急重症與心血管影像判讀

高醫大胸腔內科 內科加護病房

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講義原著：許超群醫師

授課大綱

- 各種導管的位置及併發症 (catheters, tubes, lines)
- 氣壓傷害 (barotrauma)
- 肺水腫 (cardiogenic pulmonary edema *vs* ARDS)
- 水分之評估 (fluid status evaluation)
- 肺塌陷 (lung atelectasis)
- 肺栓塞 (pulmonary embolism)

ICU CXR之特性

- Portable
- Supine
- AP view
- Poor inspiration (Hypoinflation), effects of MV (Hyperinfation)
- Catheters, tubes, lines…

Supine vs Upright

- 不易看出air-fluid level
- Pleural effusion及pneumothorax 之表現不同，較不易評估
- 上肺野之血管徑在躺著時會變粗 (cephalization)

Hypo- or Hyper- inflation

- 重症病患或使用呼吸器病患無法配合吸飽氣照，將使肺浸潤看起來更加惡化
- 使用呼吸器之病患若有過度充氣 (hyperinflation or air-trapping)，將使肺浸潤看起來呈假像的改善

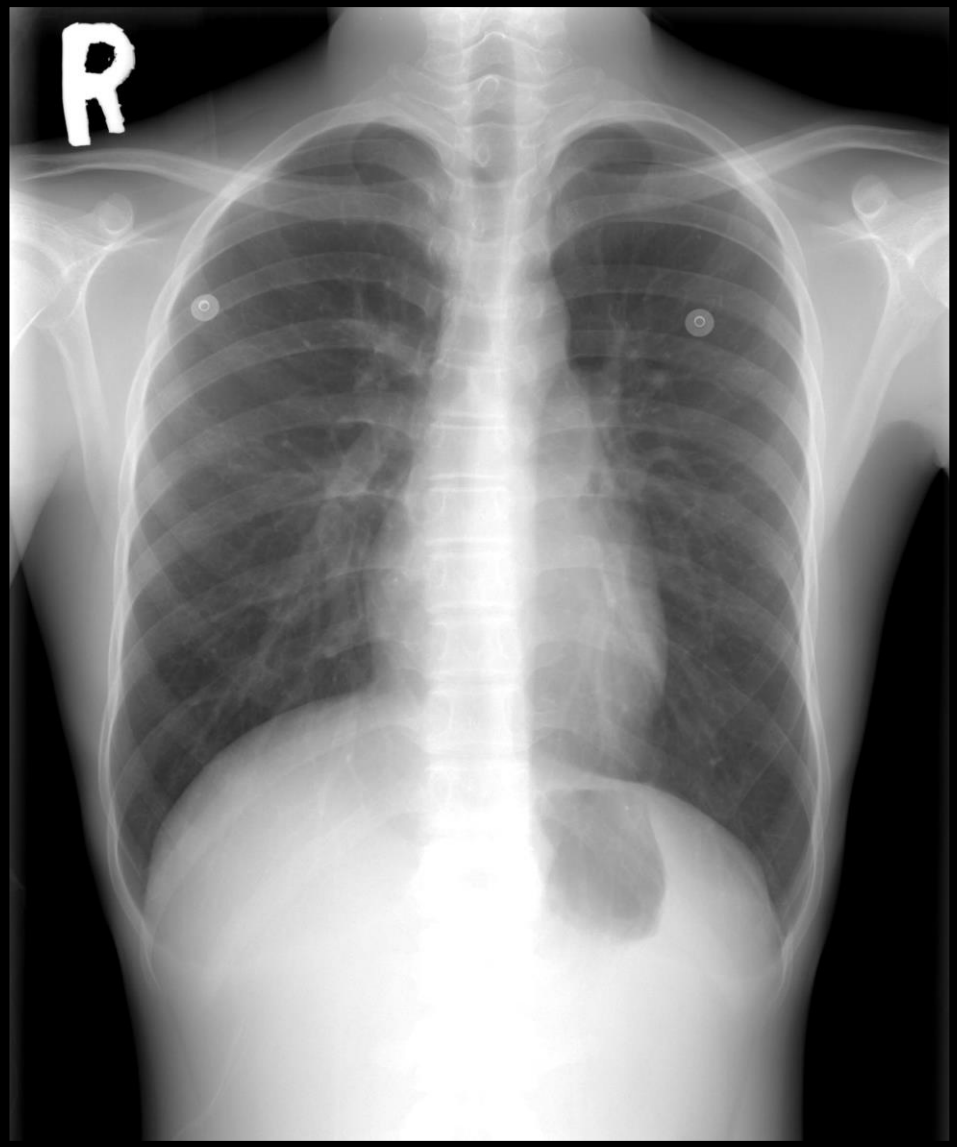
Catheters, Tubes, Lines

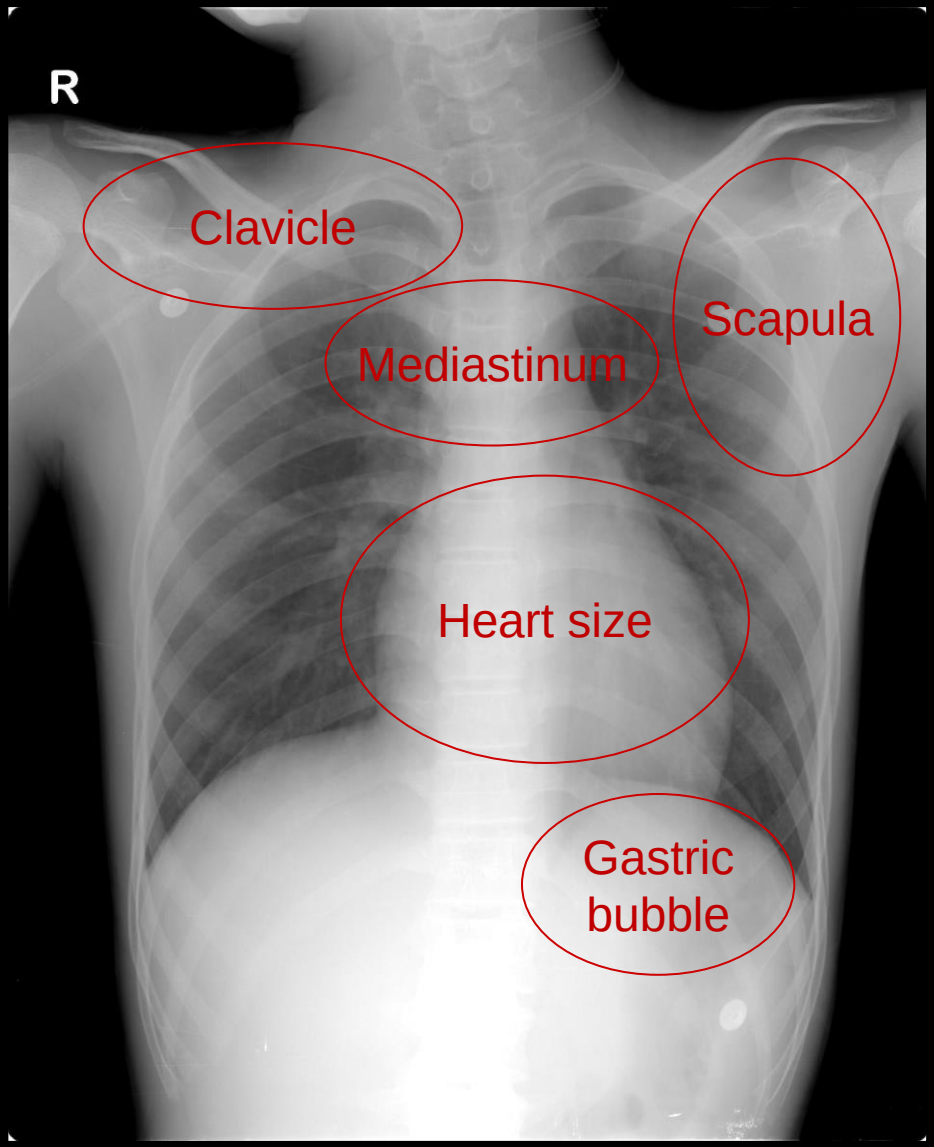
- 重症病患身上常置入多種導管，須小心評估其位置是否正確，有無發生併發症。

- Nasogastric tube
- Endotracheal tube
- Tracheostomy tube
- Central venous catheter
- Esophageal temperature probe
- Hemo-cath
- Pulmonary artery catheter
- Chest tube
- Pigtail drain tube
- Pacemaker
- IABP
- ECMO

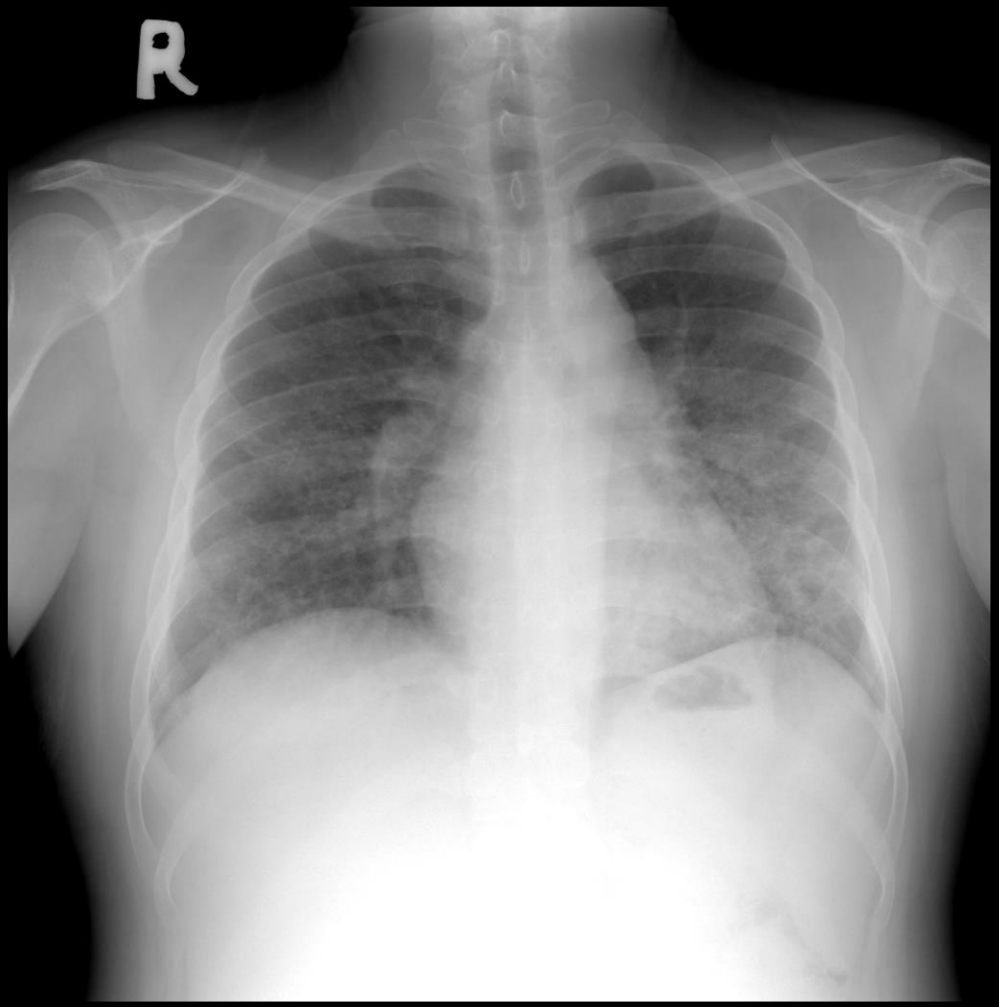
upright

Supine

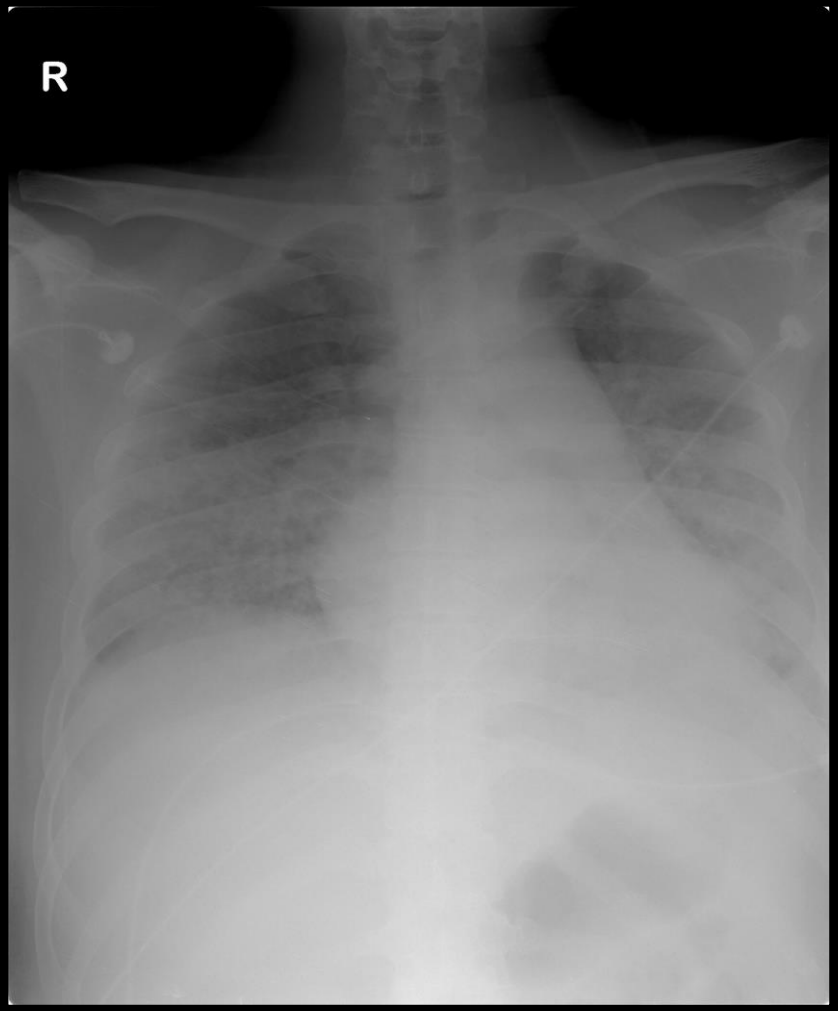




upright



Supine



加護病房病患為何要照CXR

- 確定各種導管的位置及可能發生的併發症
- 追蹤原本的心肺疾病
- 監測使用呼吸器患者肺部的變化及氣壓傷害
- 評估心臟血行動力學的變化(水分的評估)
- 診斷出臨床未預期的新病變

加護病房病患何時需照CXR

- 住進加護病房時
- 臨床狀況改變時
- 侵襲性處置後（即使導管置放失敗）
- 適時追蹤病情之變化
- **每天例行性照胸部X光**
  - Acute cardiopulmonary disease
  - Invasive mechanical ventilation
  - Arterial catheter (PAC, IABP…)

Catheters & Tubes & Lines

Endotracheal Tube

- The position of the tip of the endotracheal tube can vary with neck position (see next page)
  - *Neck extension causes a 2-cm ascent of the tip*
  - *Neck flexion causes a 2-cm descent of the tip*
- When head and neck are in the neutral position, the tip of the ET tube should rest at about 5 cm above the carina and at least 3 cm distal to the vocal cords (American College of Radiology)
- The carina is located on radiographs at the 4th rib or the T4-T5 interspace.

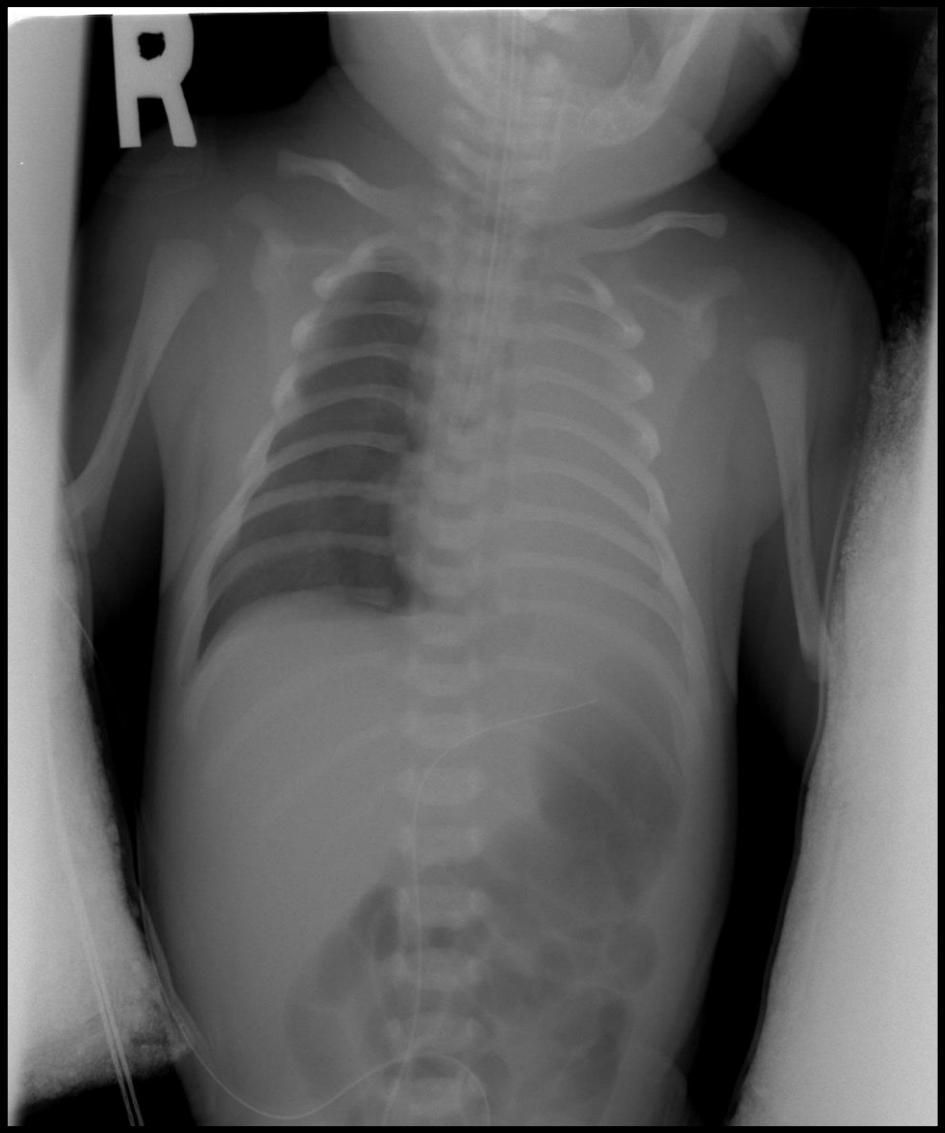
Endotracheal Tube

- **Using the MANDIBLE as a guide**
  - Neck extension (inf. border of mandible above C4)
    - Tip of tube: 7± 2 cm from carina
  - Neutral (inferior border of mandible at C5-6)
    - Tip: 5± 2 cm
  - Neck flexion (inf. border of mandible below T1)
    - Tip: 3 ± 2cm
- **Width:** 1/2 - 2/3 of trachea
- **Cuff:**
  - Inflate to occlude the trachea but do not exceed the diameter of trachea. Balloon of 1.5X the diameter of trachea will cause tracheal injury.

Endotracheal Tube

- **Complications:**
  - **One lung intubation** (usually right main)
    - Hyperinflation of right lung
      → emphysema, pneumothorax
    - Atelectasis of left lung
  - **Esophageal intubation**
    - E-T tube not in the trachea
    - Gastric distention
  - **Tracheal rupture** (usually within 7 cm of the carina)
    - Pneumomediastinum, pneumonthorax, subcutaneous emphysema..
  - **Aspiration (pneumonitis)/ Infection (pneumonia)**

One lung intubation



Malposition of the ET tube

Cuff over-inflation

Esophageal intubation

Tracheostomy Tube

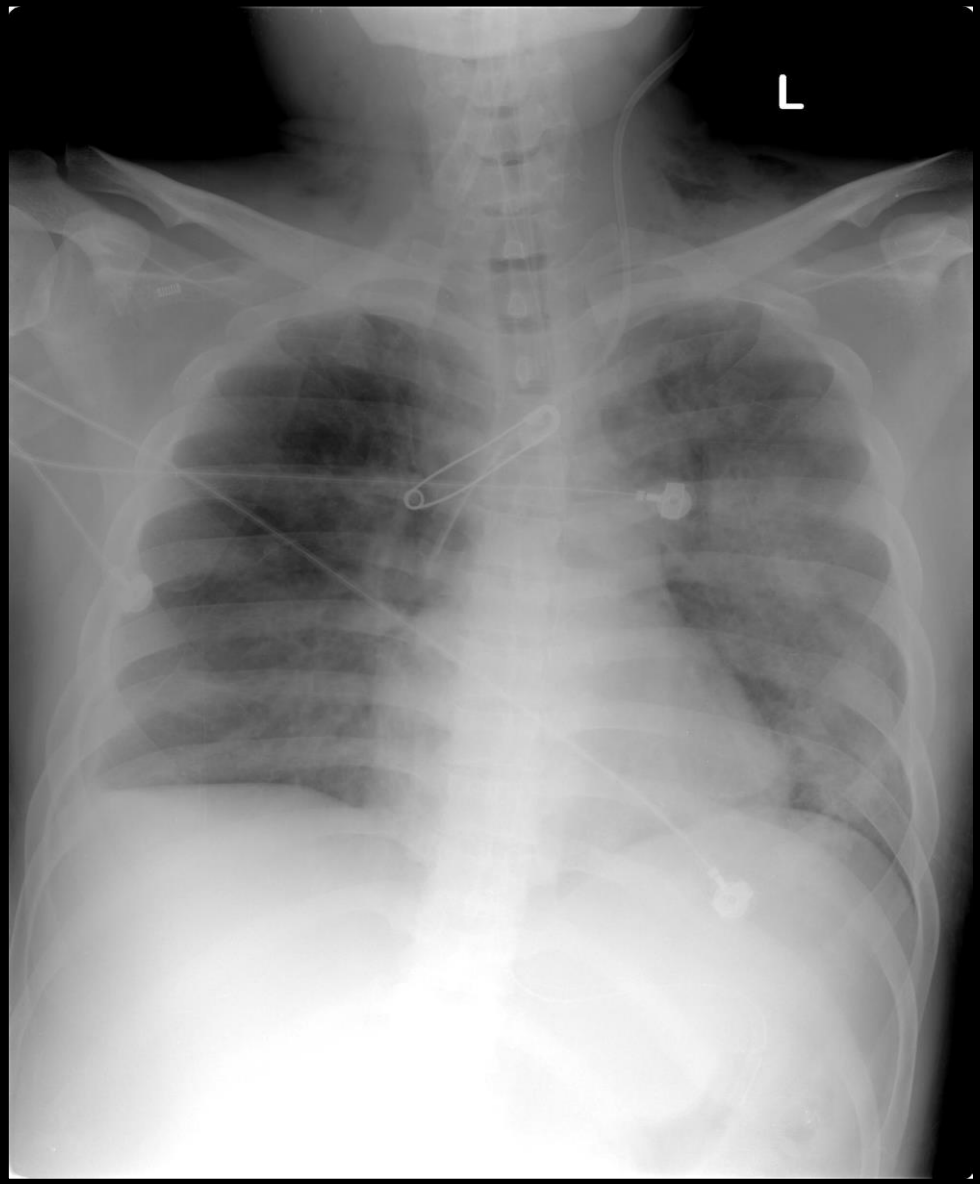
- Tip: 1/2 – 2/3 between stoma & carina
- Inner diameter: 2/3 of tracheal lumen
- Long axis: parallel to tracheal wall
- Distal end: Do not abut tracheal wall

Percutaneous Dilational Tracheostomy

- **Complications:**
  - Malposition of tracheostomy tube (false lumen)
  - Tracheal rupture -> pneumomediastinum
  - Subcutaneous emphysema, pneumothorax

  - Bleeding
  - Over-inflation of cuff
  - Infection (pneumonia)

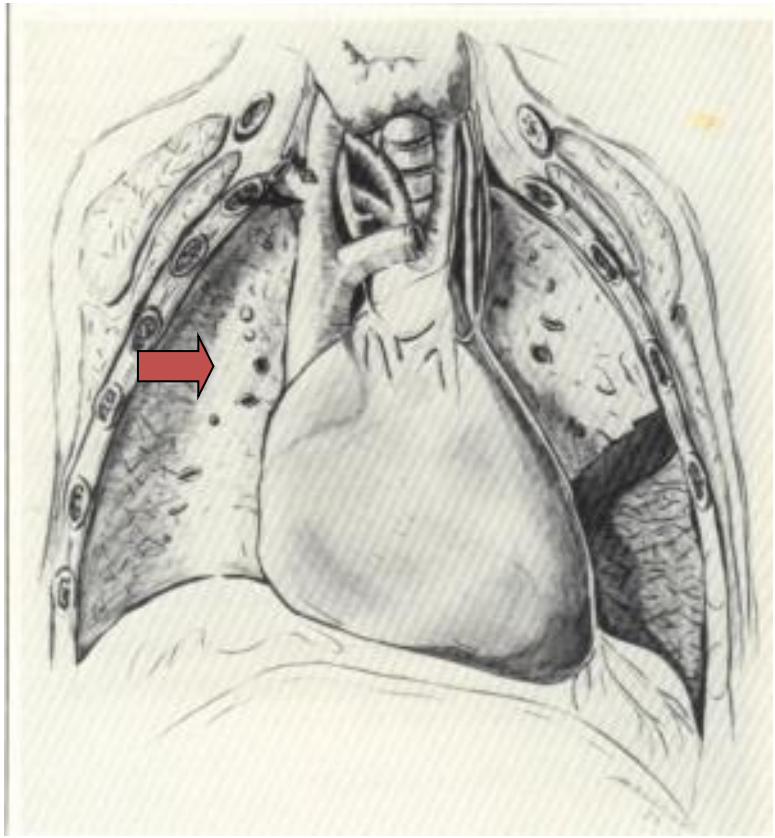
Before Tracheostomy

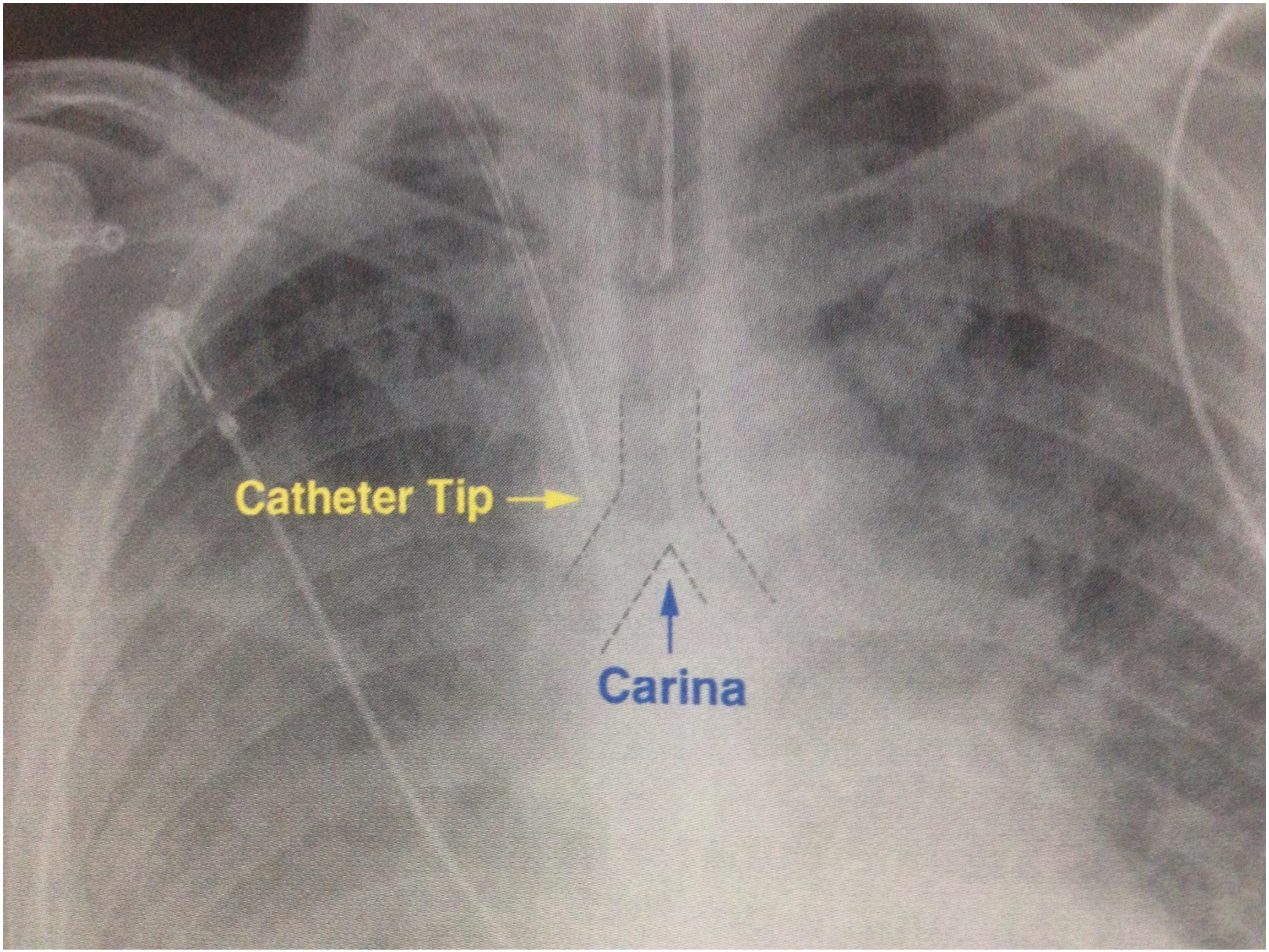


After Tracheostomy

Central Venous Catheter

- In SVC
- Tip:
  - below right brachiocephalic v. (anterior first rib) and slightly above the right atrium
  - at the level of or slightly above the azygos vein
- As many as 30% of CVP catheters are initially placed incorrectly.



