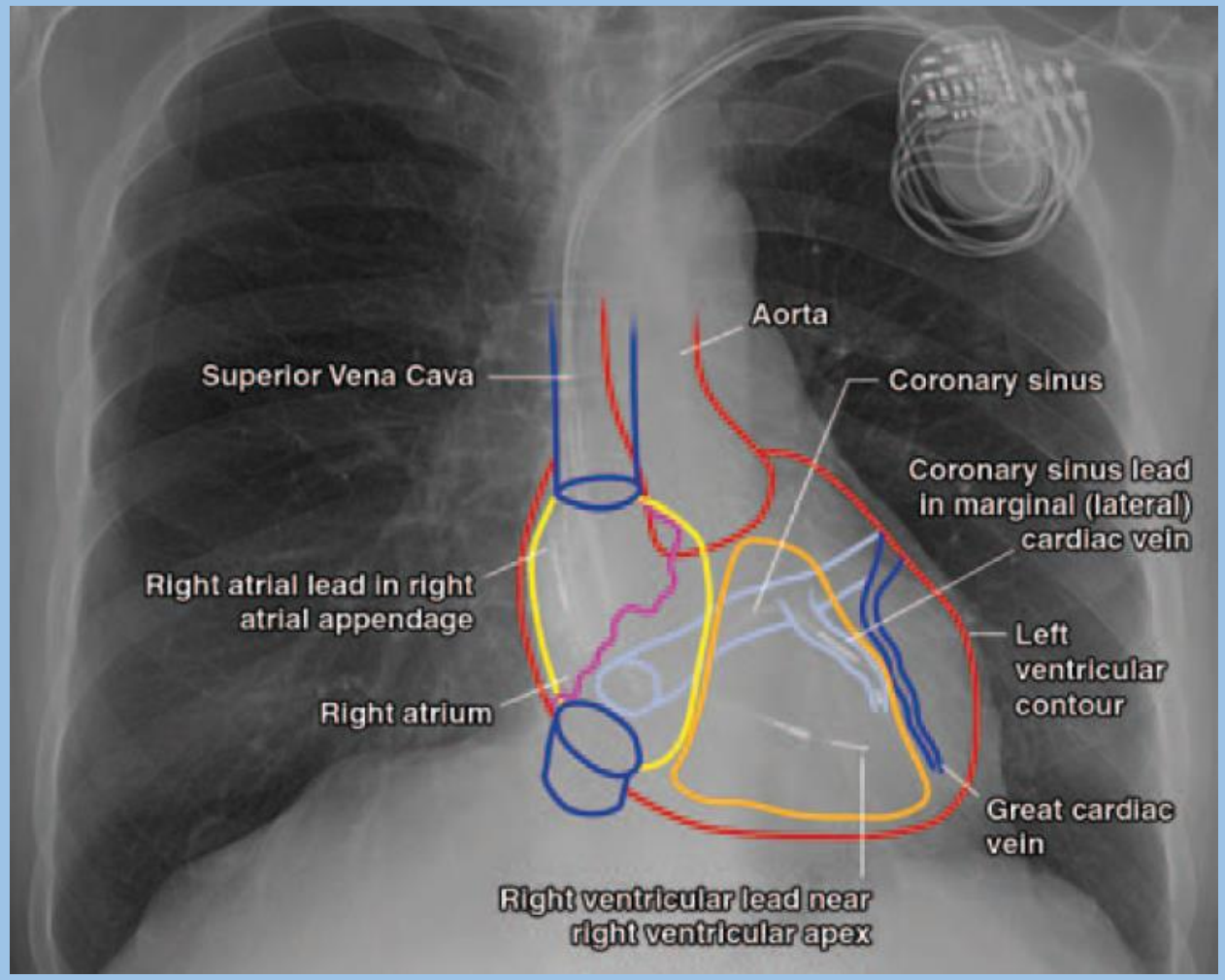


Single lead pacemaker with tip in RV (arrow)



Dual lead pacemaker with tip in RA (straight) and RV (curved)