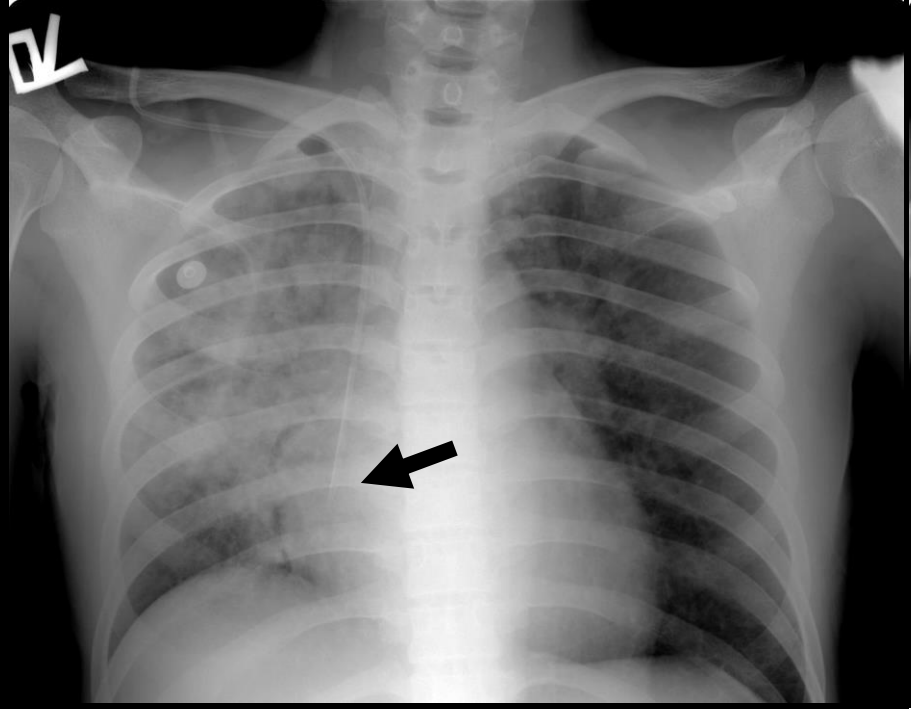

Catheter Tip
Carina

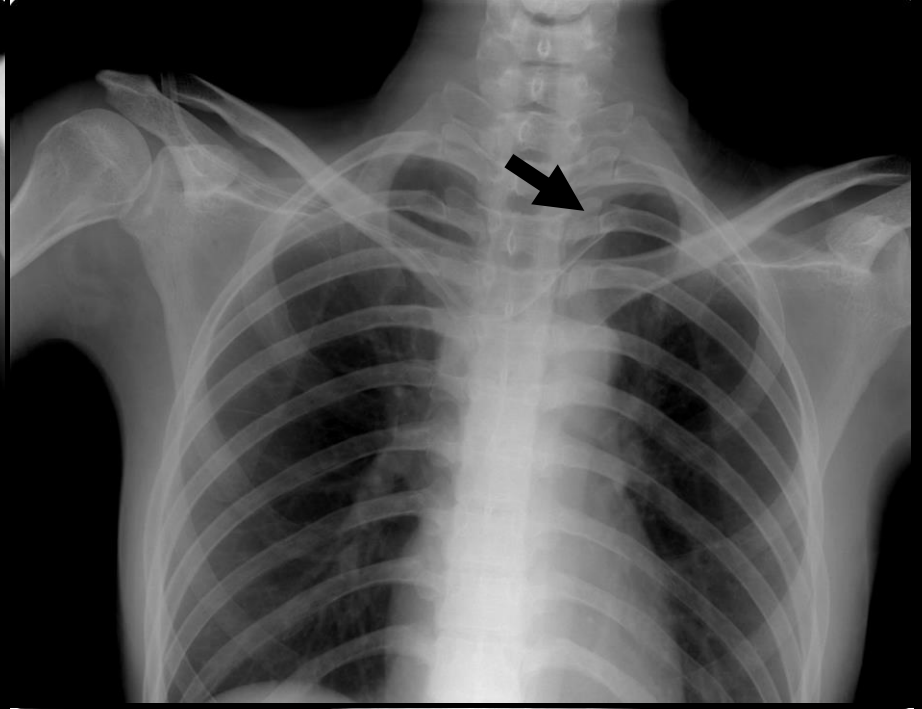
Central Venous Catheter

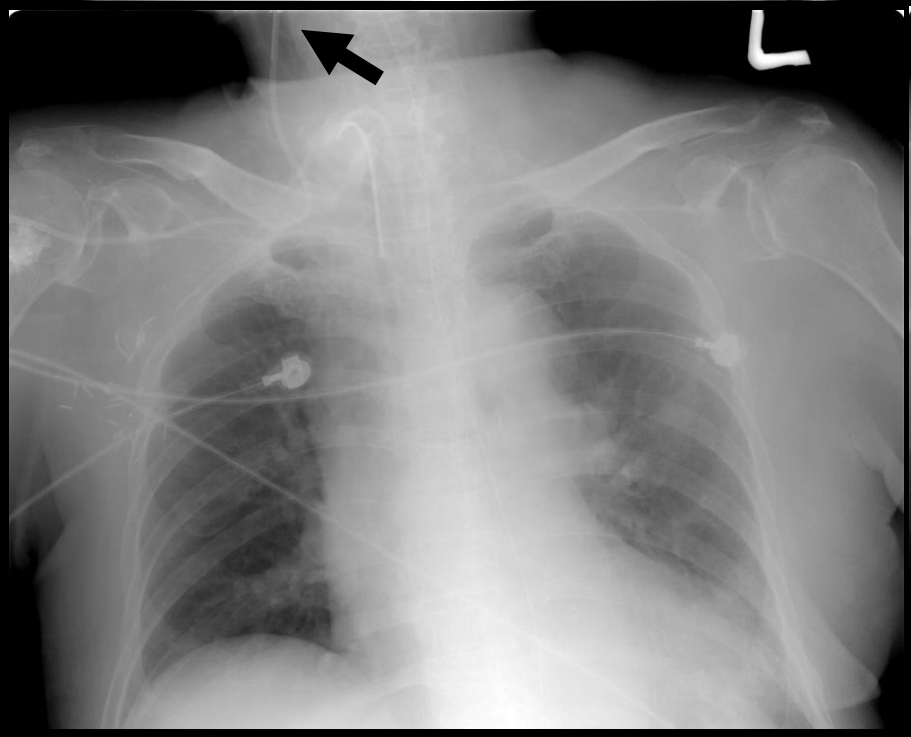
- **Complications:**
  - **Malposition: up to 40%**
    - In pleural space or In mediastinum
      - Vessel perforation
      - Pleural effusion or widening of mediastinum
    - In other veins
    - Too distal (inadequately advanced) [放太淺]
      - The proximal port will not beyond venous valves
    - Tip beyond azygos vein [放太深]
      - SVC become intrapericardial, vessel rupture will result in pericardial effusion or even temponade

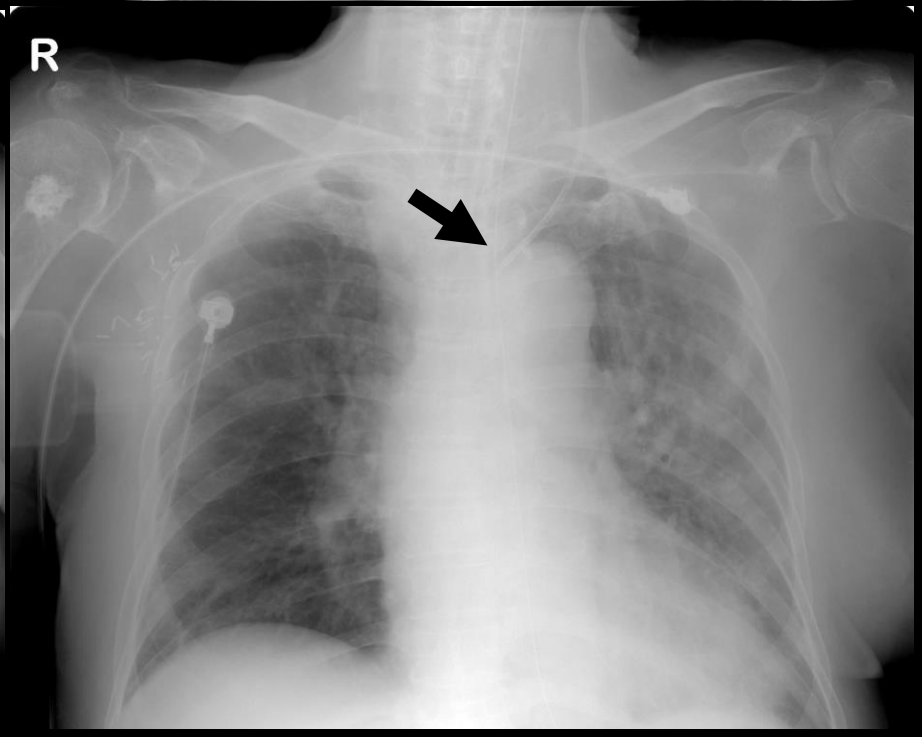
Central Venous Catheter

- **Complications:**
  - **Malposition (Cont.):**
    - In RA
      - Arrhythmia, cardiac perforation
    - Catheter tip directed against the wall of SVC
      - Easy vessel perforation
  - **Pneumothorax:** up to 5%
    - Obtain a portable CXR even after a failed attempt to place a central line





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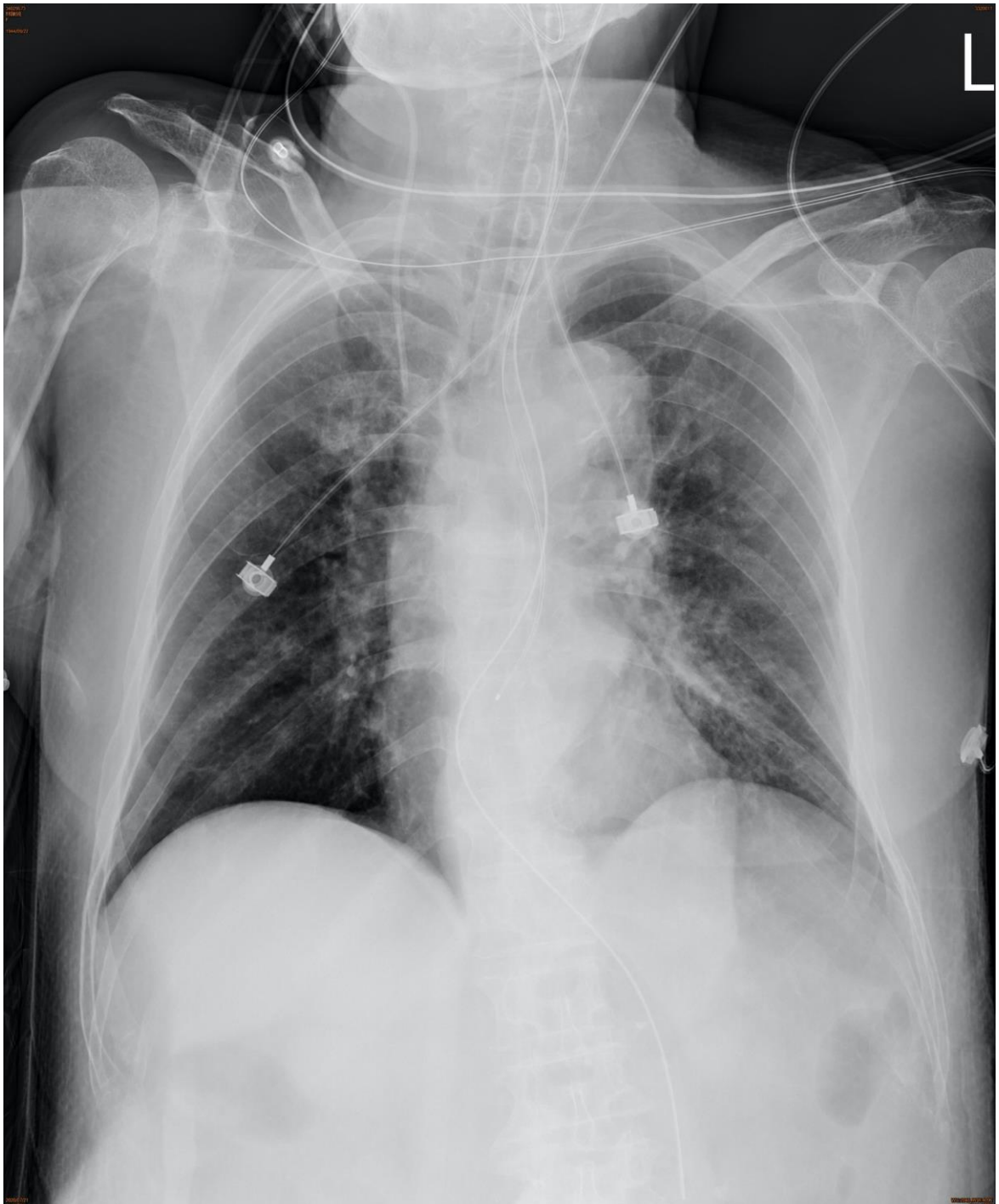
CVC in aorta, pneumothorax

Esophageal temperature probe

- Place in the lower third of the esophagus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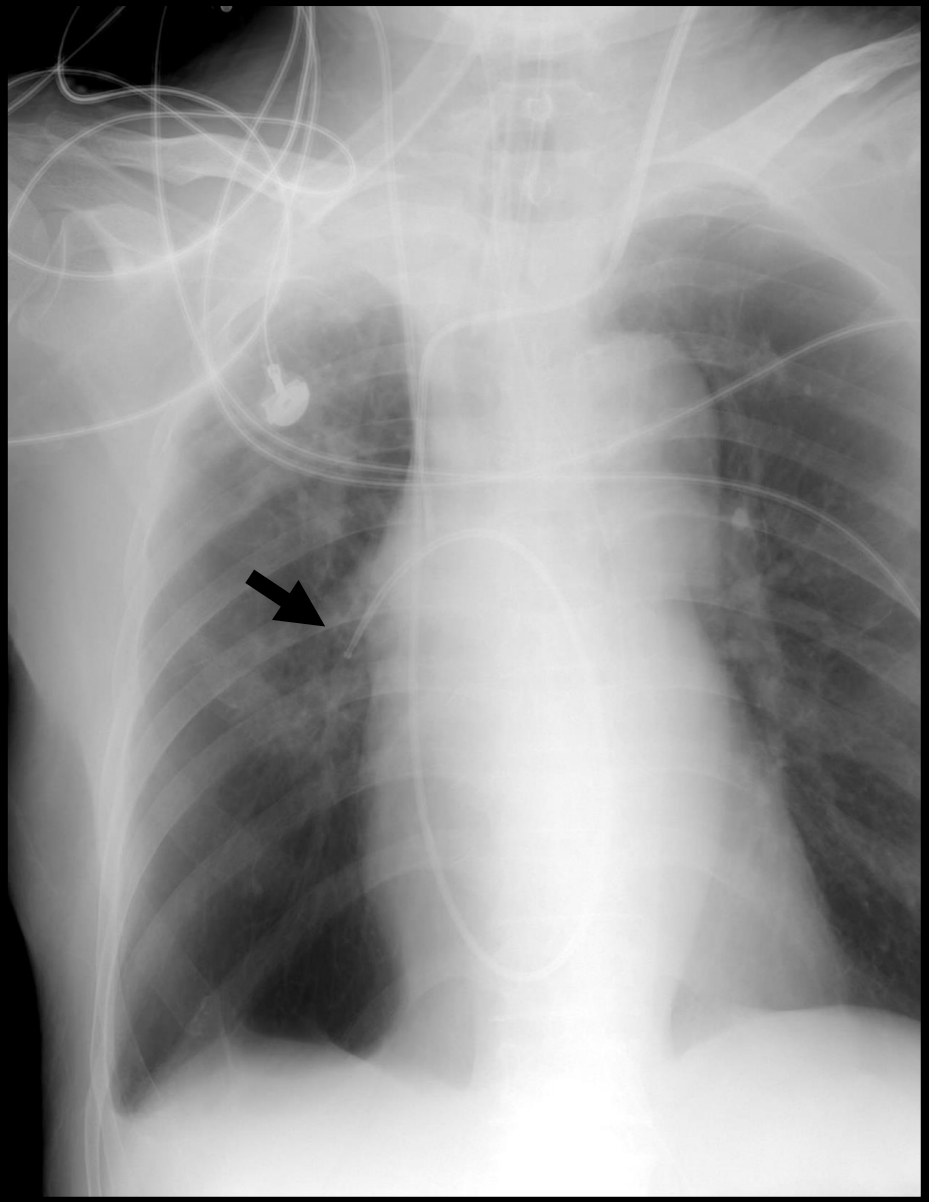
Pulmonary Artery Catheter

- Swan-Ganz Catheter
- Tip: in RPA or LPA
  - The tip should never be lodged beyond a major pulmonary artery (RPA, LPA or proximal interlobar artery)
  - Within 2 cm from hilum

Pulmonary Artery Catheter

- **Complications:**
  - **Malposition: 24%**
    - *Even initial position is correct, distal migration may occur. Daily CXR is recommended*
  - **Pulmonary infarction**
  - **Pulmonary artery rupture**
    - Pulmonary hemorrhage
  - **PA pseudoaneurysm**
    - May present as a new solitary pulmonary nodule months after discharge from ICU

PA catheter in right PA



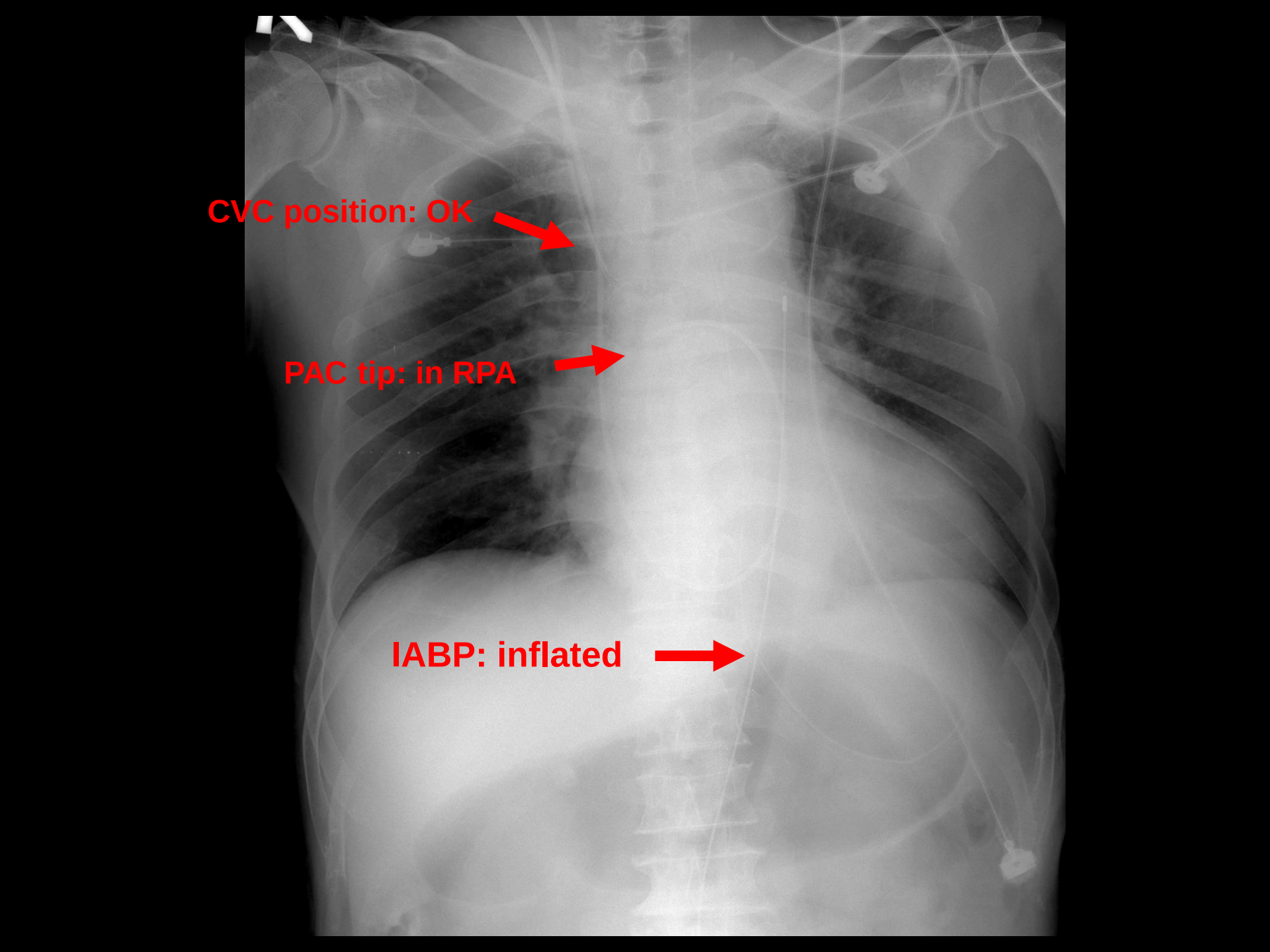
PA catheter in left PA

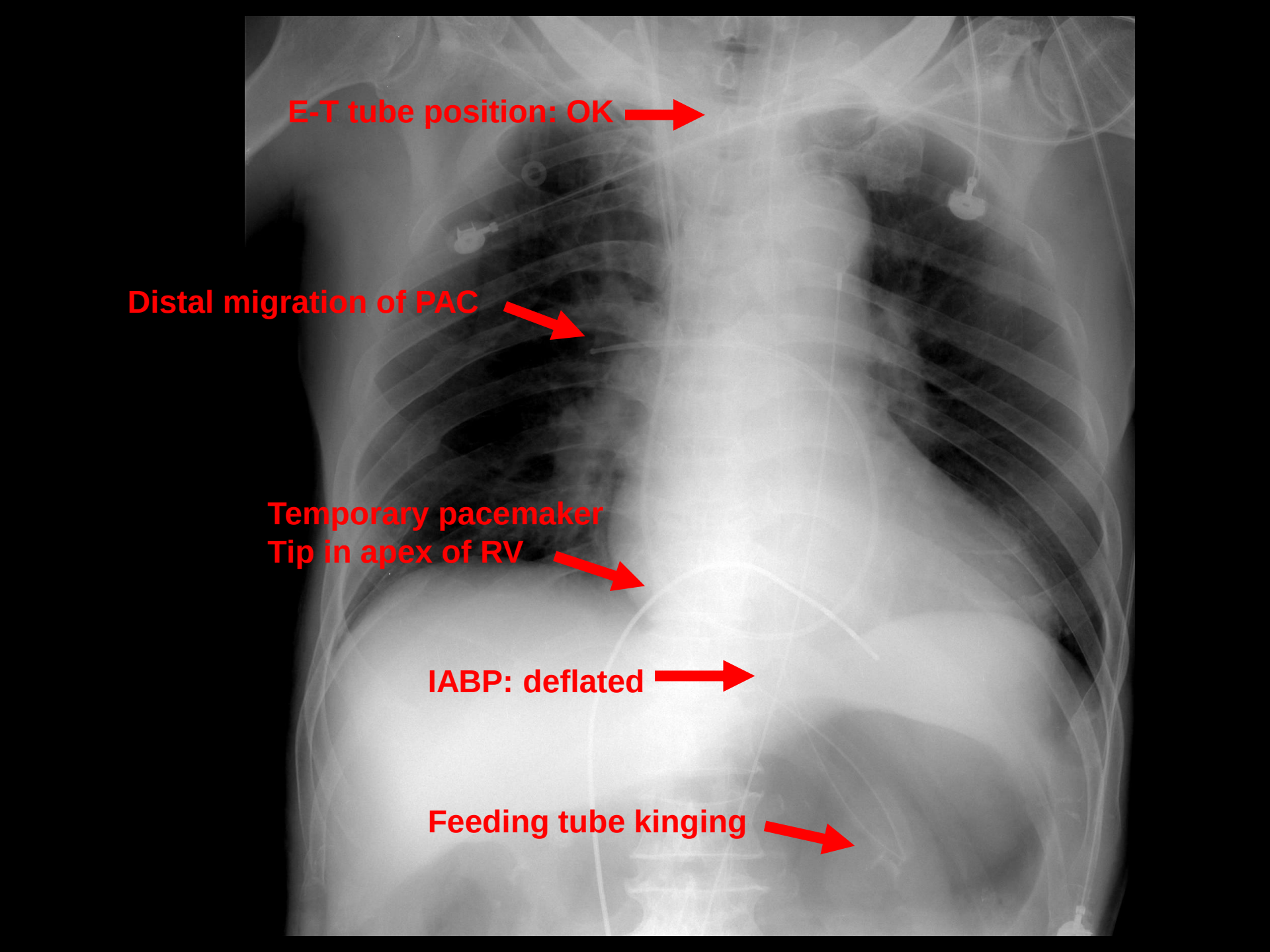
IABP (intra-aortic balloon pump)

- Inflate in diastole; deflate in systole
- The balloon is in thoracic aorta
- Tip is ideally located in the descending aorta, 2 cm distal to the origin of left subclavian a. (just caudal to the aortic arch)

IABP (intra-aortic balloon pump)

- **Complications:** 8-36%
  - **Proximal migration of tip:**
    - Cerebral, vertebral, subclavian a. obstruction
  - **Distal migration of tip:**
    - Mesenteric and renal a. obstruction
  - **Other complications:**
    - Aortic dissection
    - Balloon rupture with gas embolization


CVC position: OK
PAC tip: in RPA
IABP: inflated


E-T tube position: OK
Distal migration of PAC
Temporary pacemaker
Tip in apex of RV
IABP: deflated
Feeding tube kinging

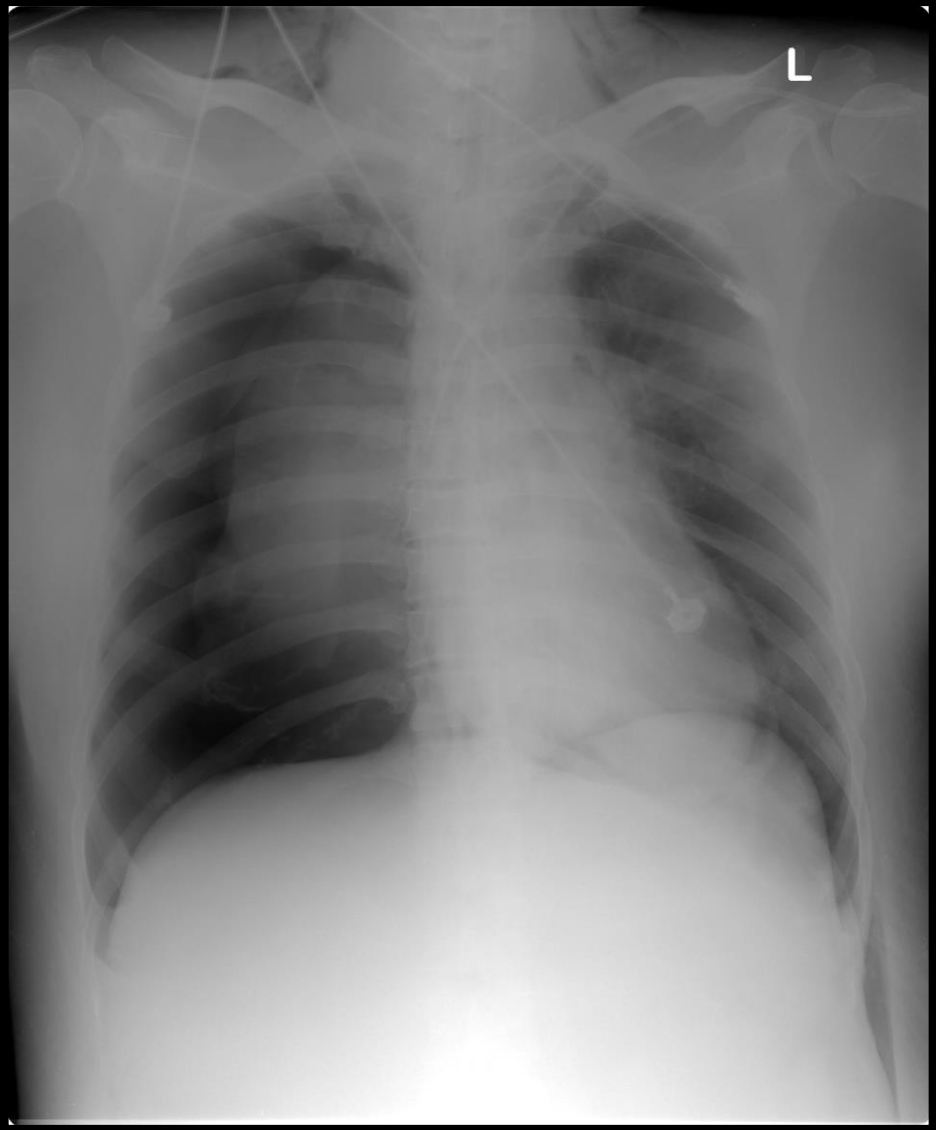
Chest Tube

- To drain air (pneumothorax) or fluid (pleural effusion or empyema). Air will be collected anteriomedially, fluid will be collected posteriorly
- Insertion site: the 4th intercostal space (about the level of nipple) at ant- or mid- axillary line
- The tip should ideally be aimed **apically**, except for drainage of loculated pleural fluid.
- The side holes should be always positioned medial to the inner margin of ribs
-

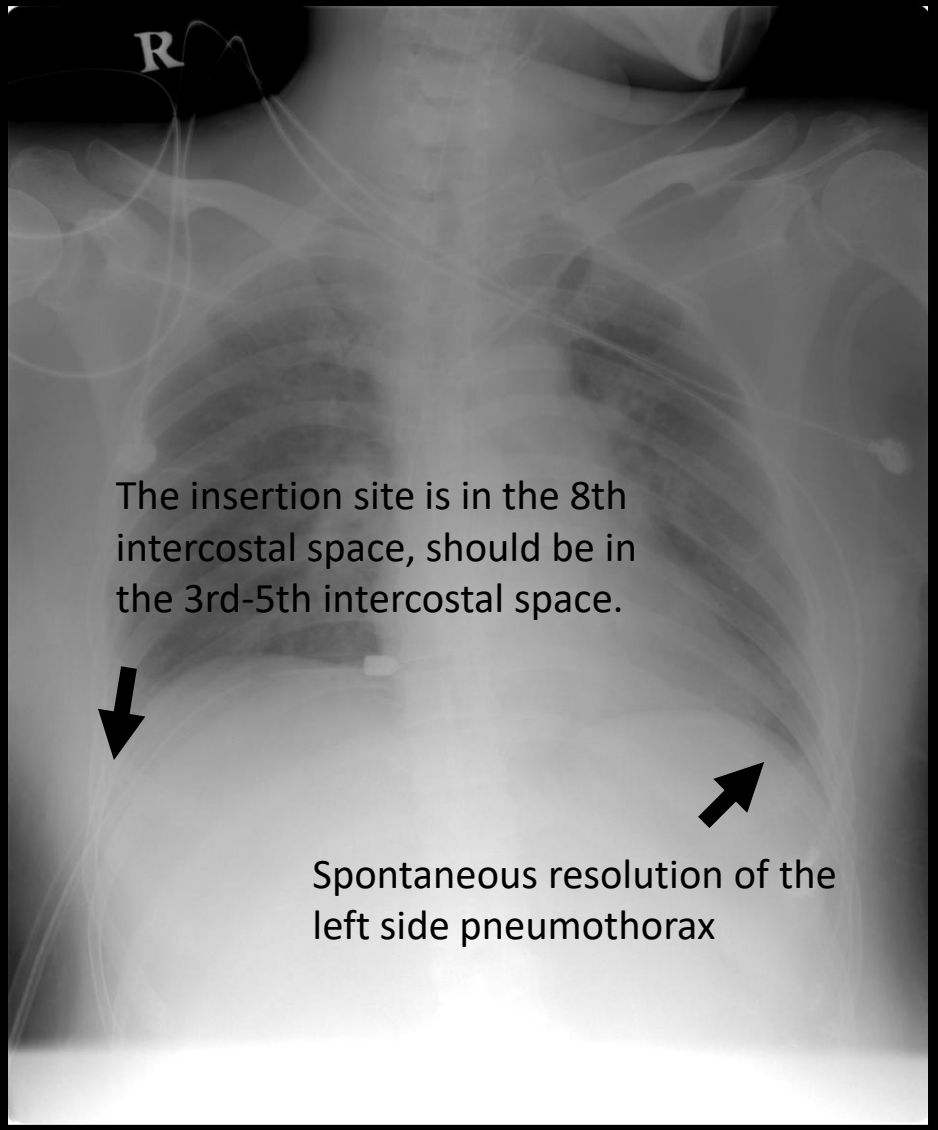
Chest Tube

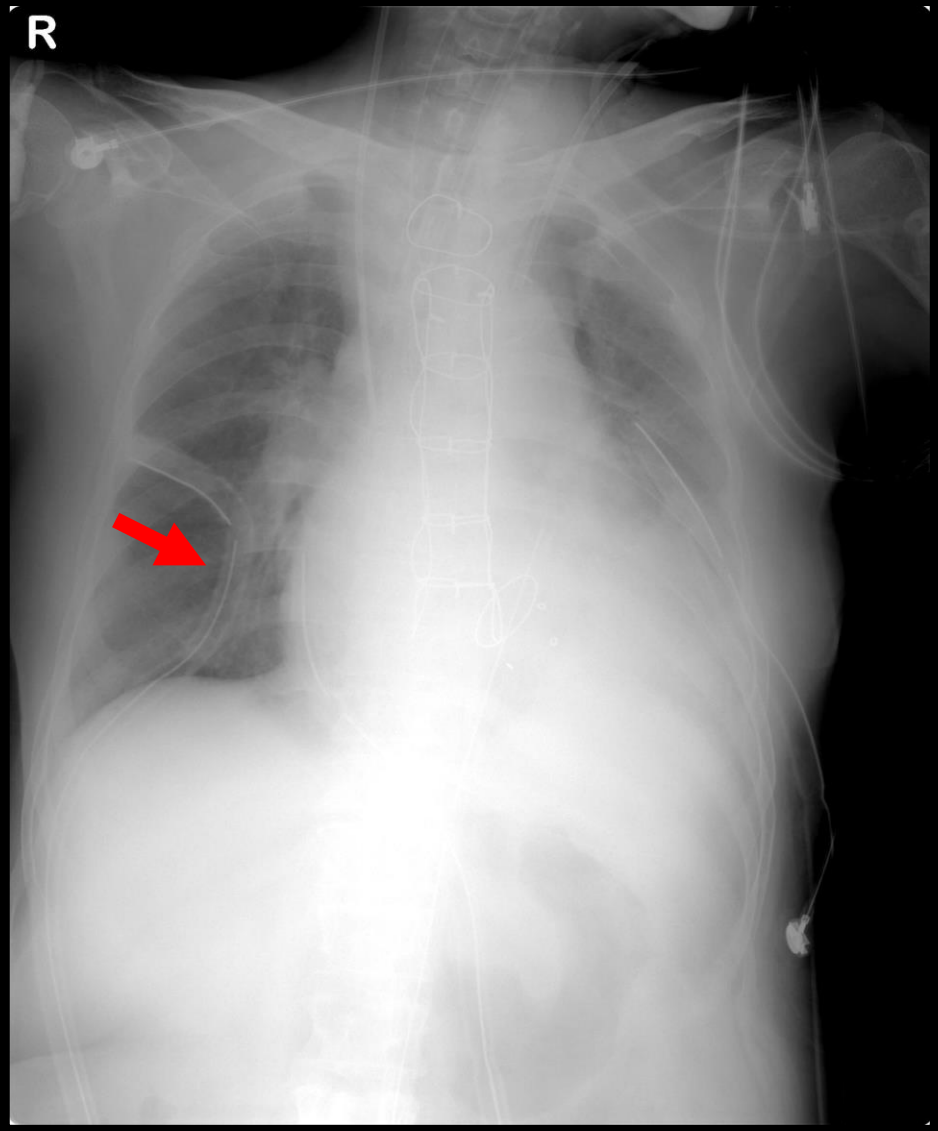
- **Complications:**
  - Lung, mediastinum penetration
  - Liver, spleen, and diaphragm trauma
  - Chest tube In the fissure
  - Chest tube in the subcutaneous tissue
  - Side hole in the subcutaneous tissue
  - Subcutaneous emphysema
  - Hemorrhage

Pneumothorax



After chest tube placement

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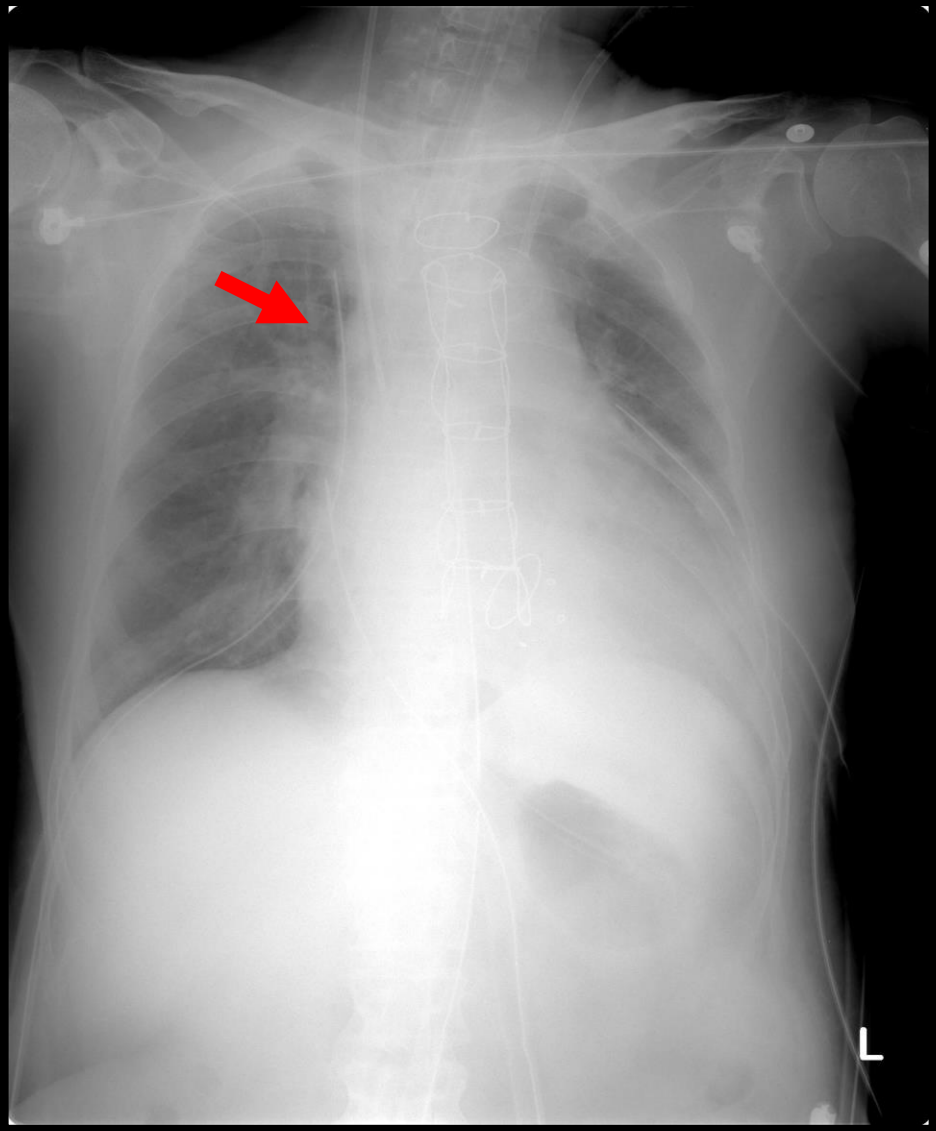
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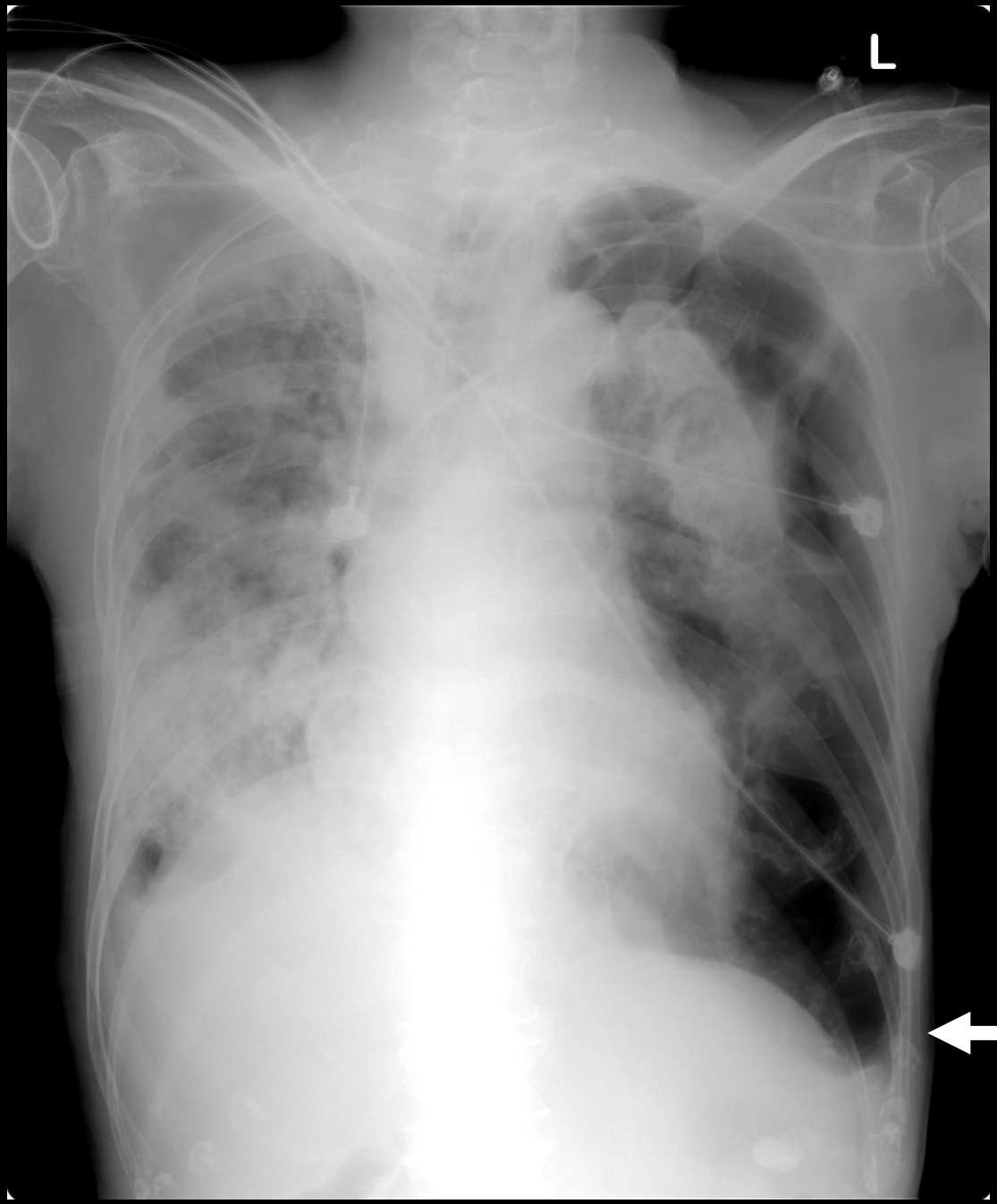
Barotrauma

Barotrauma

- Ventilator associated lung injury:
  - (Oxygen toxicity)
  - Volumetrauma
  - Atelectrauma
  - Biotrauma
  - Barotrauma: Presence of extra-alveolar air

Barotrauma

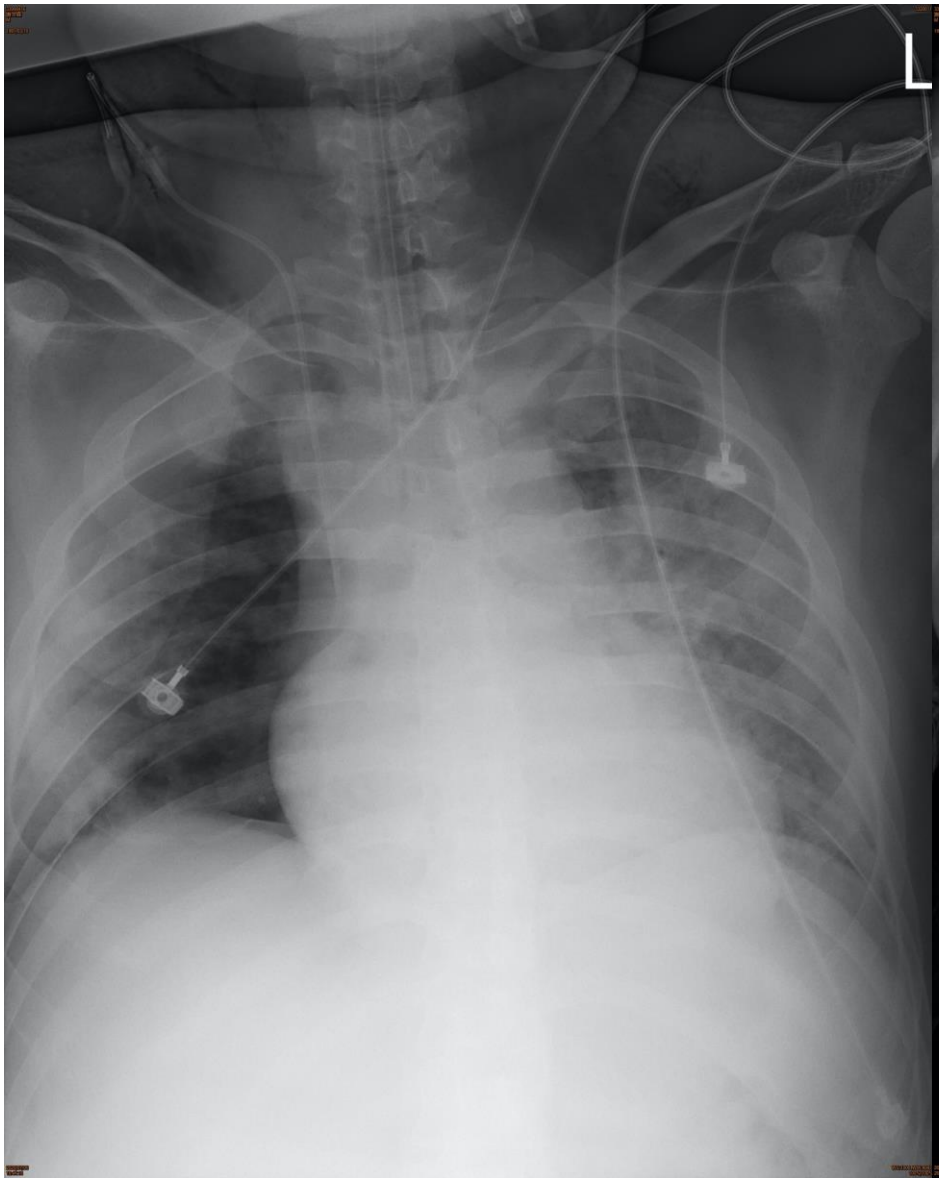
- High airway pressures can cause gross injury manifest as air leaks
  - Air get access into the interstitial tissues → track along the bronchovascular sheath → into mediastinum
- **Manifestations: (extra-alveolar air)**
  - *Pulmonary interstitial emphysema*
  - *Pneumomediastinum*
  - *Subcutaneous emphysema*
  - *Pneumothorax*
  - *Pneumopericardium,*
  - *Pneumoretroperitoneum,*
  - *Systemic embolism*