Cardiac Devices – Normal Position

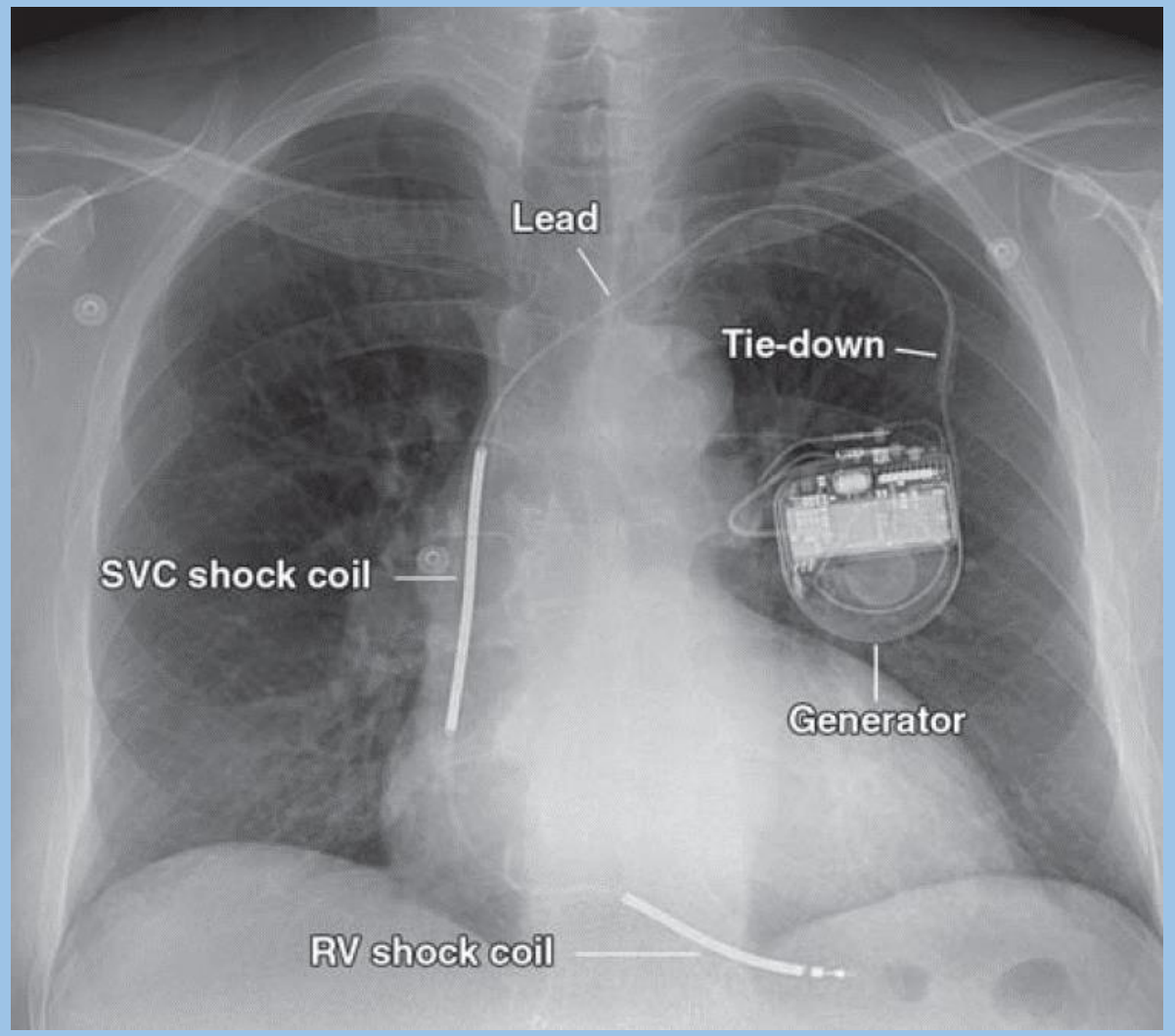


Triple lead pacemaker with leads in RA, RV, and coronary sinus

Cardiac Devices – Normal Position

- AICDs
  - Pulse generator and lead wires with electrodes
  - Leads distinguished from pacemakers by generally thicker wires and thick, radiopaque coils distally
    - Coil necessary for higher energy discharge (i.e. defibrillation)
    - Thicker wires → greater insulation
      - Less reliable indicator
  - Generally have two coils (single or separate wires)
    - Primary coil - RV
    - Additional coil – SVC or brachiocephalic vein