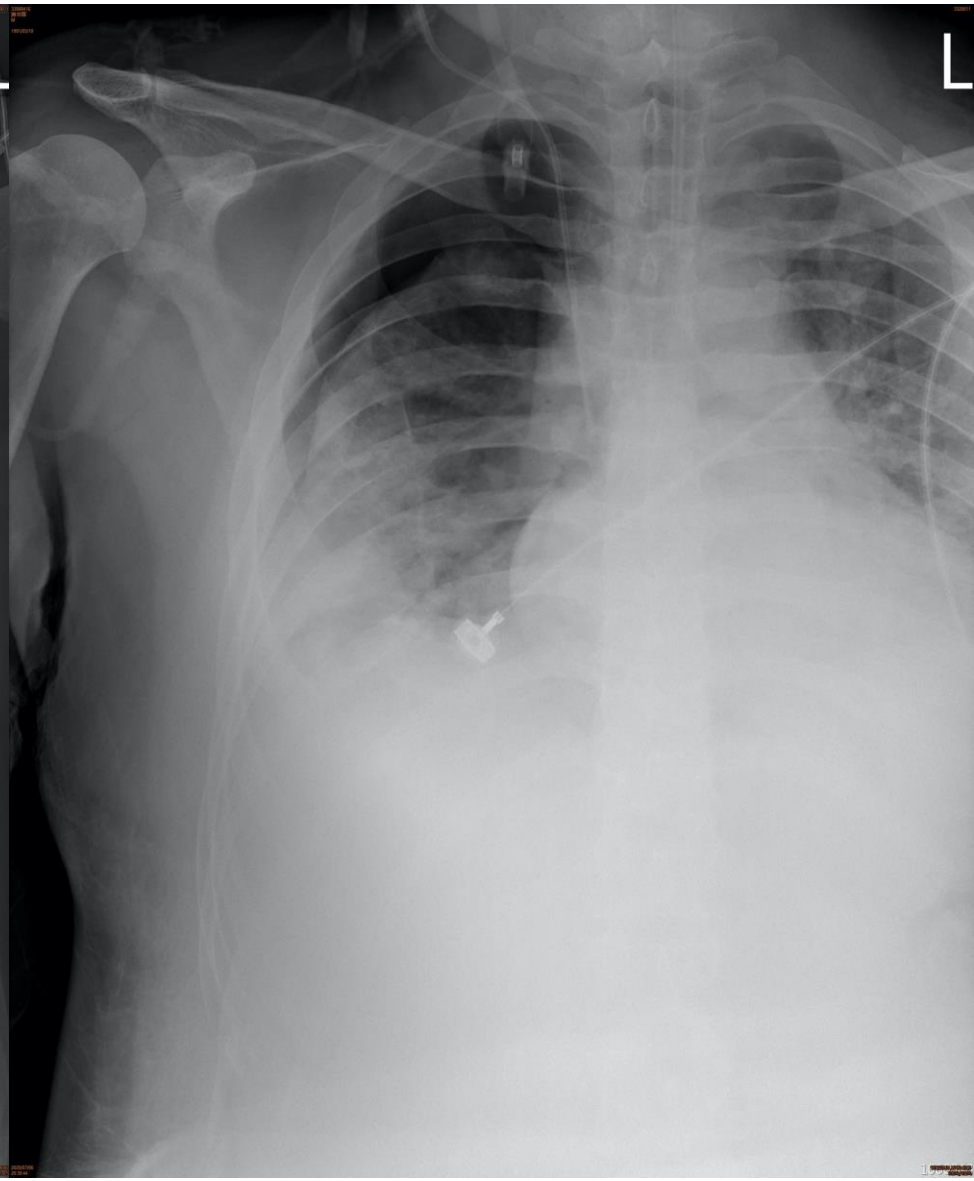
Pneumothorax

Deep sulcus sign

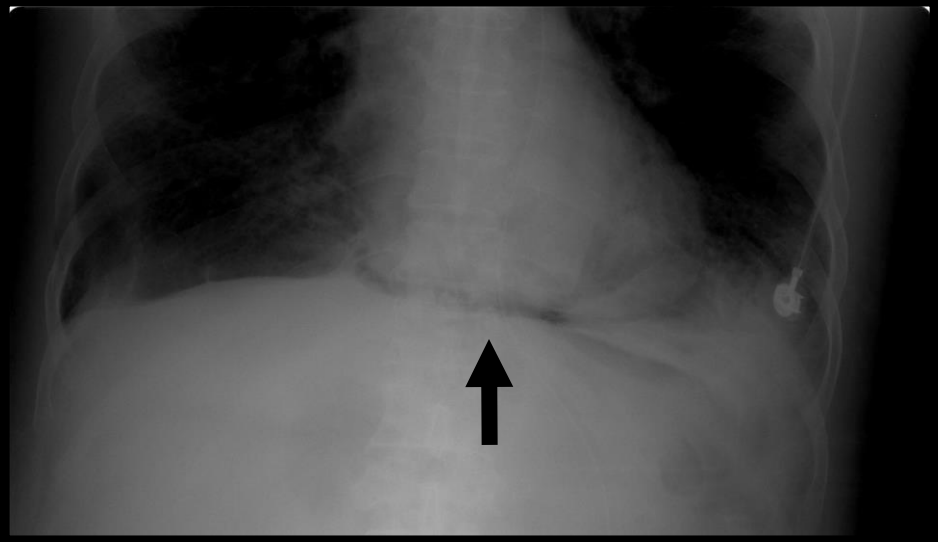
Supine



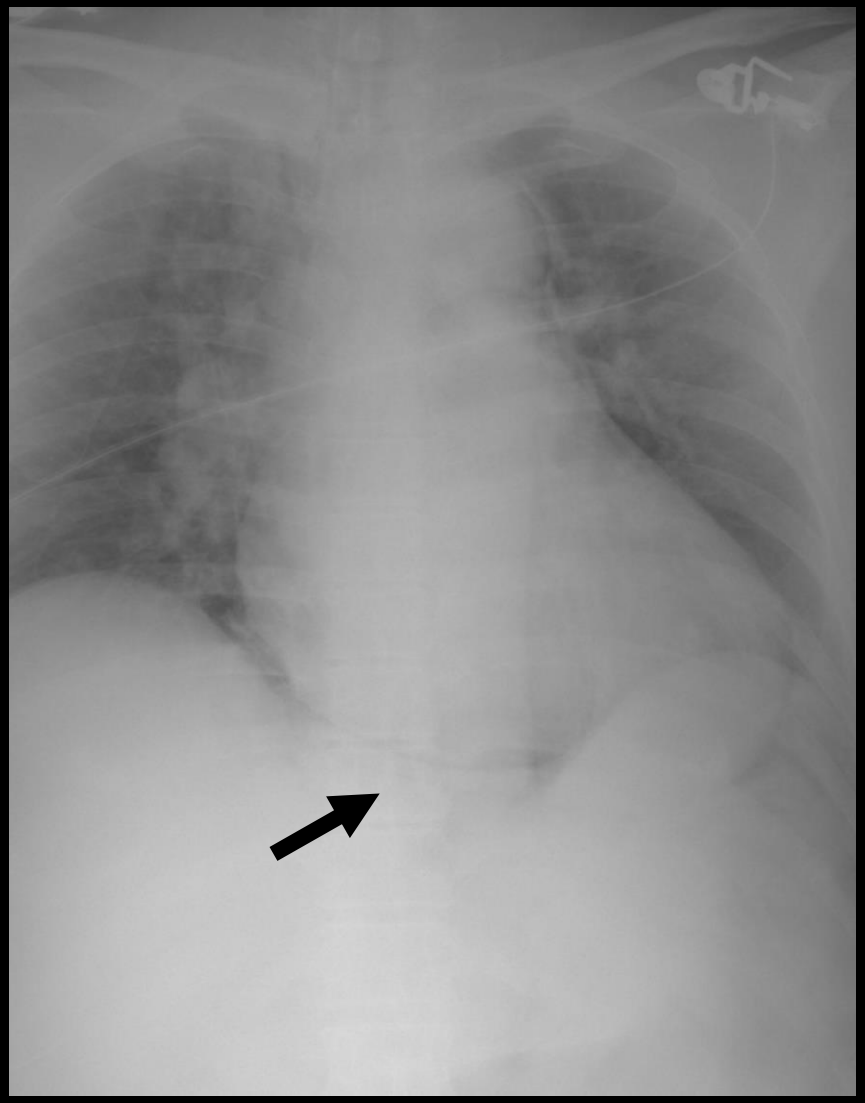
Sit



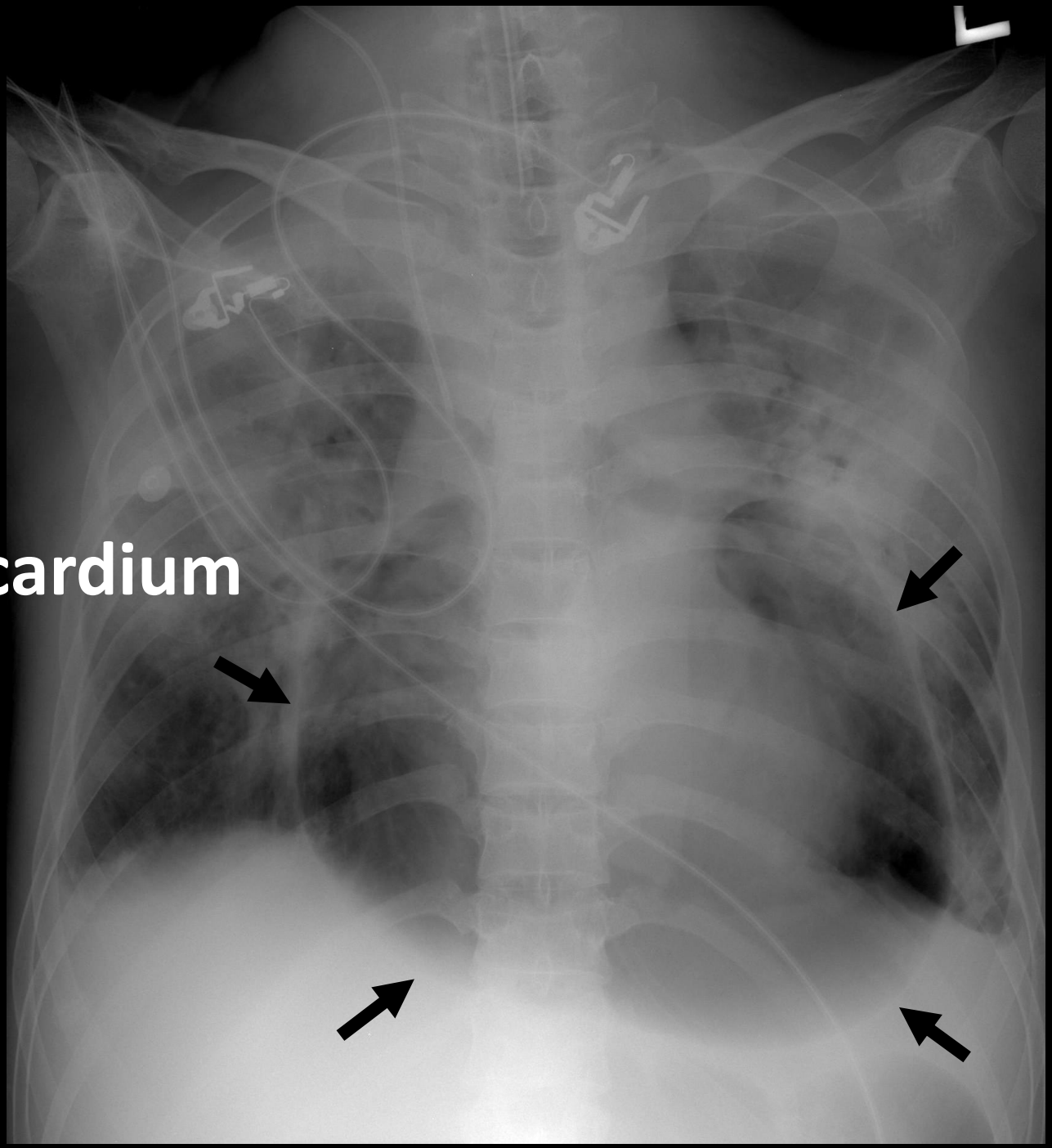
Pneumomediastinum



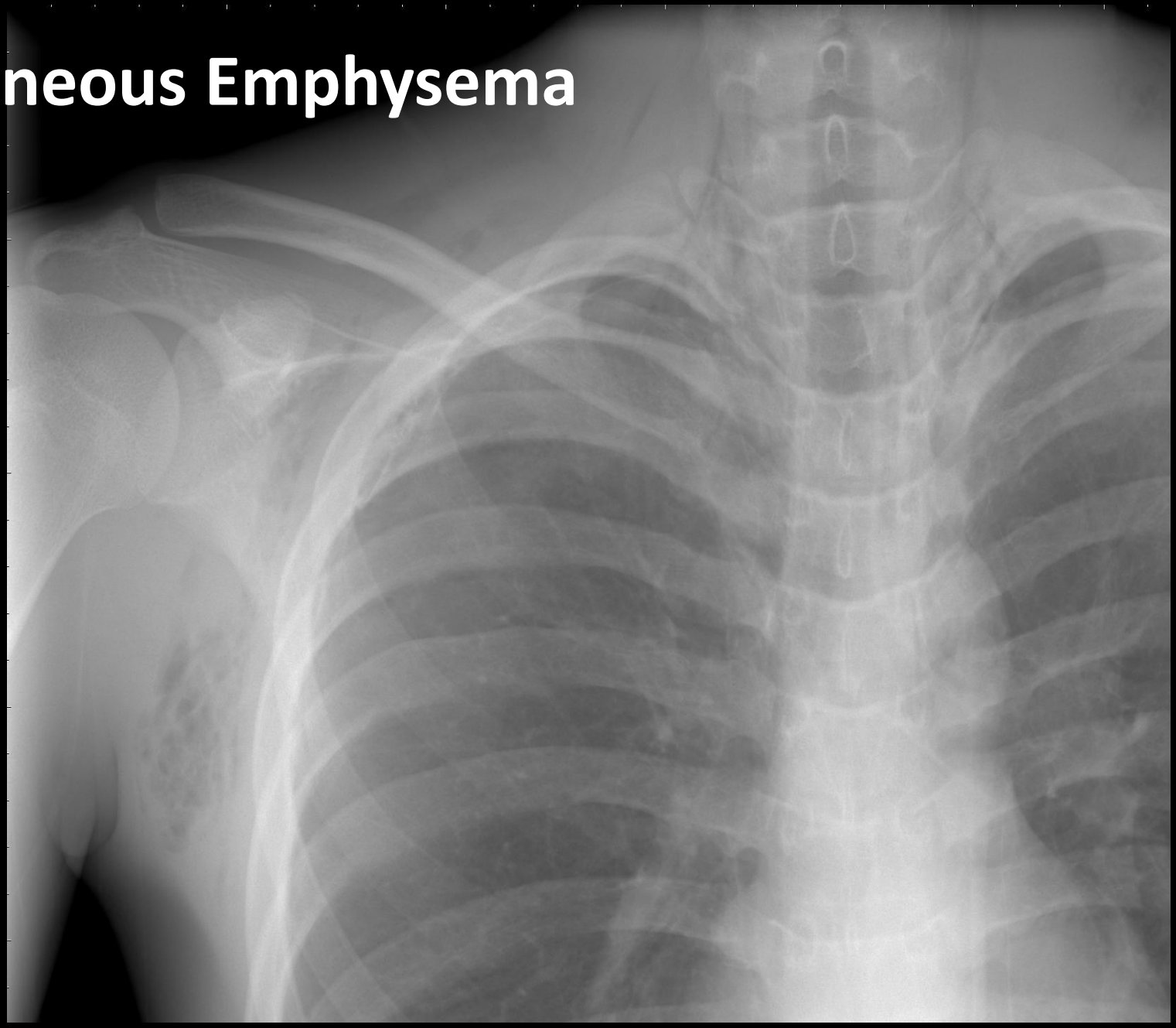
Continuous diaphragm sign



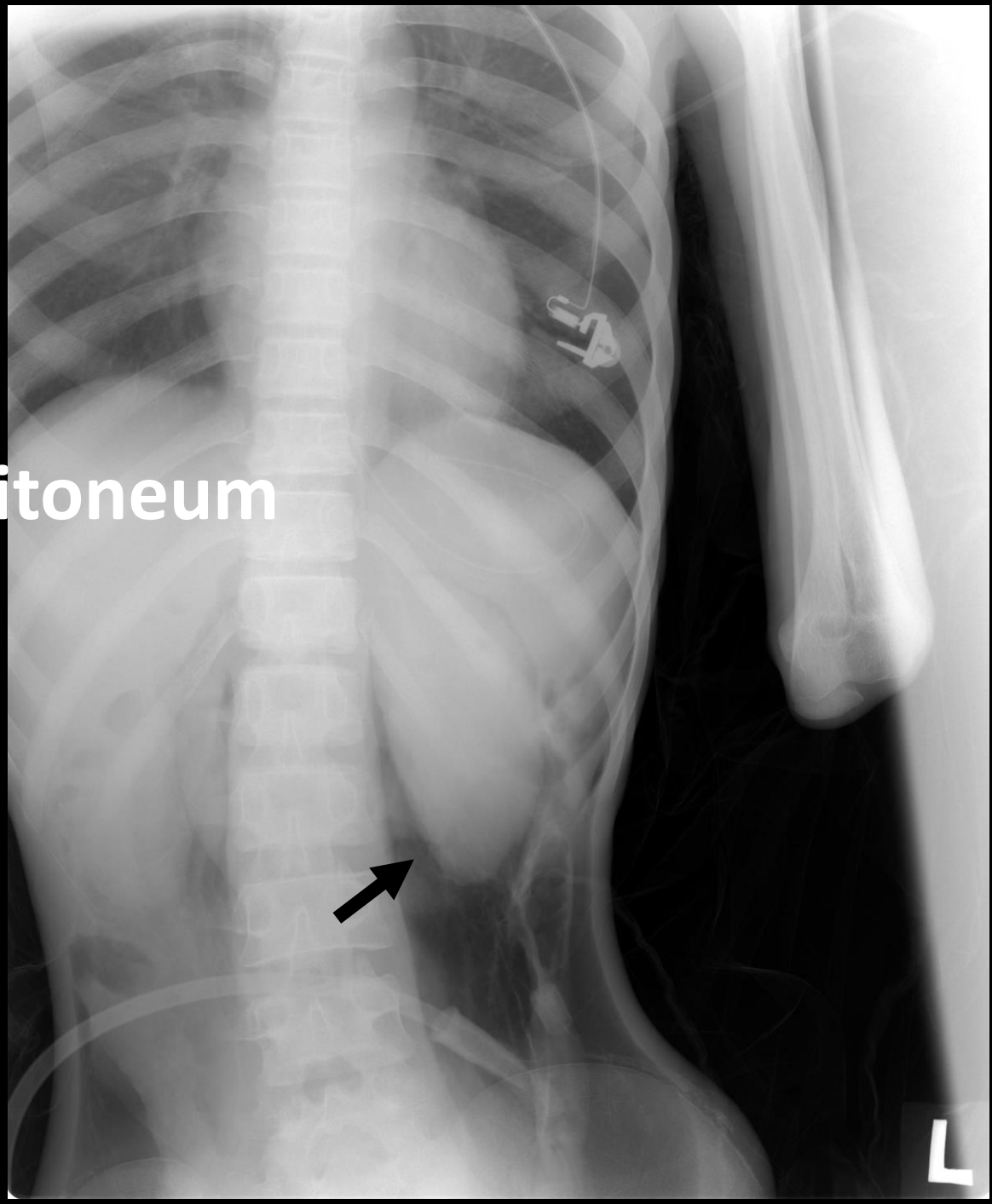
Pneumopericardium



Subcutaneous Emphysema



Pneumoretroperitoneum



Pulmonary edema

Cardiogenic pulmonary edema

Non-cardiogenic pulmonary edema (ARDS)

Pulmonary Edema

- **Mechanism:**
  - Elevated pulmonary venous pressure
  - Increased permeability of alveolar-capillary membrane
  - Decreased plasma oncotic pressure
  - Lymphatic insufficiency
  - Unknown

Pulmonary Edema

- **Cardiogenic:**
- **Noncardiogenic:**
  - Adult Respiratory Distress Syndrome
  - Neurogenic
  - Re-expansion
  - Upper airway obstruction
  - High altitude
  - Drug (Heroin)
  - Hantavirus pulmonary syndrome

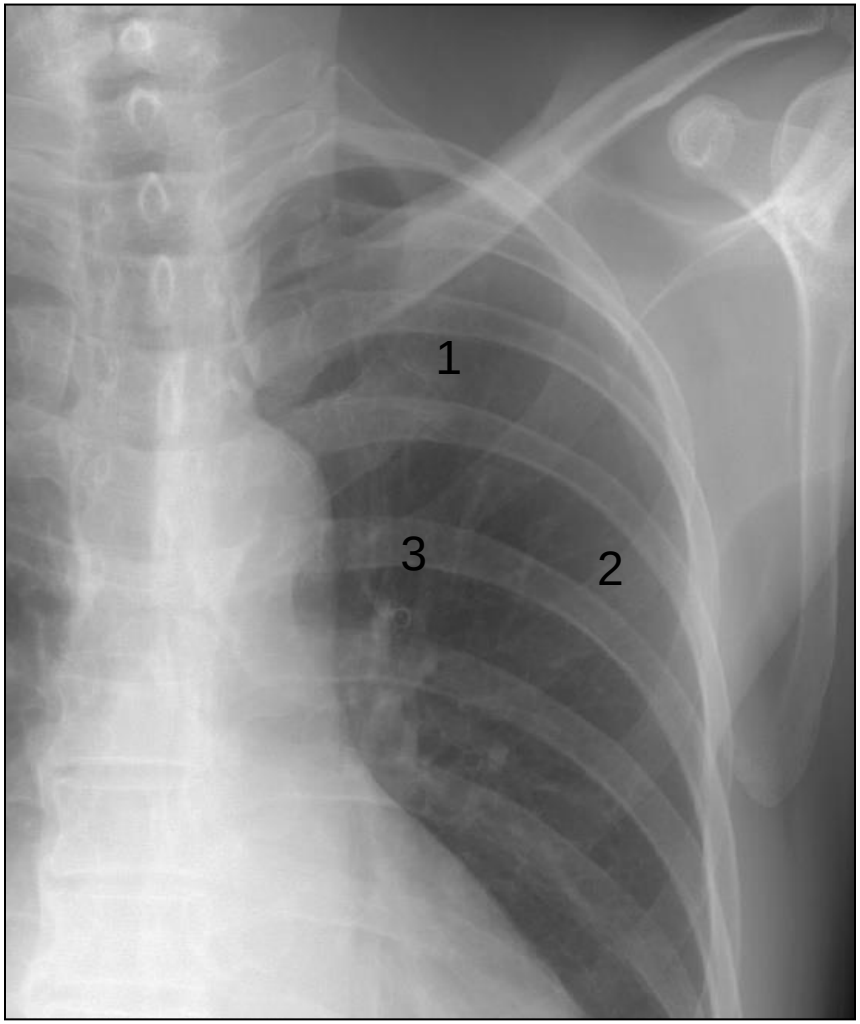
Cardiogenic Pulmonary Edema

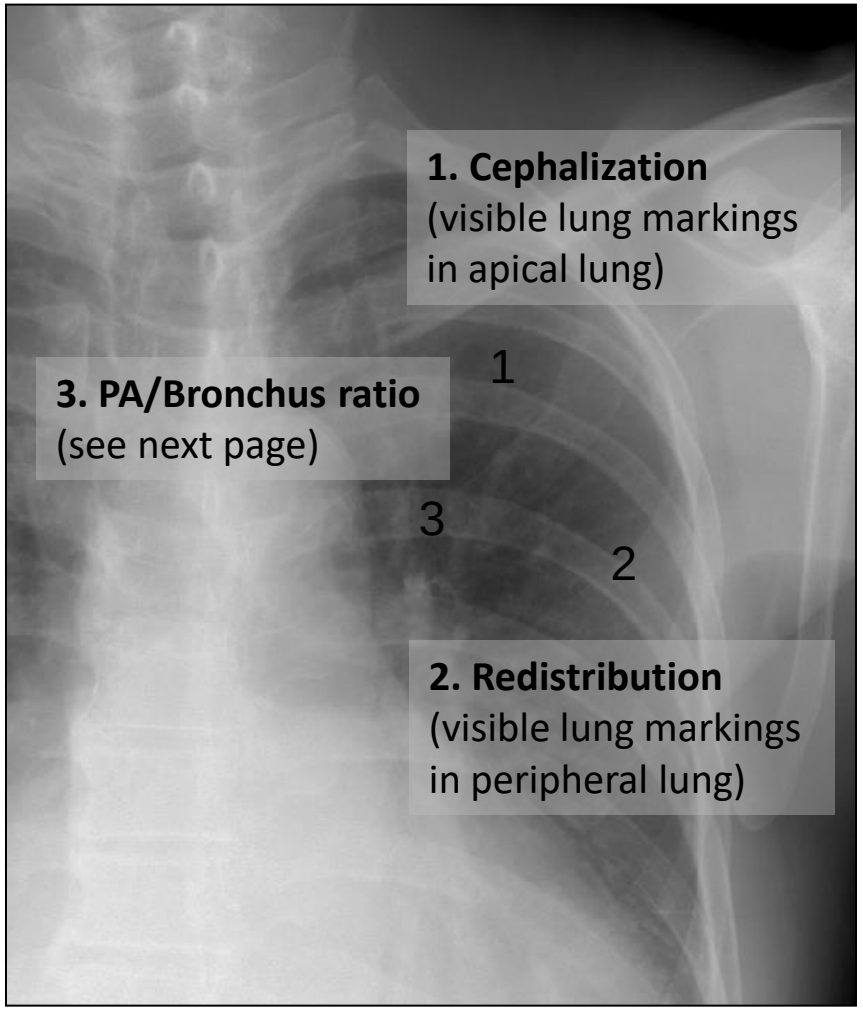
- **Increased LVEDP**
  → increased LA pressure
  → increased PV pressure
  → increased PCWP pressure
  → capillary leak
- **Cause of cardiogenic pulmonary edema:**
  – Heart failure: CHF, AMI, VHD…
  – Fluid overload
  – Renal failure

Cardiogenic Pulmonary Edema

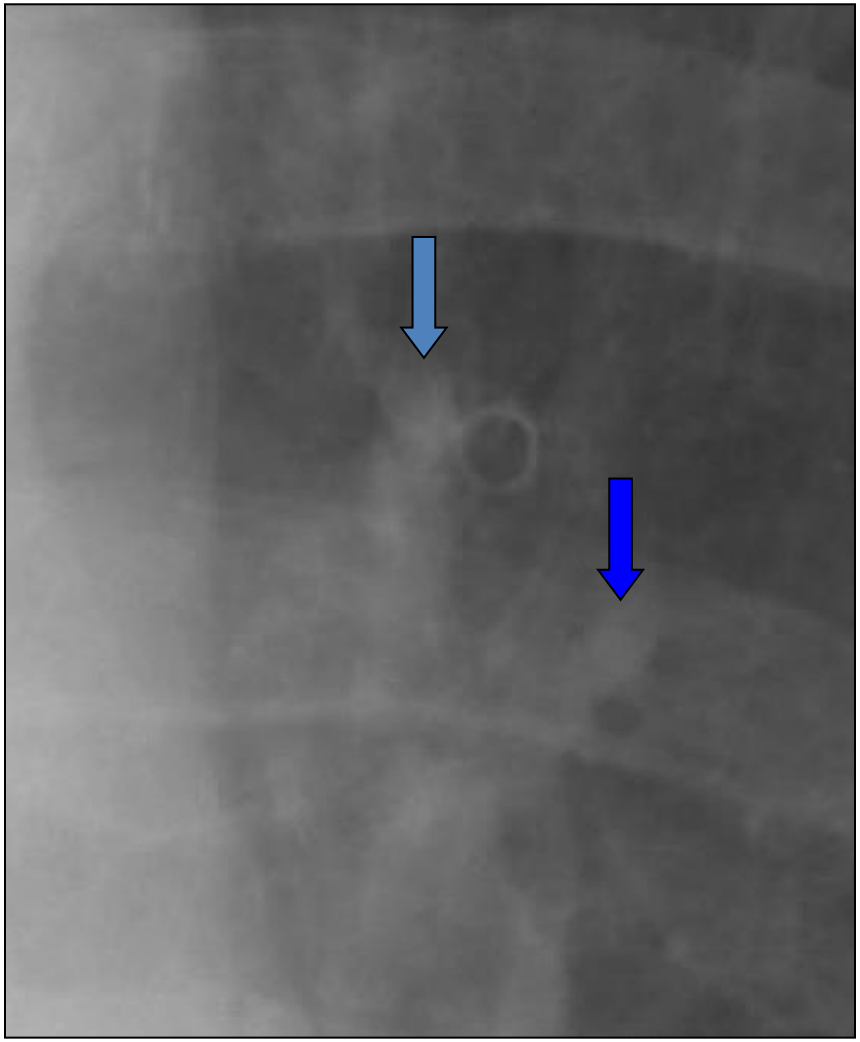
- **Signs of raised pulmonary venous pressure:**
  - 正常之站立CXR，下肺野之血管較上肺野之管粗，當肺靜脈壓上昇時，上肺野之血管會與下肺野一樣，甚至更粗。
    → **Redistribution, Cephalization**
  - Vessels in the first intercostal space should not exceed 3 mm in diameter
  - The ratio of PA and bronchus

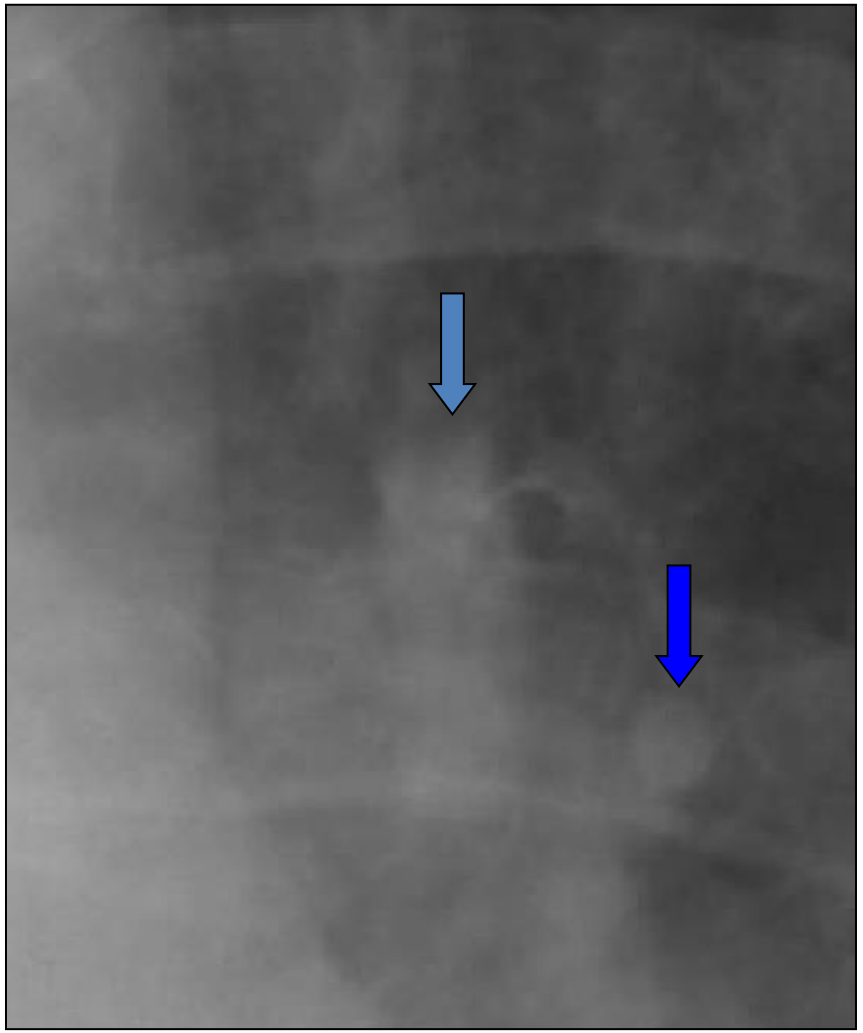
Vascular Redistribution and Cephalization





Pul Artery / Bronchus





Cardiogenic Pulmonary Edema

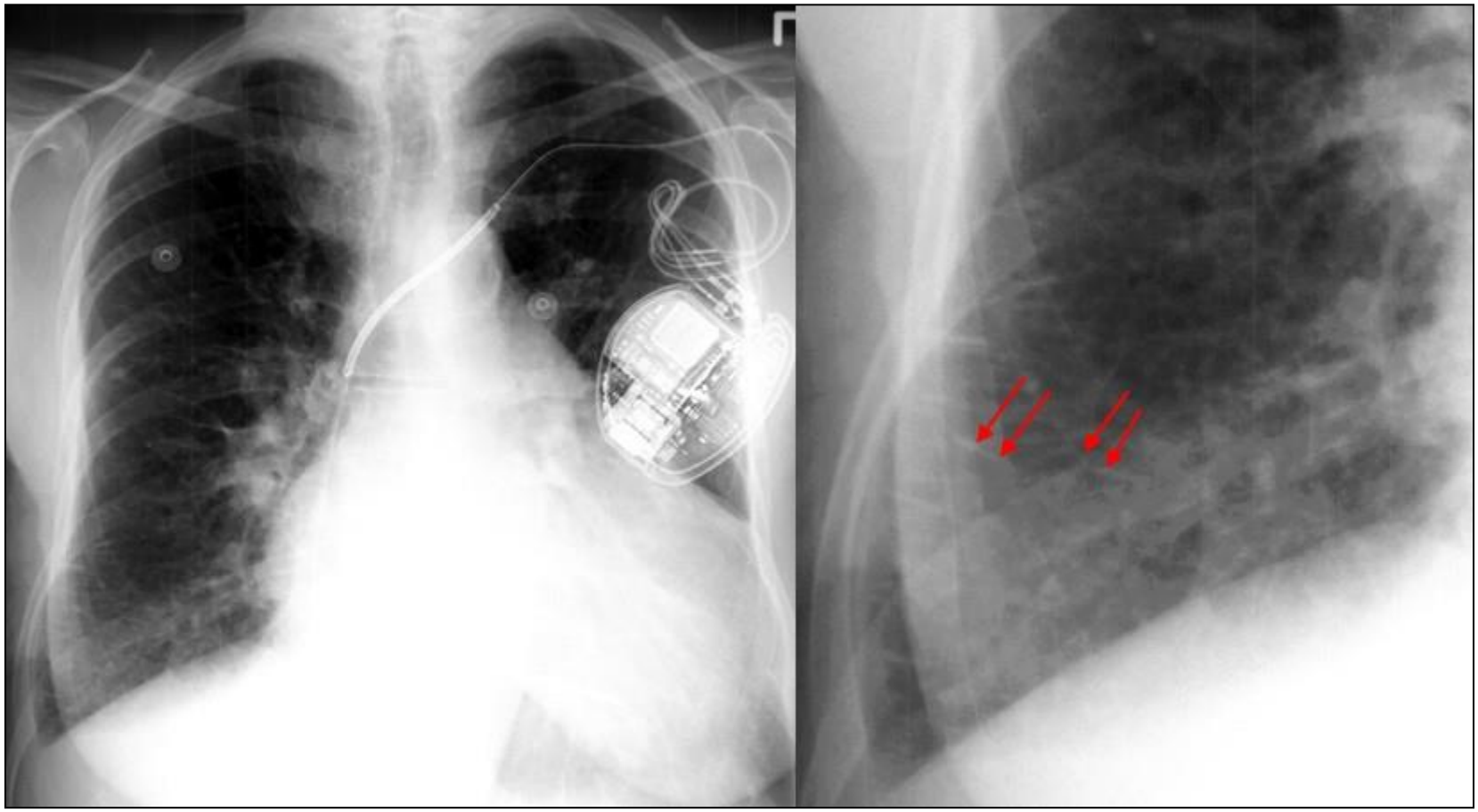
- Normally, the pulmonary interstitium and alveoli are relatively dry.
- Increased pulmoary venous pressure → increased interstitial fluid → increase lymphatic drainage
- Once the capacity of lymphatic drainage is exceeded, **interstitial edema** results. When fluid spills into the air space, **alveolar edema** results.

Interstitial Pulmonary Edema

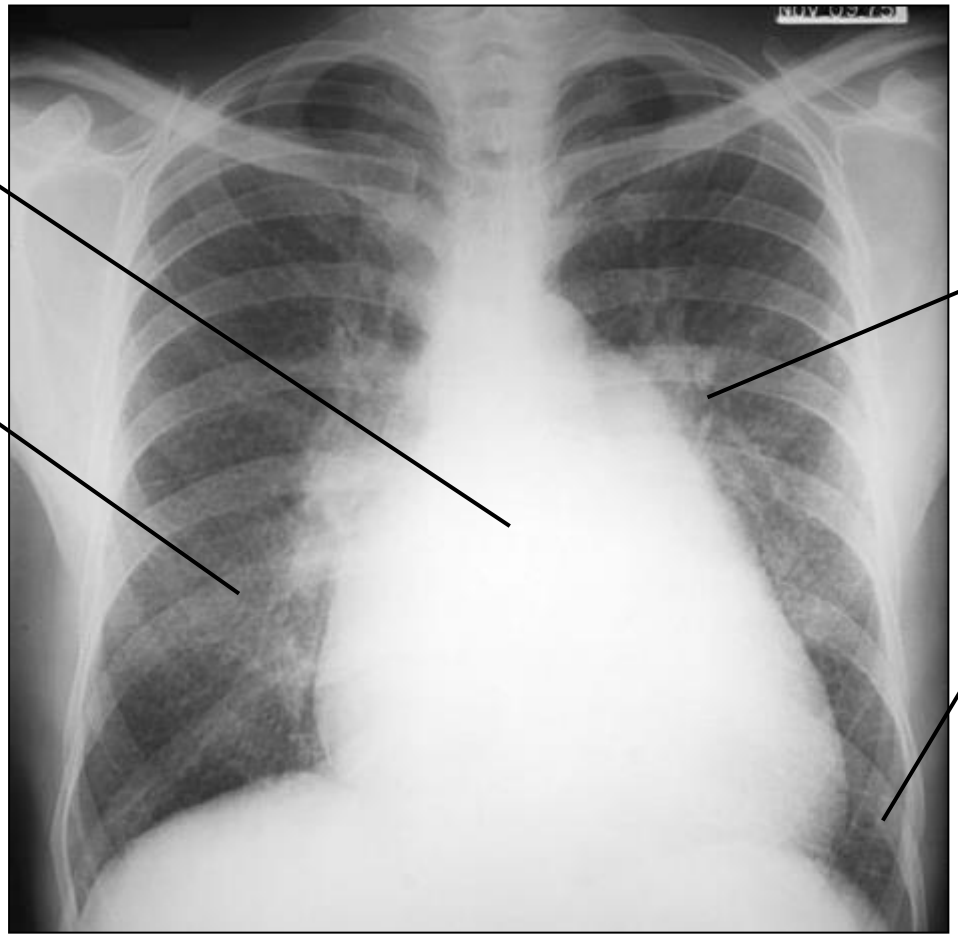
- Septal lines: Kerley's A line, Kerley's B line
- Bronchial wall thickening (peribronchial cuffing)
- Interlobar septal thickening
- Pleural effusion
- Hilar haze: loss of definition of large pulmonary vessels
- Diffuse reticular pattern resembling interstitial fibrosis
- Increased density of the lung parenchyma
- Enlarged mediastinal LN and mediastinal fat opacification

Interstitial Pulmonary Edema

Septal Lines: Kerley's B Lines



Interstitial Pulmonary Edema



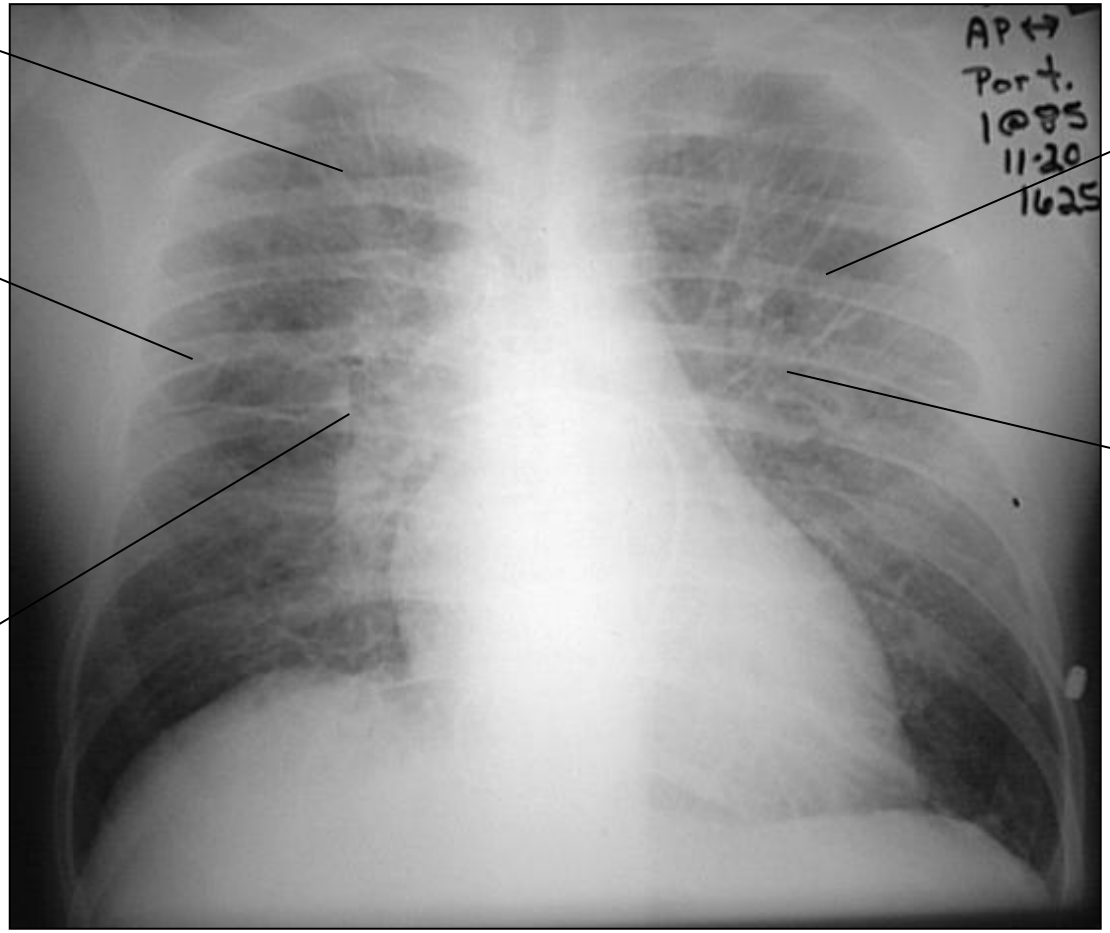
Cardiomegaly

Increased density of lung parenchyma

Hilar haze

Kerley's B line

Interstitial Pulmonary Edema



Cephalization

Thicken Minor Fissure

Engorged Pul Artery

Kerley's A line

Hilar Haze

Alveolar Pulmonary Edema

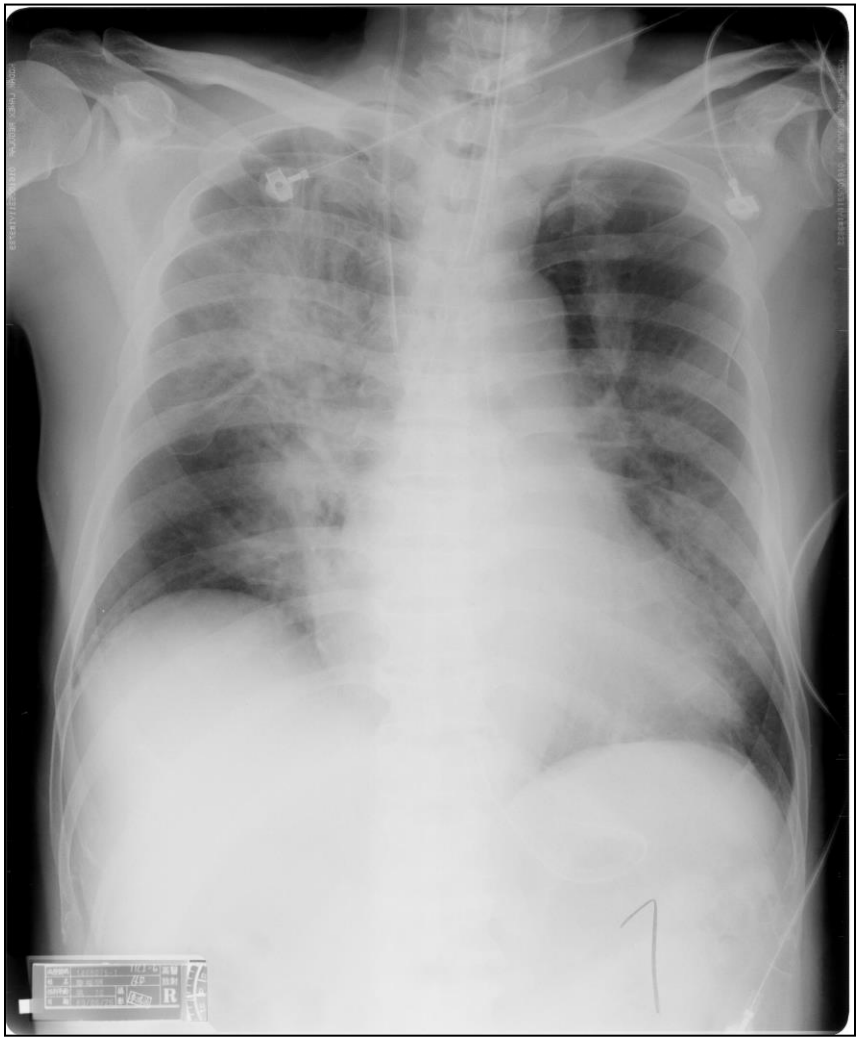
- **Air-space filling**
  - ill-defined, tends to coalesce
  - Air bronchograms or air alveolograms
- **Distribution**
  - Patchy and widespread
  - Usually bilateral, occasionally unilateral (R't lung), rarely lobar (MR→RUL)
  - Central or Perihilar distribution: "Bat's wing" or "Butterfly" pattern.

Alveolar Pulmonary Edema

- **Butterfly pattern:**
  - Perihilar distribution of air-space filling, leaving an aerated outer “cortex”.
  - 此雖為心因性肺水腫之典型表現，但並不十分常見。多數患者之CXR呈現更為瀰漫且不規則之分佈，某些肺葉顯得較為嚴重。

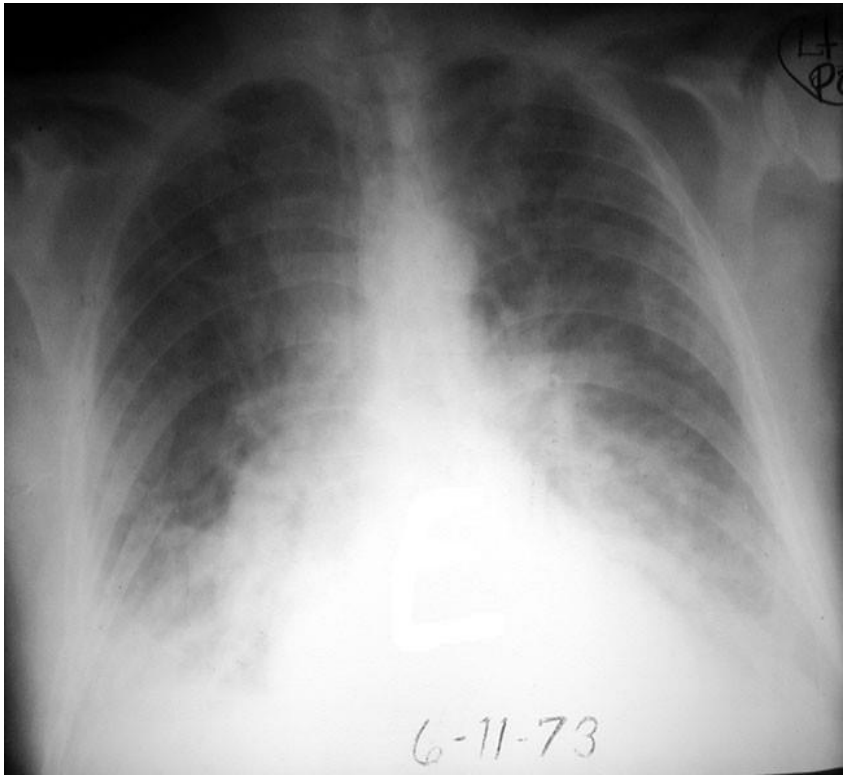
A case of AMI with Acute MR

Alveolar Pulmonary Edema



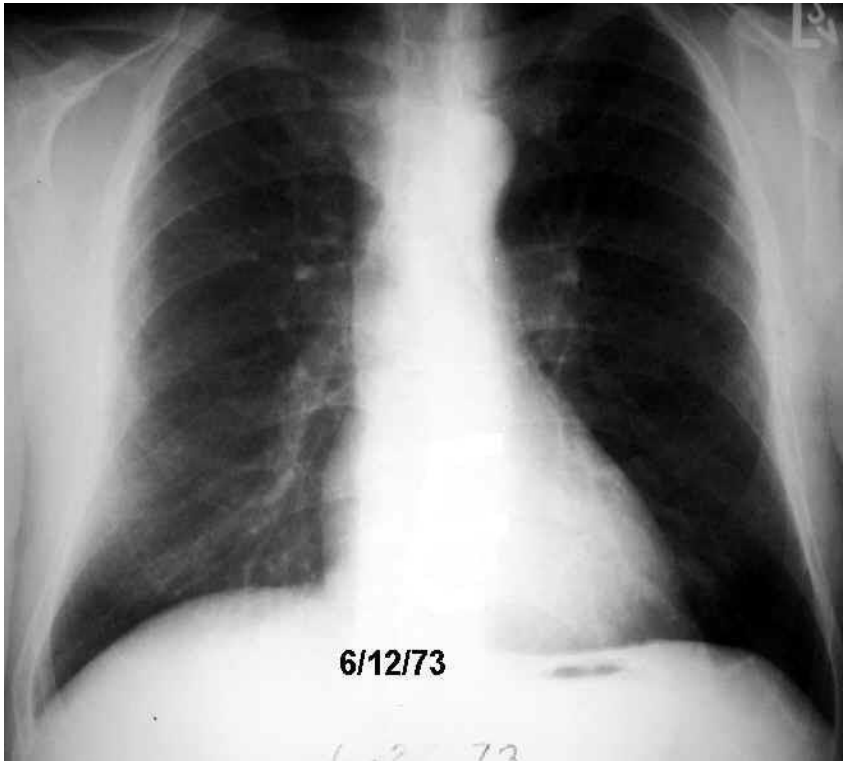
- **Rapid change on films over short intervals**
- Change of distribution several hours after patients change their position
- **Rapid clearing** suggest cardiogenic pulmonary edema

Uremia



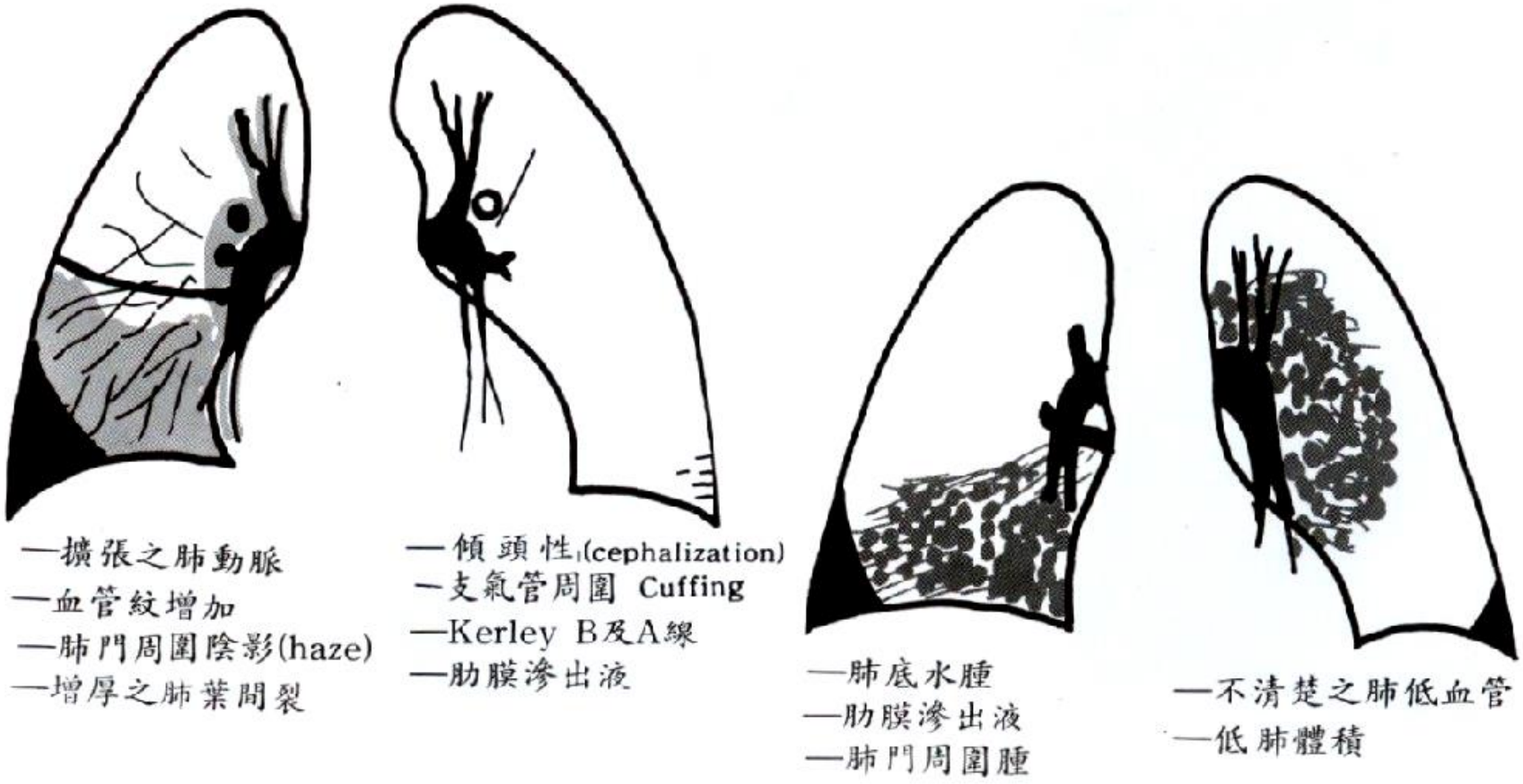
Interstitial and alveolar edema
Bilateral pleural effusion

After HD



One day later

Cardiogenic Pulmonary Edema



Interstitial edema

Alveolar edema

Non-cardiogenic Pulmonary Edema

Acute Respiratory Distress Syndrome (ARDS)

Diagnostic Criteria (1994 AECC Definition):

1. **Acute onset**

   usually within 24 hours, most within 72 hours

2. **Bilateral infiltrates on CXR**

3. **PaO_2/FiO_2 of 200 or less**

   PaO_2/FiO_2 of 300 or less → Acute Lung Injury (ALI)

4. **PCWP of 18 mmHg or less, or no clinical signs of left atrial hypertension**

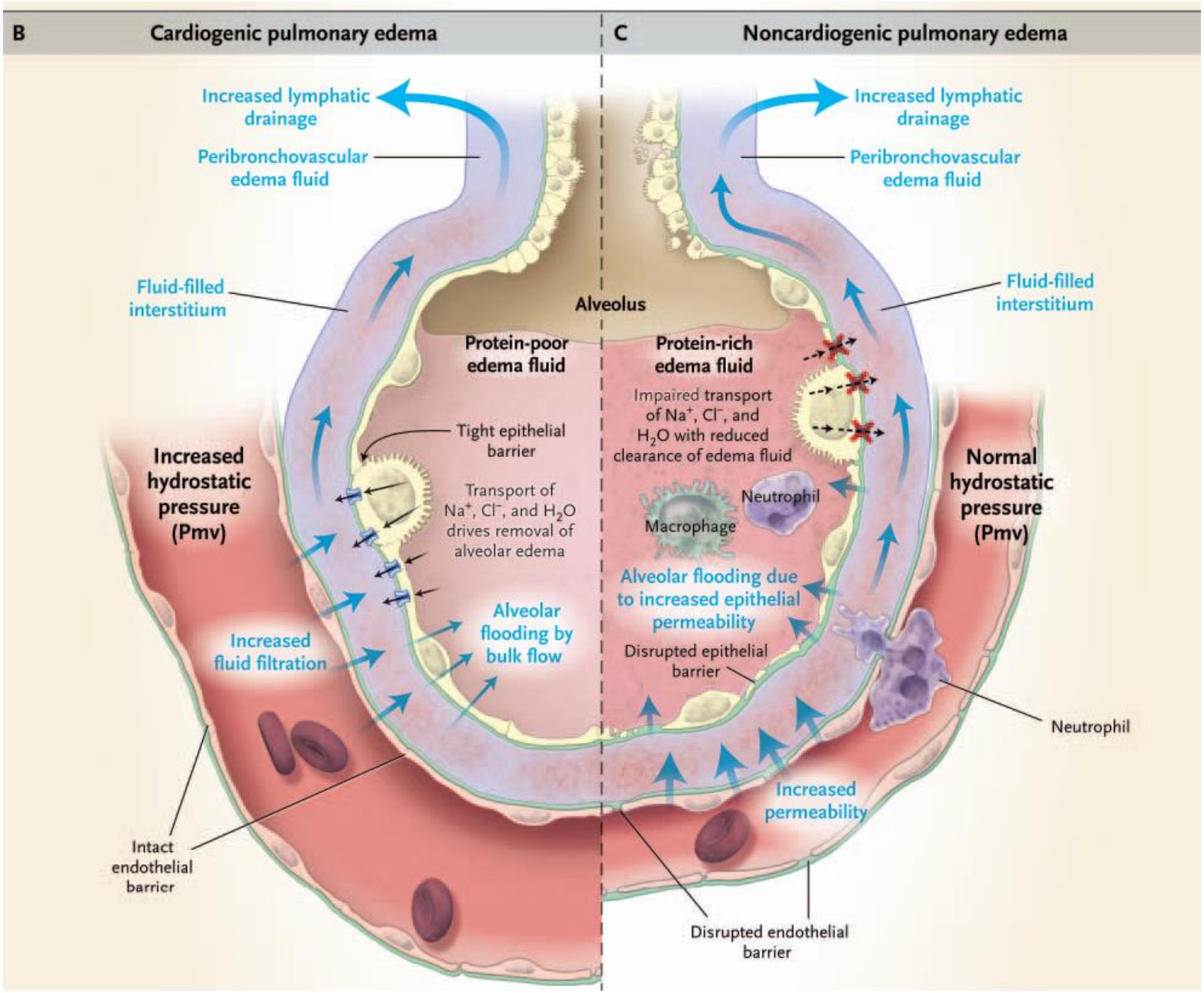
   No clinical evidence of fluid overload or cardiogenic pulmonary edema

Non-cardiogenic Pulmonary Edema

Acute Respiratory Distress Syndrome (ARDS)

Diagnostic Criteria (2012 Berlin Definition):

1. 急性發生 (於七日內)
2. 胸腔影像呈現兩側肺部不透明
3. 無法由心衰竭或體液過多解釋的肺水腫
4. 氧合不佳 (在CPAP或PEEP ≥ 5 cm H_2O下 P/F ratio ≤ 300)
   - P/F 200-300 → Mild ARDS
   - P/F 100-200 → Moderate ARDS
   - P/F < 100 → Severe ARDS



Ware LB el al. NEJM, 2005

CXR of ARDS

- Bilateral, widespread, patchy, ill-defined air-space filling.
- Usually all lung zone are involved both centrally and peripherally.
- Signs of interstitial edema may also be present, but septal lines are rare.