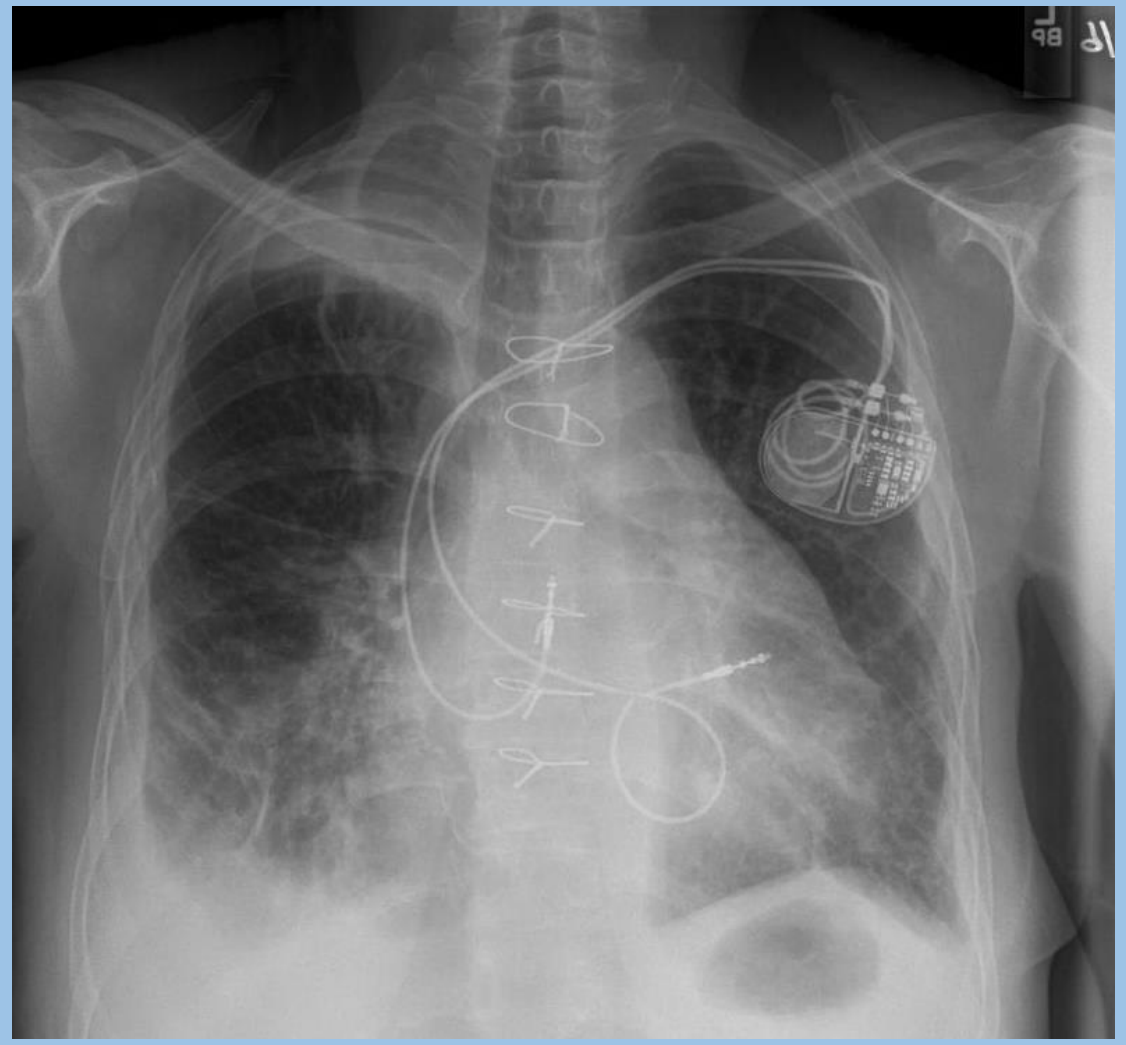
Cardiac Devices – Normal Position



AICD with coils in SVC and RV (single wire)