CT Scan of ARDS

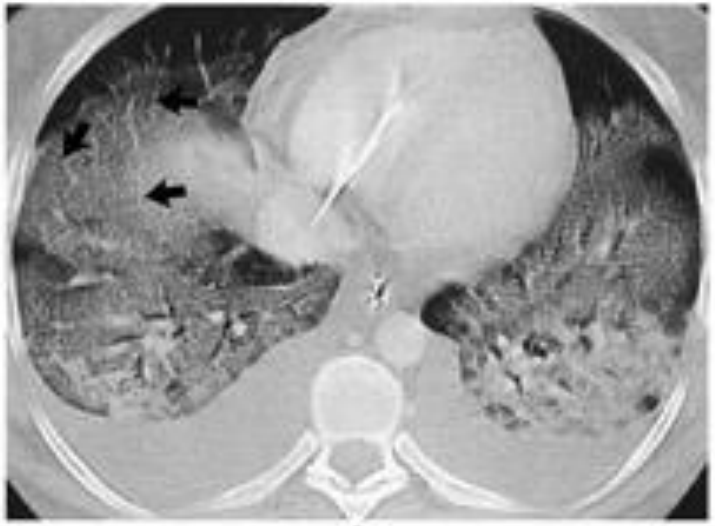
- Heterogenous
- Air-space consolidation and ground-glass opacity
- The densely consolidated lung tends to locate on the dependent site
- Interstitial thickening, fibrosis in late stage
- Cyst or bullae formation
- Bilateral pleural effusion

Exudative Phase

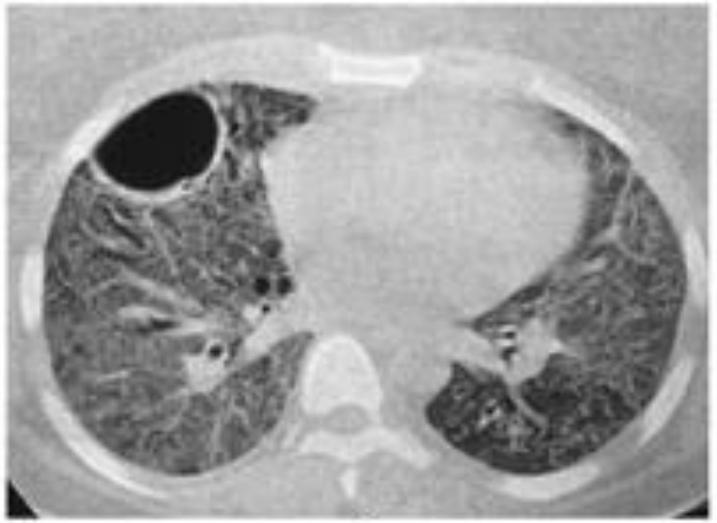
Fibrosing-alveolitis Phase

A

B



C

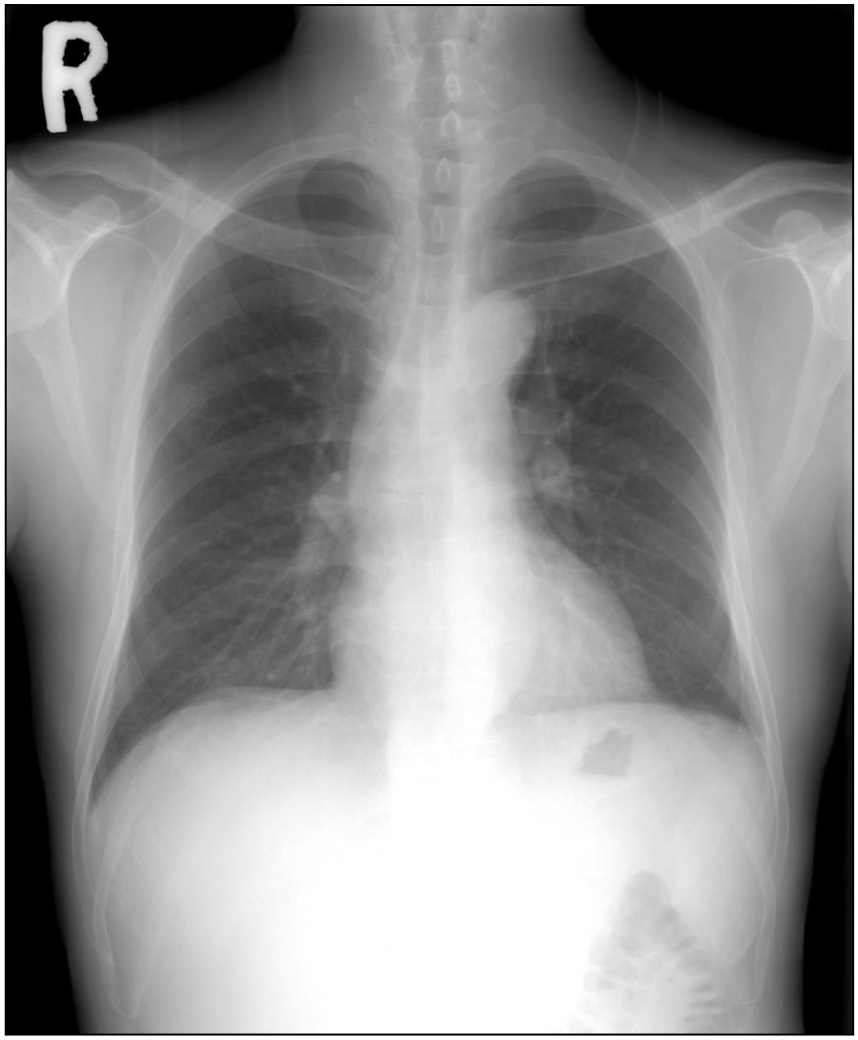


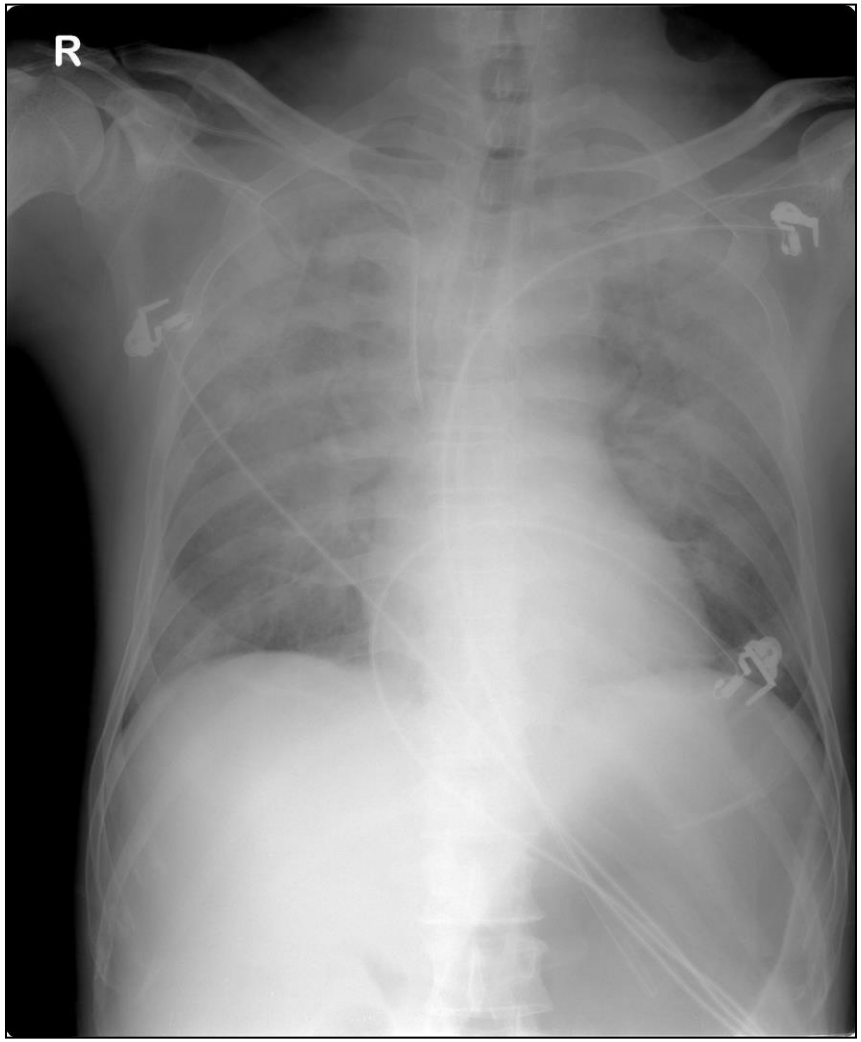
D

Ware LB et al, NEJM, 2000

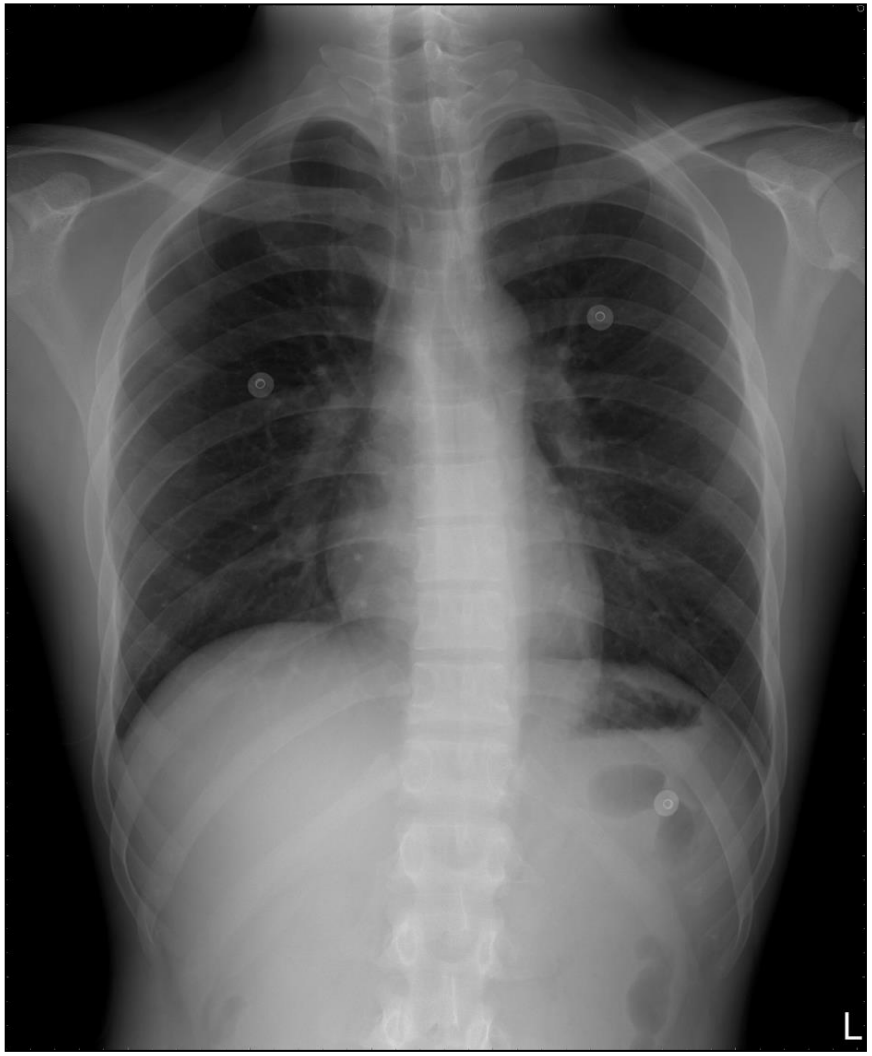
Sepsis-induced ARDS

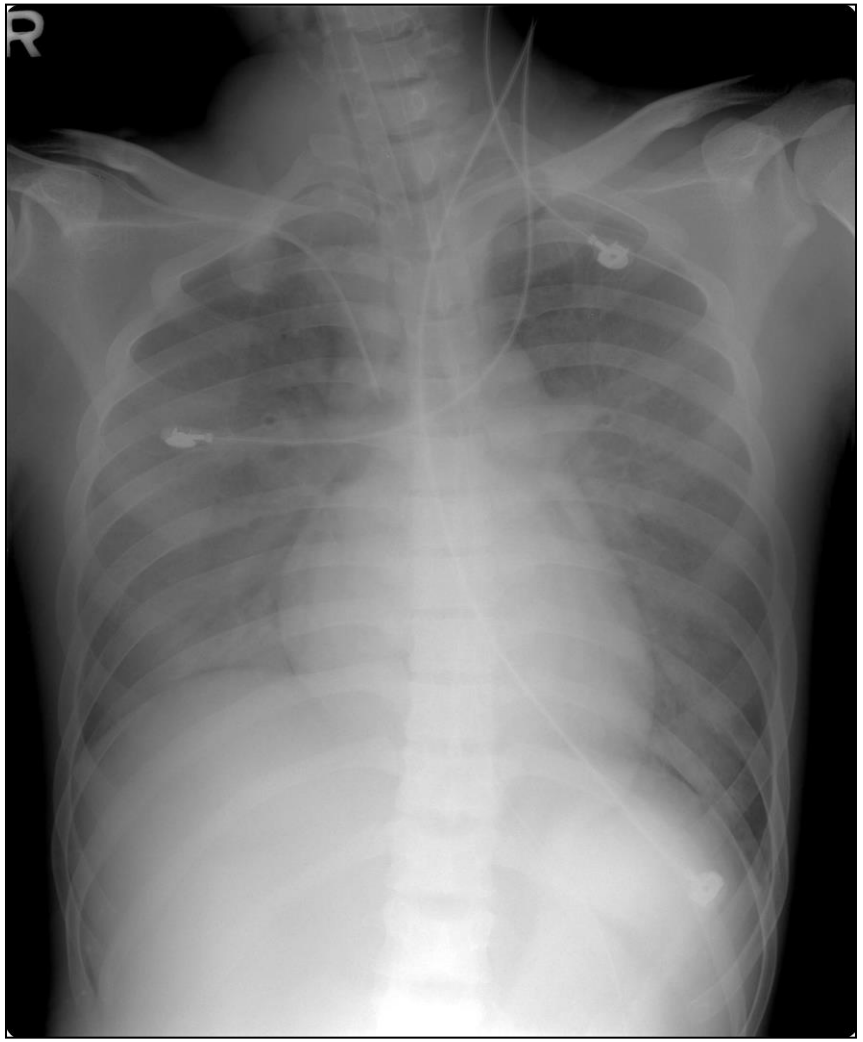
A case of Vibrio infection



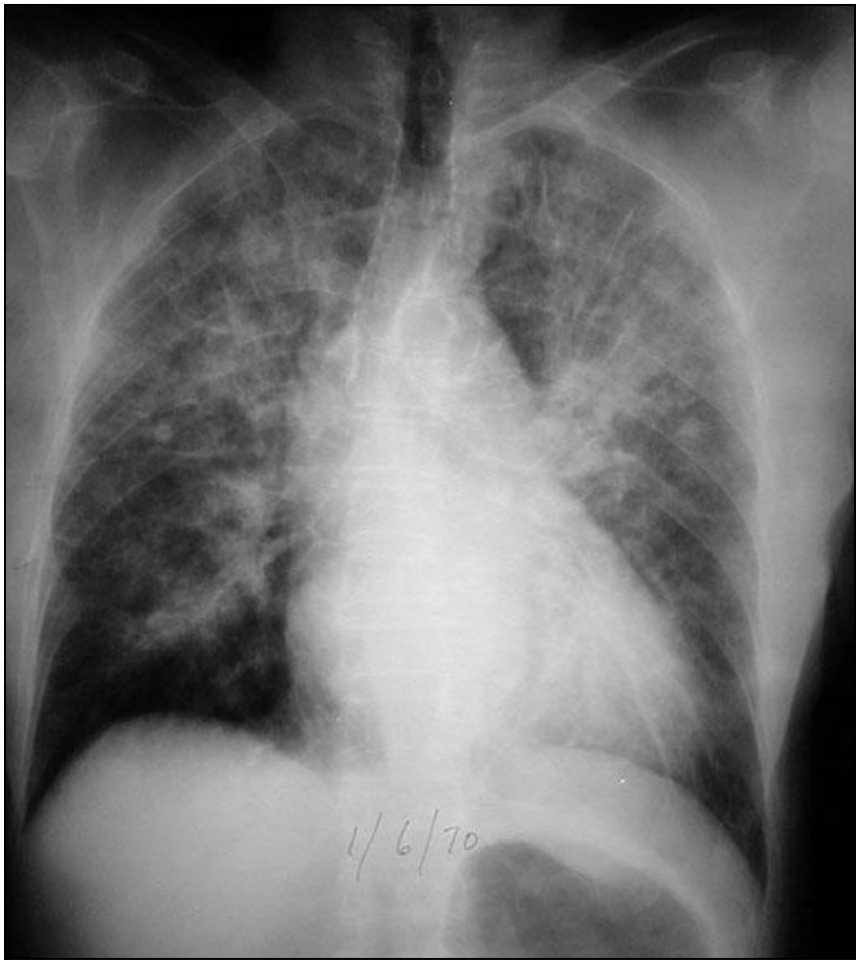


Paraquat Intoxication



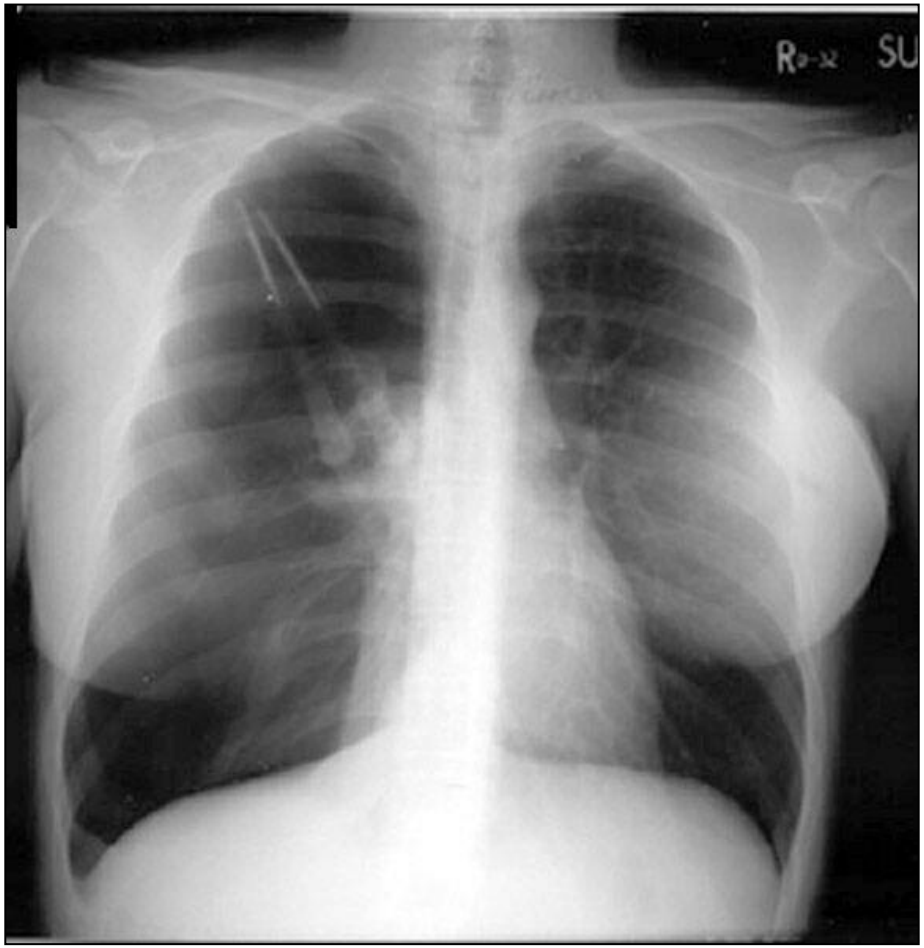


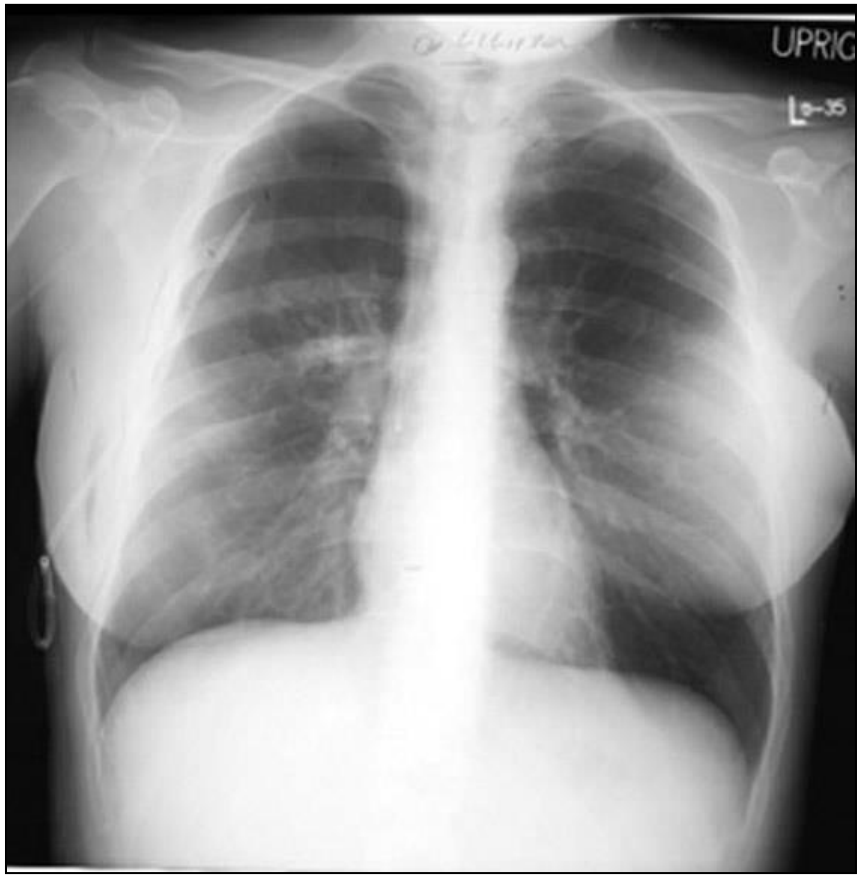
Neurogenic Pulmonary Edema



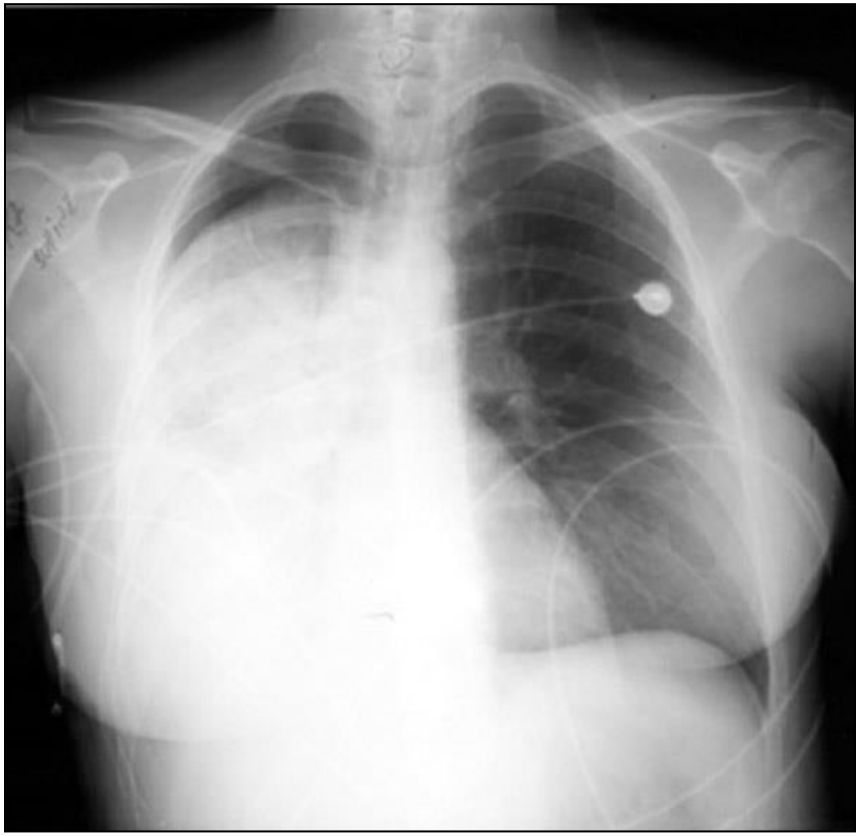
- 多發生於Head injury、ICH、Seizure、Brain tumors之病人。
- Mechanism: unknown
  可能由於交感神經突然過度興奮，導致肺血流量增加，肺靜脈壓上昇。另外endothelial damage亦有其角色。
- The heart is not enlarged.
- Can occur in a minute. The lung usually clear within 24 to 48 hours