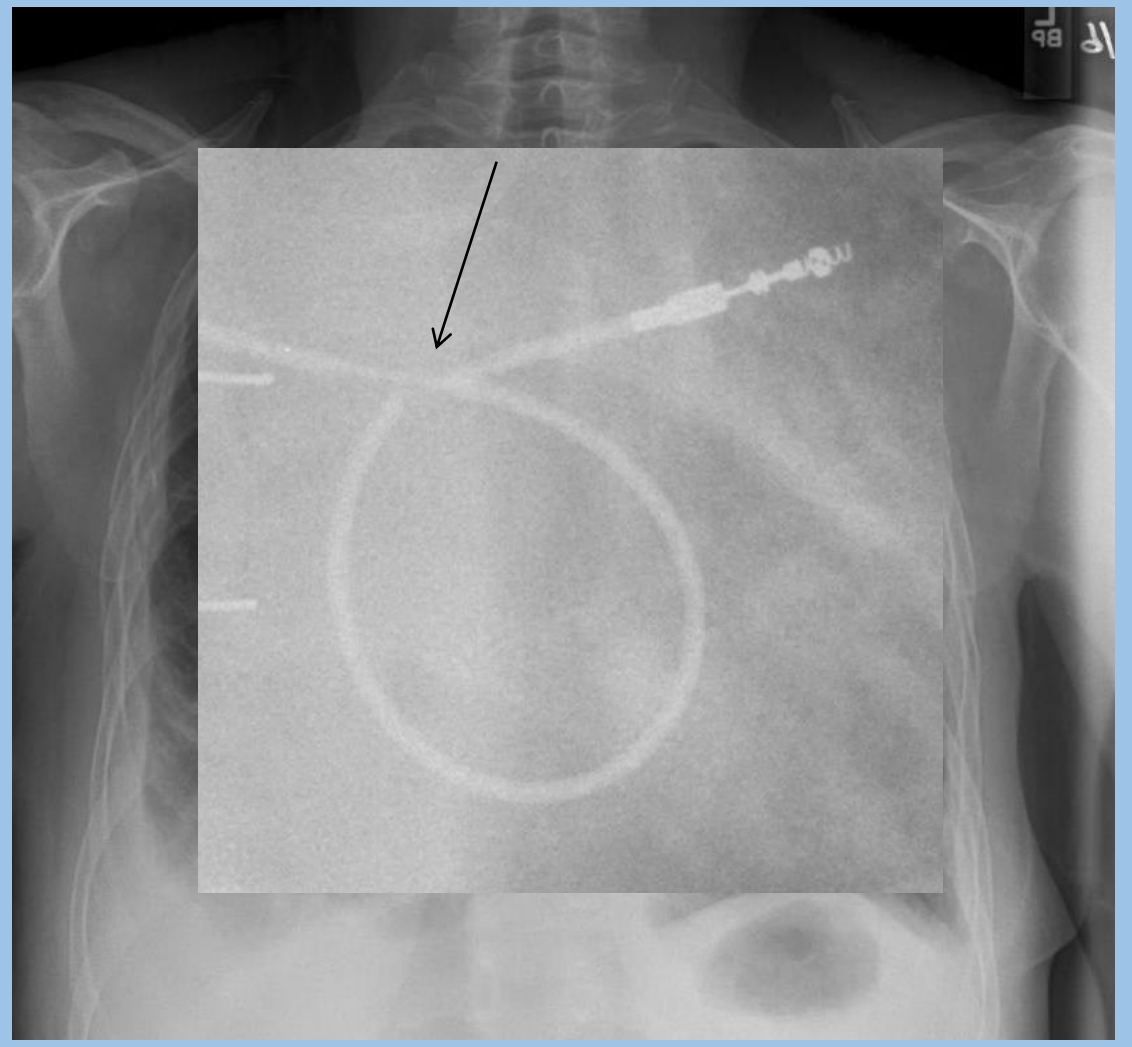
Cardiac Devices– Complications

- Complications
  - Pneumothorax
  - Vascular injury
  - Myocardial perforation (RV)
    - Pericardial effusion
    - Tamponade
  - Lead fracture
  - Lead twisting (Twiddler’s syndrome)



Cardiac Devices– Complications

- Complications
  - Pneumothorax
  - Vascular injury
  - Myocardial perforation (RV)
    - Pericardial effusion
    - Tamponade
  - Lead fracture
  - Lead twisting (Twiddler's syndrome)



Right ventricular lead fracture

Summary

- Endotracheal tubes

Normal Position	Common Positioning Errors	Important Complications
•At least 2 cm above carina •At or below medial ends of the clavicle •Varies ±2 cm with neck movement	•Too high •Mainstem bronchus intubation •Esophageal intubation	•Spontaneous extubation •Aspiration •Atelectasis •Pneumothorax •Gastric/esophageal injury or perforation

Summary

- Tracheostomy tubes

Normal Position	Common Positioning Errors	Important Complications
•Similar tip positioning as ETT •At least 2/3 of “smooth” portion in trachea	•Too high/incomplete insertion	•Tracheal injury •Pneumothorax •Hemorrhage

Summary

- Central venous catheters

Normal Position	Common Positioning Errors	Important Complications
•Tip terminating over cavo-atrial junction (inferior border of right bronchus)	•Ipsilateral IJ •Contralateral brachiocephalic •RA/RV *Beware of anatomic variants	•Pneumothorax •Vascular perforation

Summary

- PA catheters

Normal Position	Common Positioning Errors	Important Complications
•Tip position in proximal interlobar PA (roughly within mediastinal shadow) *Resting position depends on function	•Too distal positioning •Otherwise similar to that of CVCs	•PA infarction •PA rupture/dissection •Otherwise similar to that of CVCs

Summary

- Chest tubes

Normal Position	Common Positioning Errors	Important Complications
•Air removal – directed anterior and superior •Fluid removal – posterior and inferior •All side holes completely visualized with the pleural space	•Incomplete insertion •Tube kinking •Chest wall •Lung fissures	•Ineffective drainage •Pulmonary laceration/contusion •Pulmonary infarction •Subcutaneous emphysema •Reexpansion pulmonary edema

Summary

- Enteric tubes

Normal Position	Common Positioning Errors	Important Complications
•Roughly vertical/midline course down esophagus •Tip and all side holes distal to GE junction •Distal position depends on function	•Coiled tube •Proximal/”marginal” •Kinked tube •Pulmonary placement	•Aspiration •Pulmonary contusion/laceration •Pneumothorax •Esophageal/gastric perforation

References

- Amorosa, J. K., et al. (2013). "ACR appropriateness criteria routine chest radiographs in intensive care unit patients." J Am Coll Radiol 10(3): 170-174.
- Siela, D. (2008). "Chest radiograph evaluation and interpretation." AACN Adv Crit Care 19(4): 444-473; quiz 474-445.
- Godoy, M. C., et al. (2012). "Chest radiography in the ICU: Part 1, Evaluation of airway, enteric, and pleural tubes." AJR Am J Roentgenol 198(3): 563-571.
- Godoy, M. C., et al. (2012). "Chest radiography in the ICU: Part 2, Evaluation of cardiovascular lines and other devices." AJR Am J Roentgenol 198(3): 572-581.
- Costelloe, C. M., et al. (2012). "Radiography of pacemakers and implantable cardioverter defibrillators." AJR Am J Roentgenol 199(6): 1252-1258.
- Khan, A. N., et al. (2009). "Reading chest radiographs in the critically ill (Part I): Normal chest radiographic appearance, instrumentation and complications from instrumentation." Ann Thorac Med 4(2): 75-87.
- Jain, S. N. (2011). "A pictorial essay: Radiology of lines and tubes in the intensive care unit." Indian J Radiol Imaging 21(3): 182-190.
- Schaefer-Prokop, Cornelia. *Critical Care Radiology*. Stuttgart: Thieme, 2011.