Pneumothorax
→ Chest tube insertion





Reexpansion Pulmonary Edema



- 常發生於大量胸水或嚴重且慢性氣胸經胸管快速引流後
- Mechanism: hypoxic capillary damage?
- 通常於reexpansion 2小時內發生，1-2天內持續惡化，於5-7天內緩解。
- 預防方式: 減緩Lung reexpansion之速度
- 亦稱**reperfusion pulmonary edema**

CXR: Cardiogenic pulmonary edema vs. ARDS

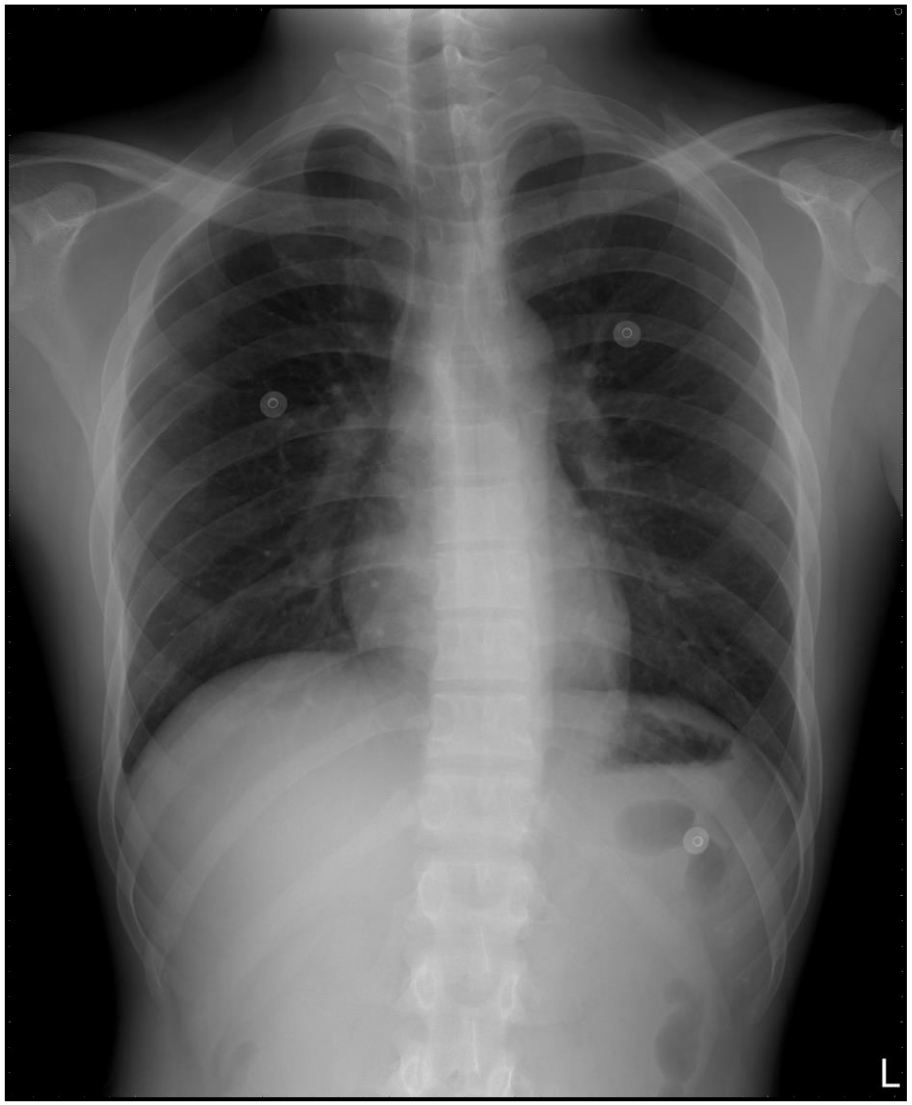
	Cardiogenic Pulmonary Edema	ARDS
CXR之表現	較症狀早或同時發生	較症狀晚出現
Change on serial CXR	Rapid	Slow
Distribution	Central distribution, Peripheral sparing	More diffuse, both centrally & peripherally
Cardiomegaly, Cephalization	常見	較少見
Septal lines, Peribronchial Cuffing	常見	少見
Air bronchograms	少見	常見
Pleural effusion	量多	量少

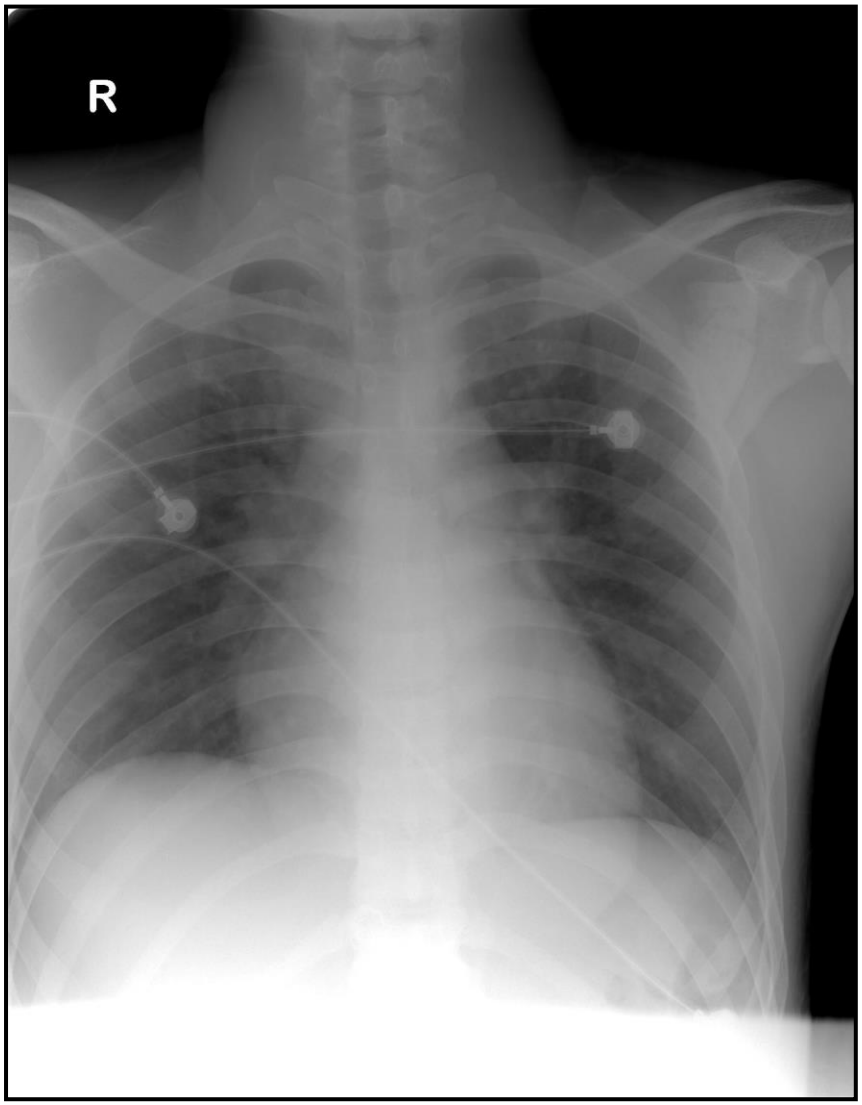
Fluid Status Evaluation

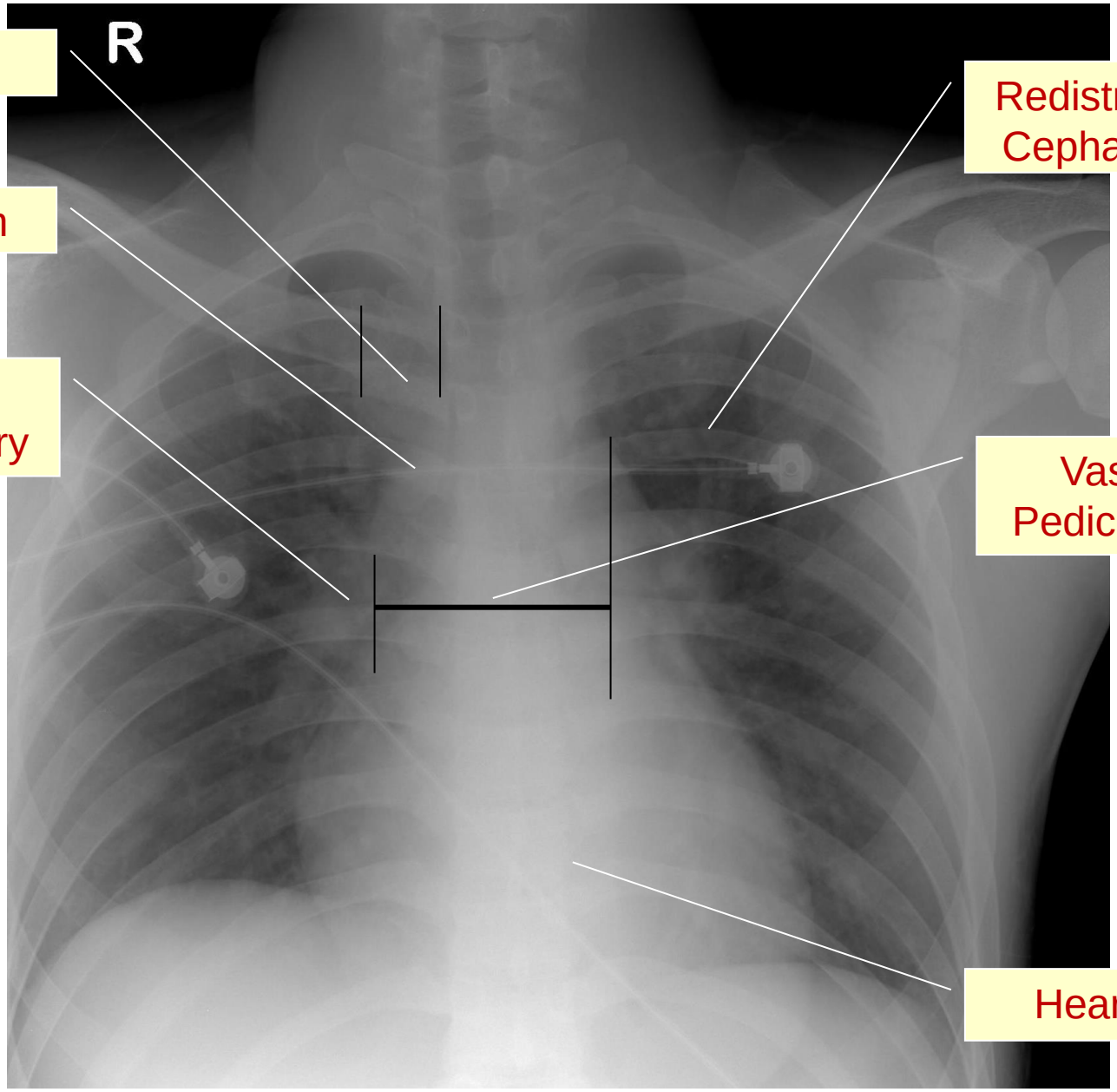
Evaluation of Fluid Status on CXR

- Signs of increased pulmonary venous pressure
- Signs of interstitial edema
- Signs of alveolar edema
- Heart size
- SVC and Azygos vein
- Vascular Pedicle Width (VPW)

3 days later, after fluid resuscitation of 8000 ml



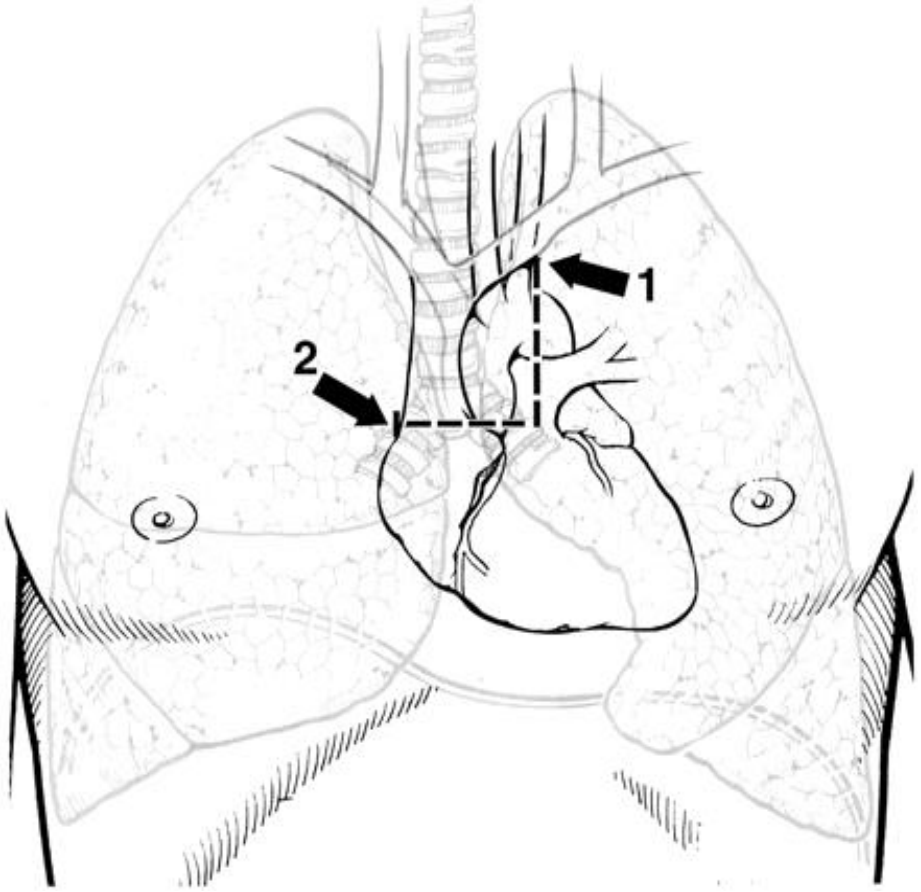



R
SVC
Axygos Vein
Right lower lobe pul artery
Redistribution, Cephalization
Vascular Pedicle Width
Heart size

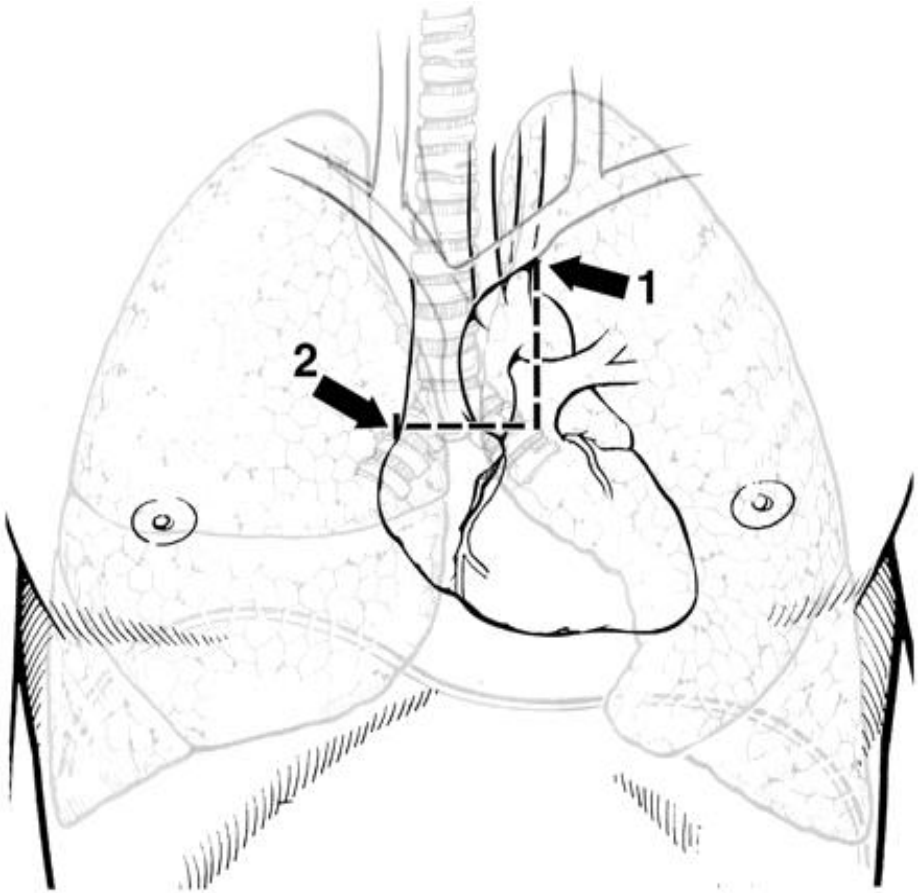
Vascular Pedicle Width

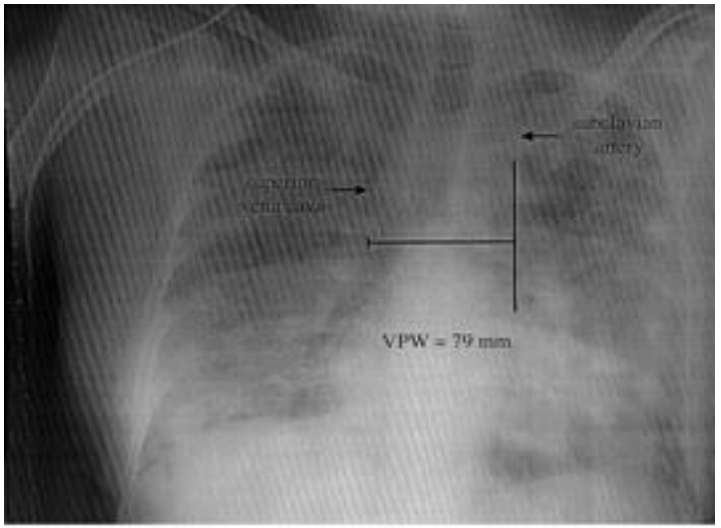
1. Aortic arch上left subclavian artery出口處劃下垂直線
2. SVC與right main bronchus之交界

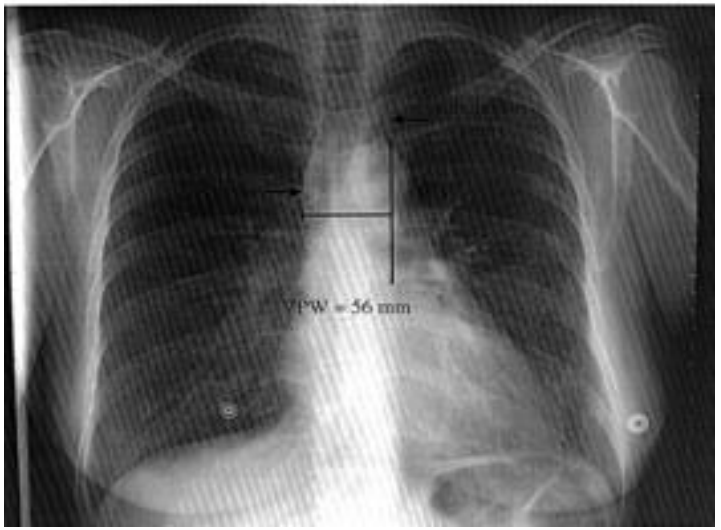
- 正常upright CXR之VPW = 48 ± 5 mm
- CTR > 55%且VPW > 70 mm較正常時有三倍以上之機會PCWP > 18 mmHg



Vascular Pedicle Width



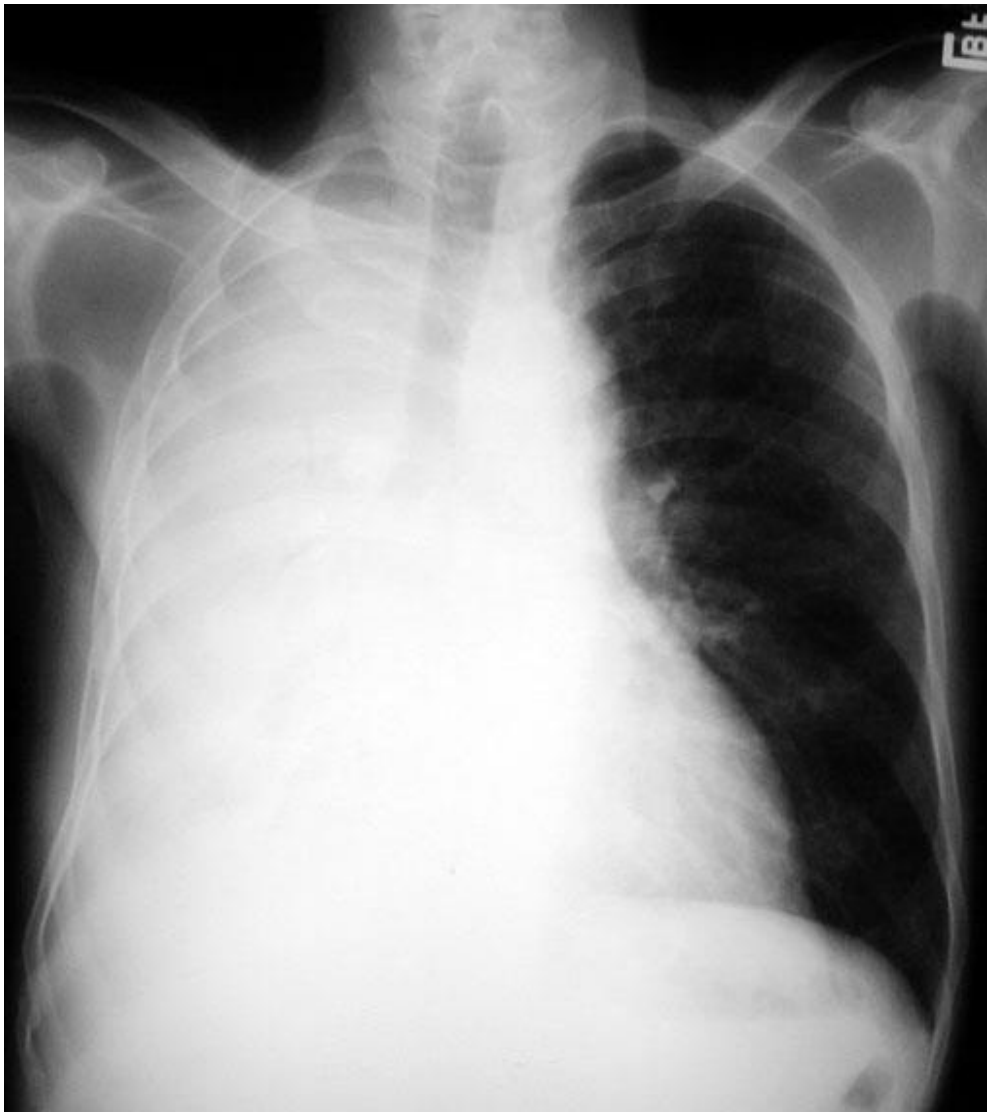




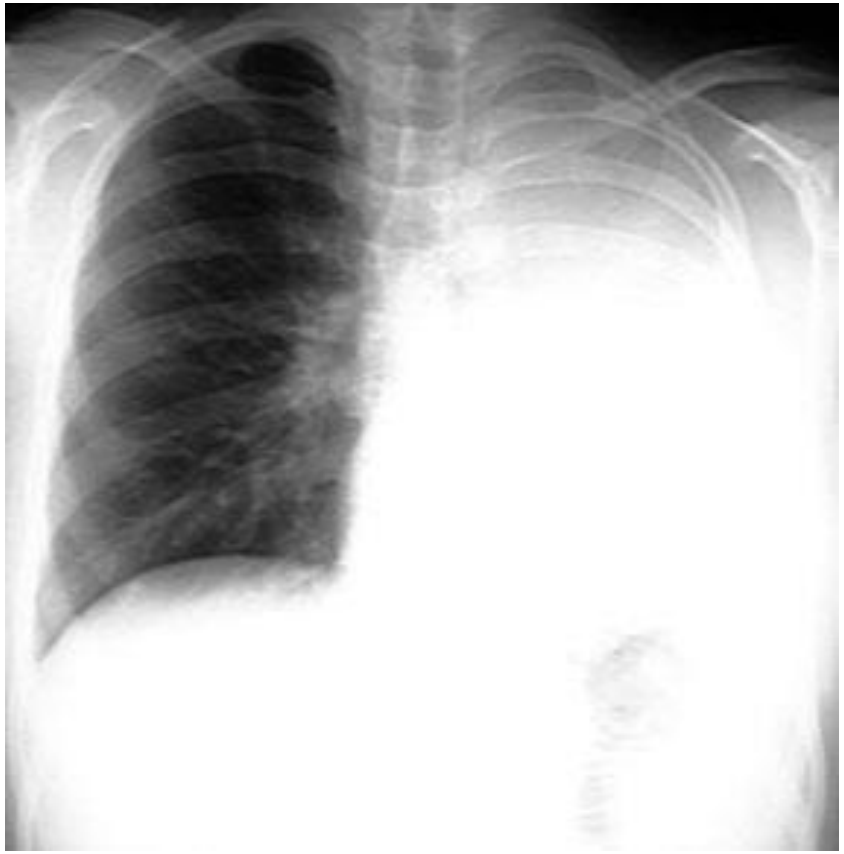
Atelectasis

- Direct sign: collapsed lung
- Indirect sign: volume reduction
  - Trachea, heart, hilum, fissure, diaphragm, intercostal space

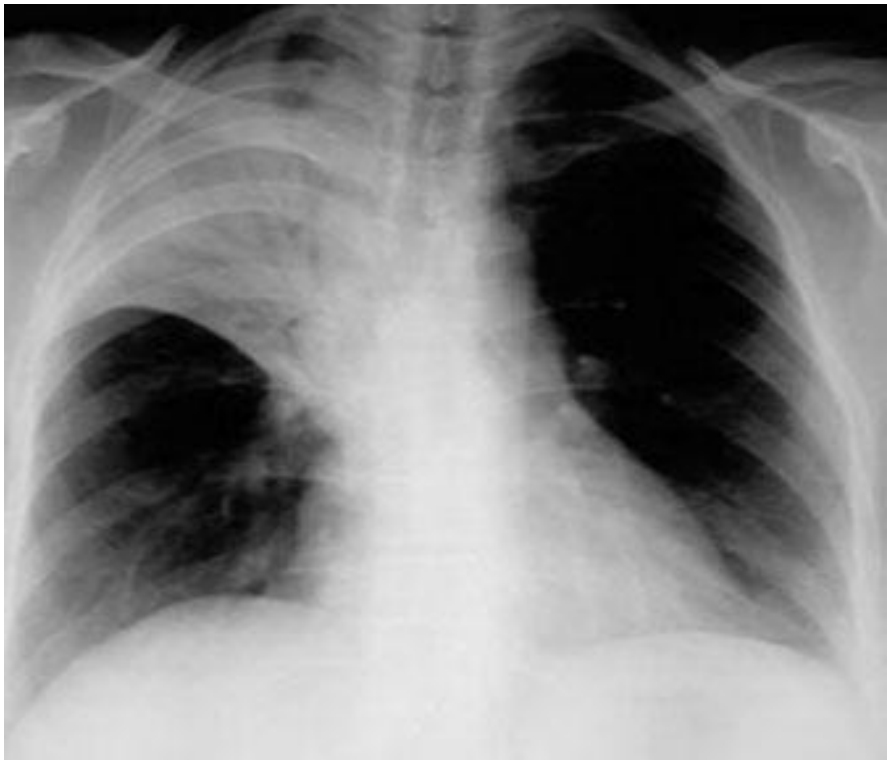
Right Lung Collapse



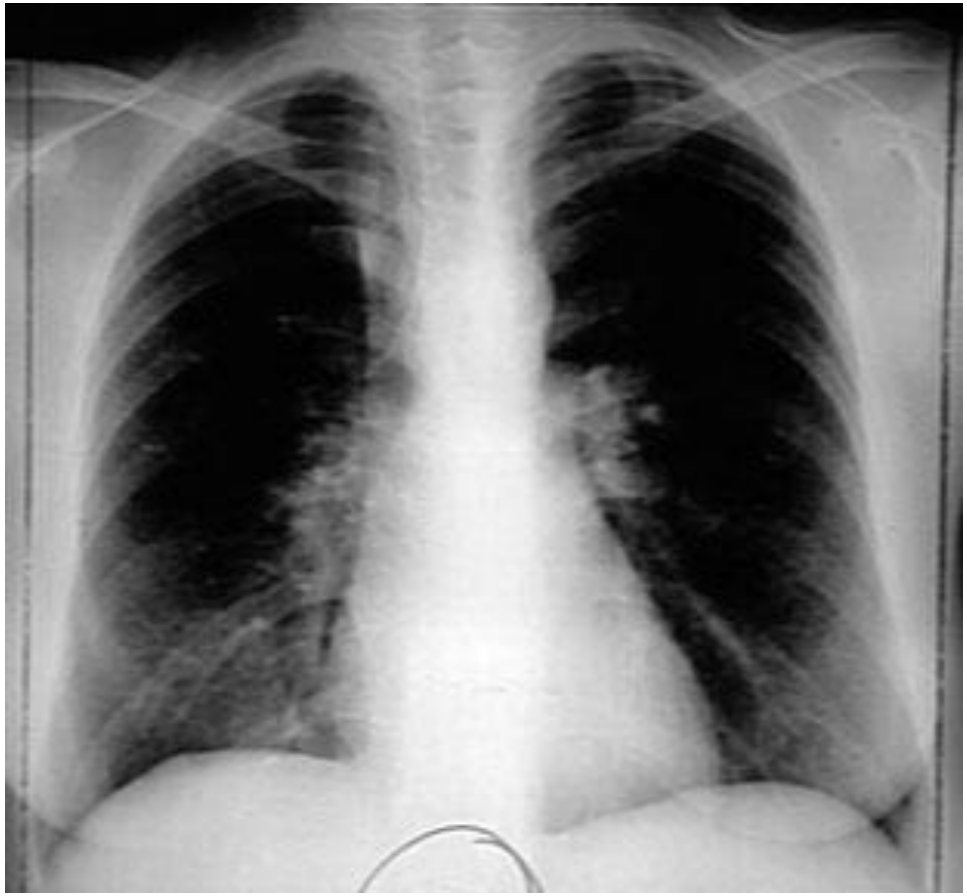
Left Lung Collapse



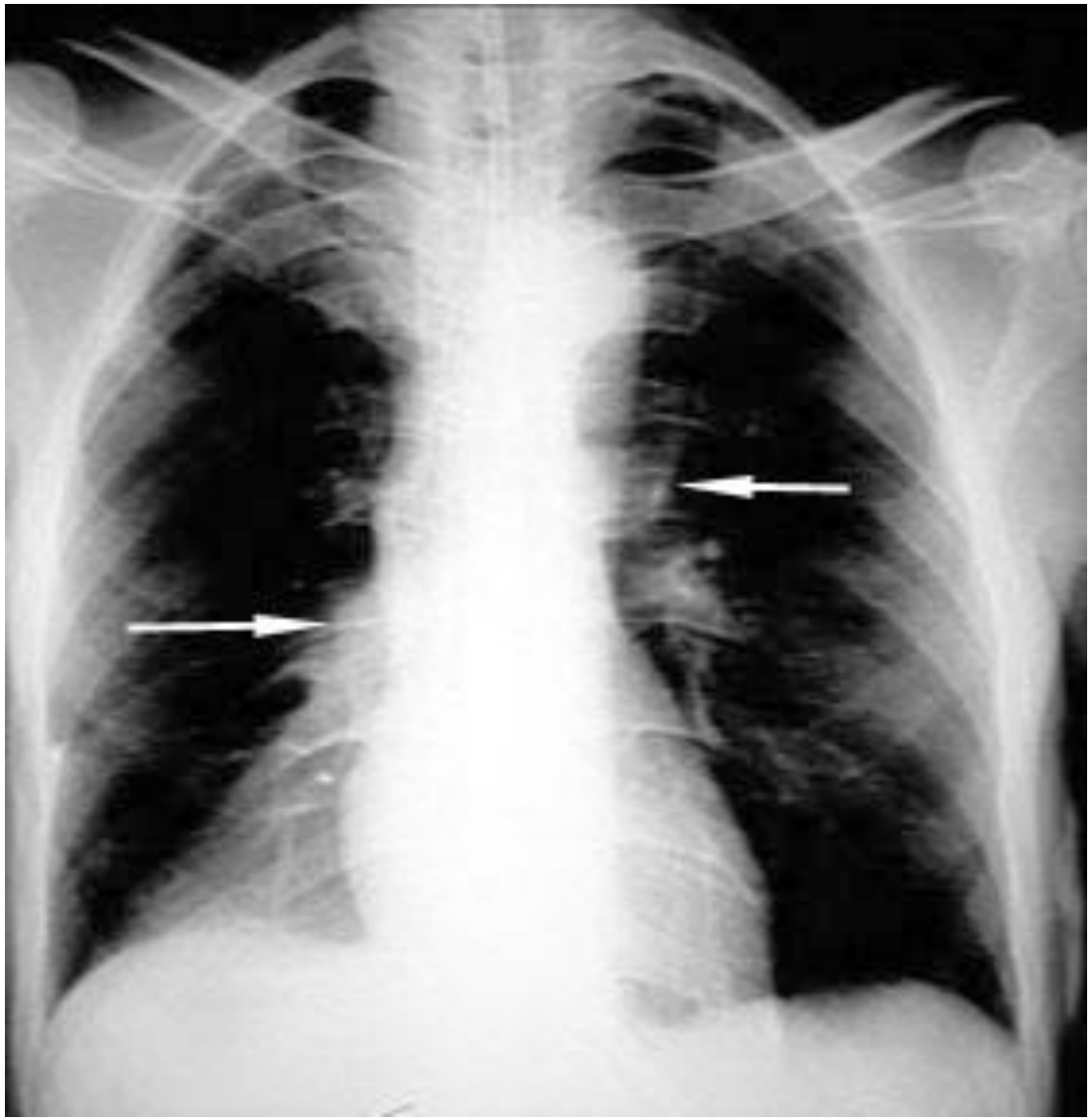
RUL Collapse



RML Collapse

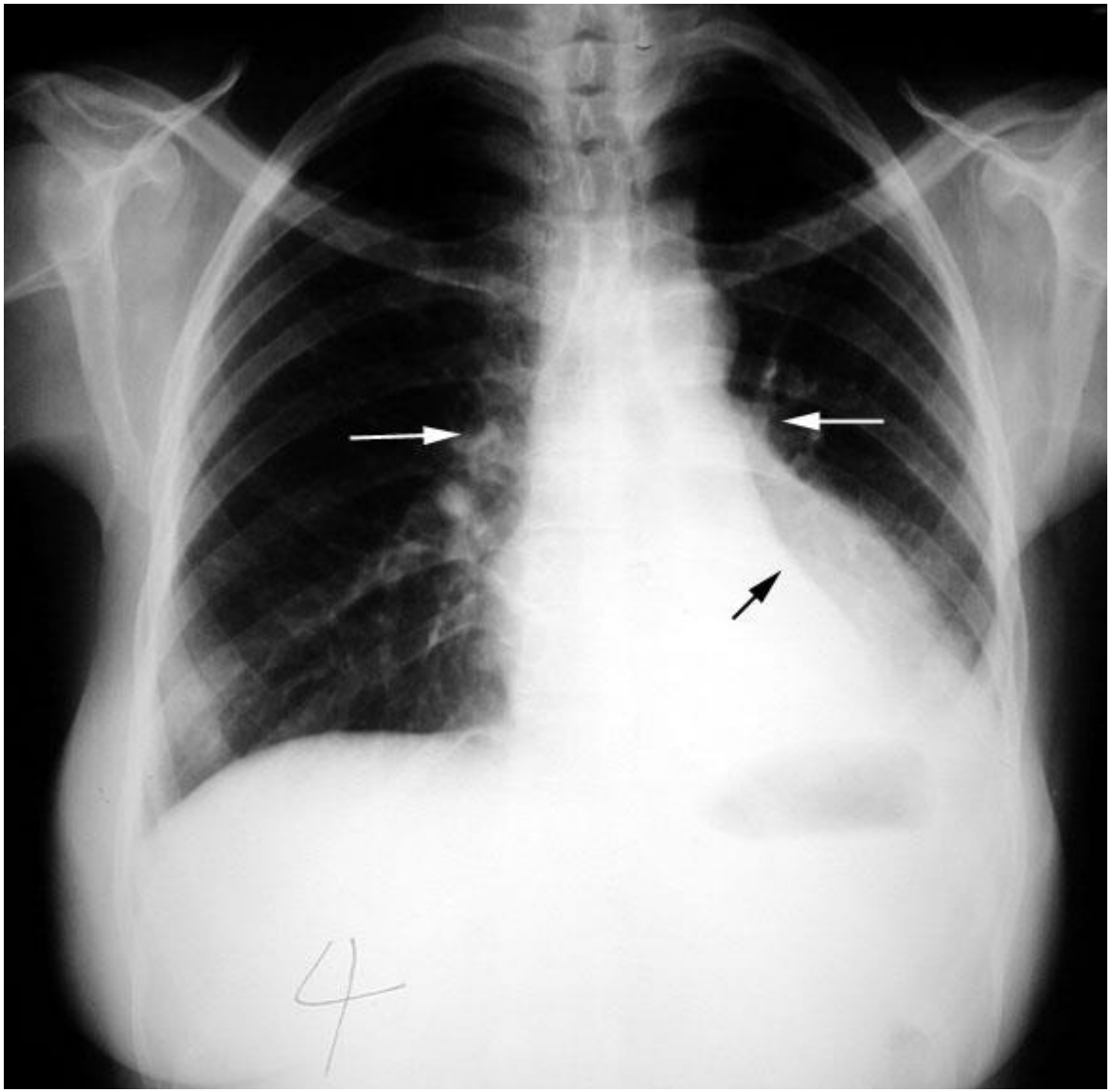


RLL Collapse

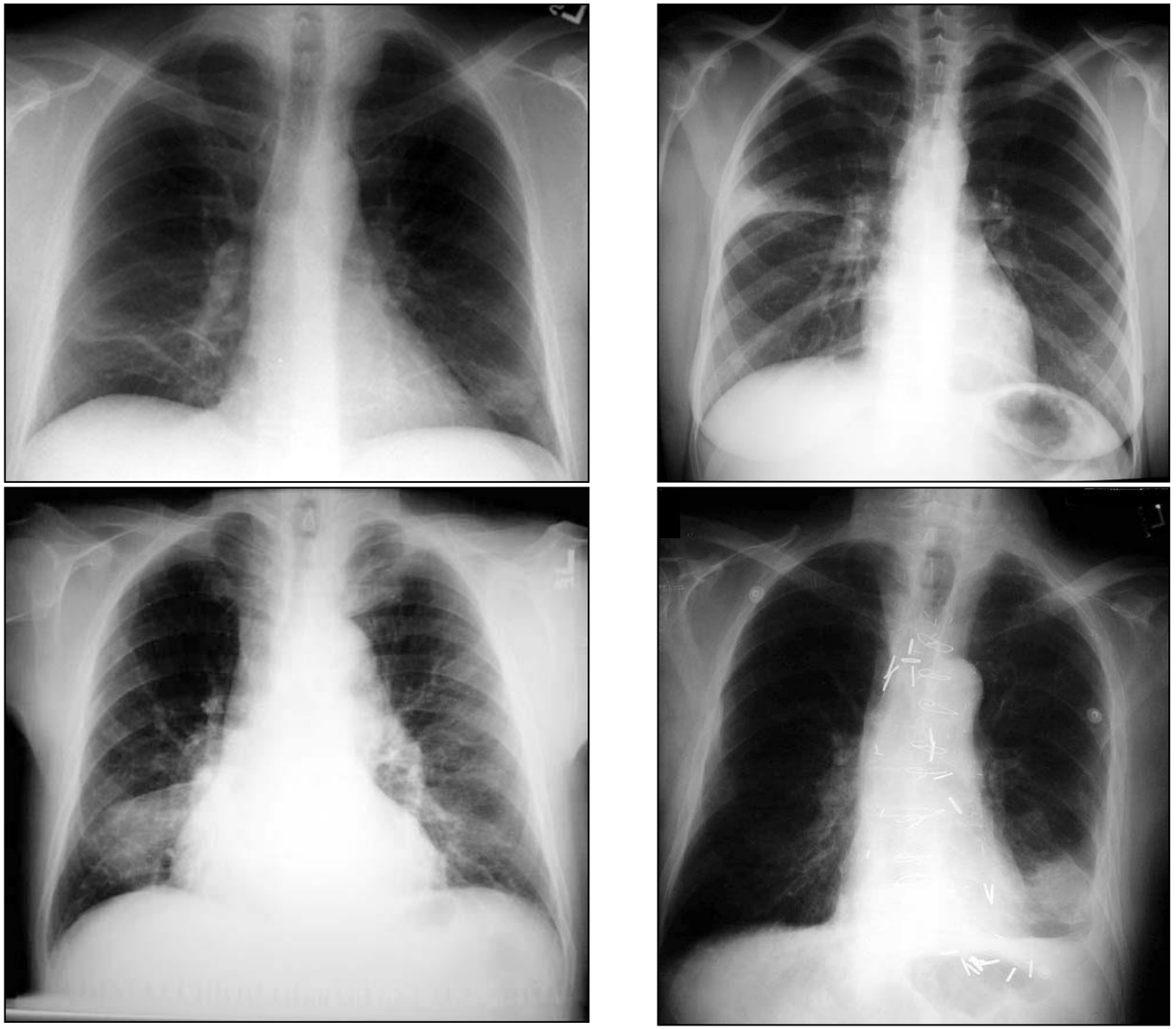


LUL Collapse

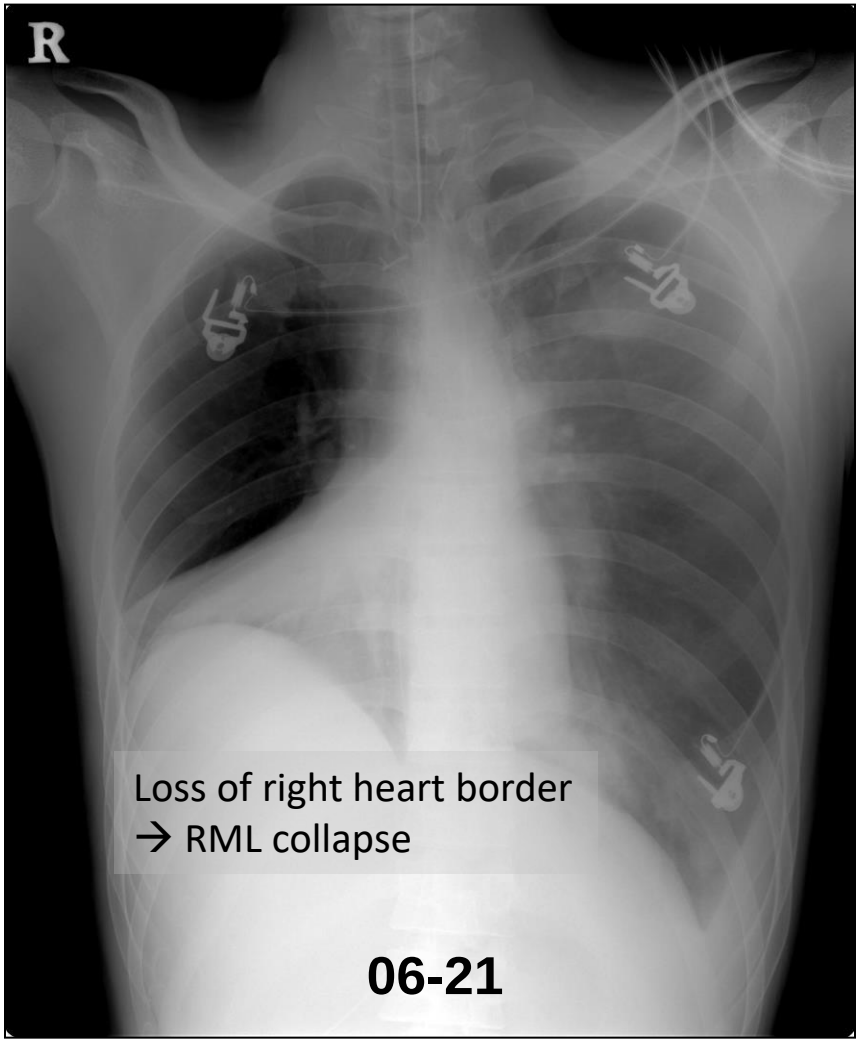
LLL Collapse

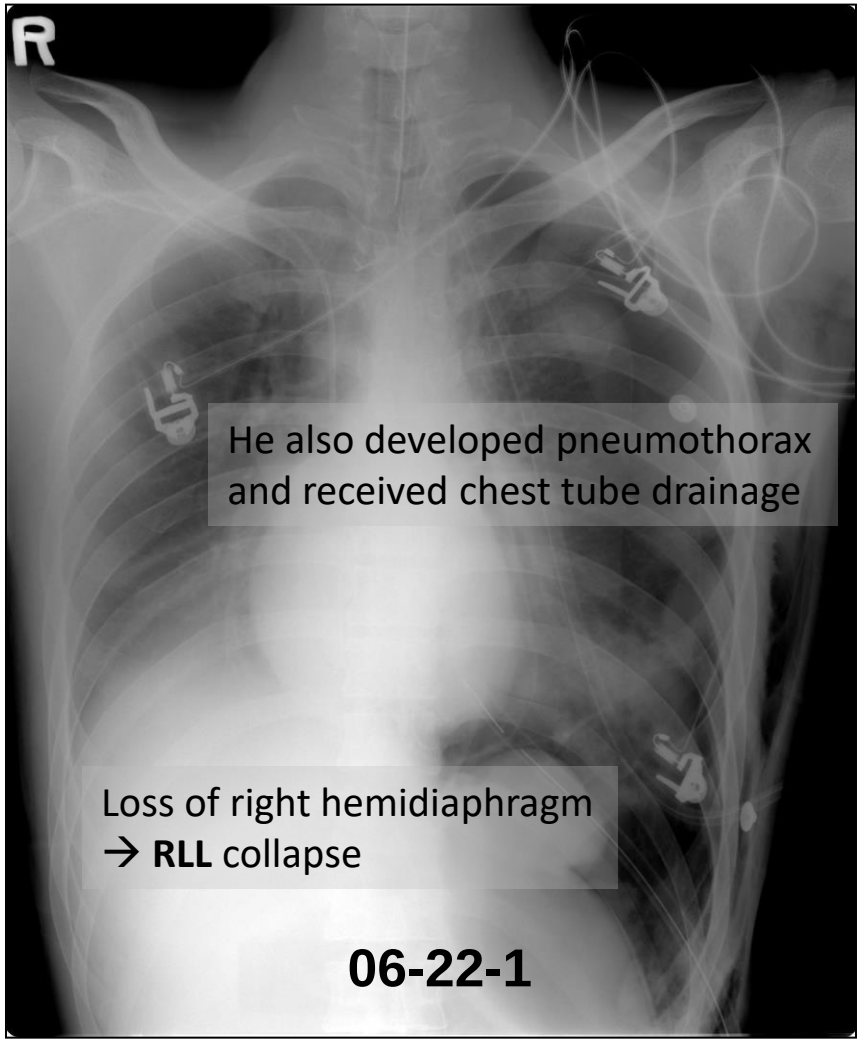


Segmental or Subsegmental Atelectasis

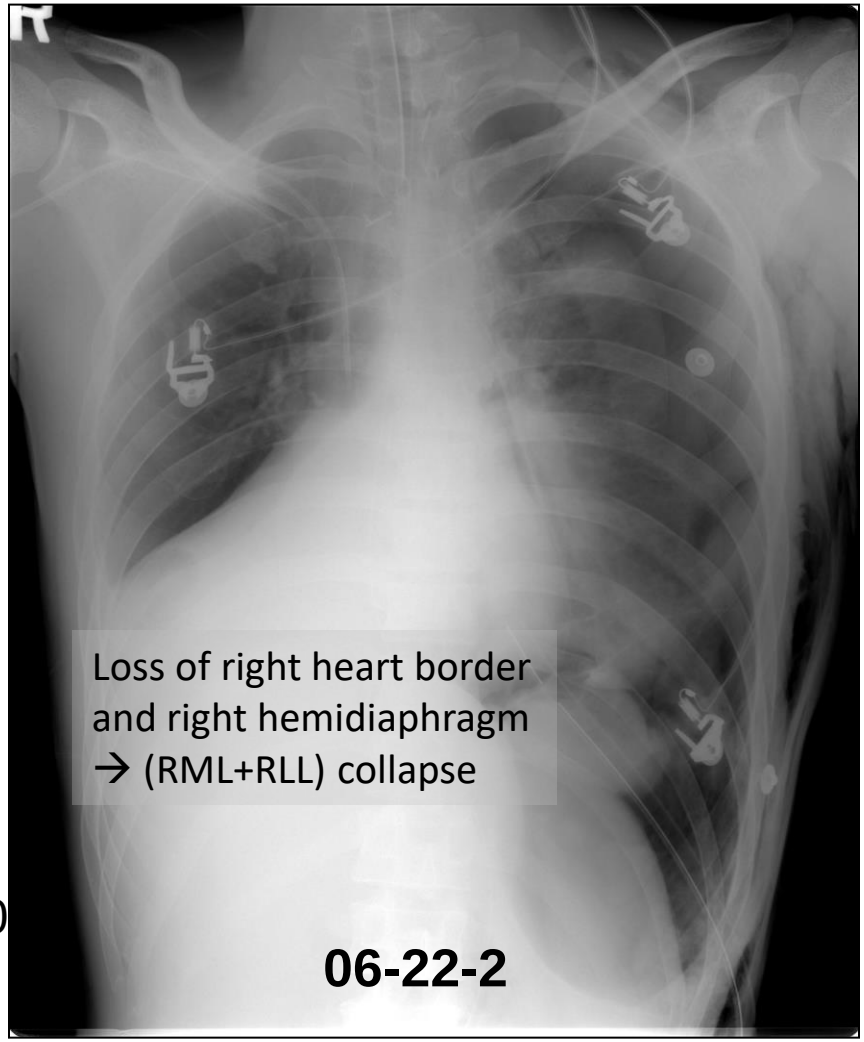


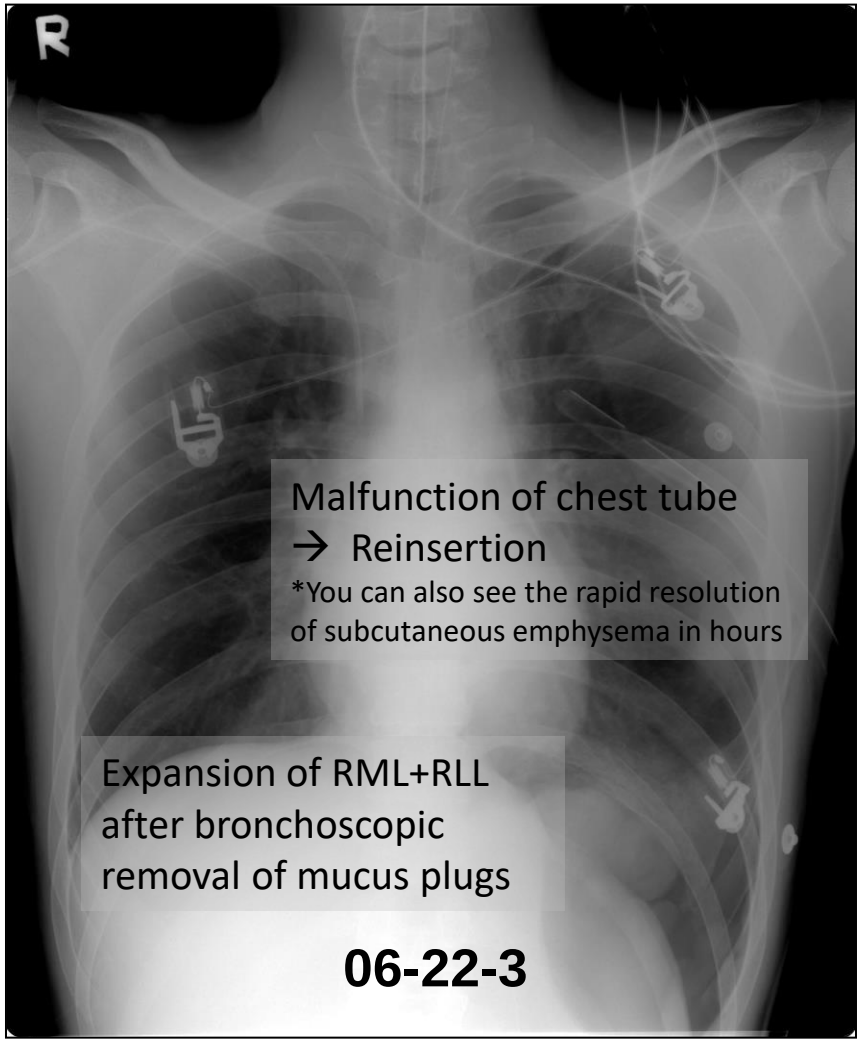
An ICU patient with atelectasis changing rapidly over time



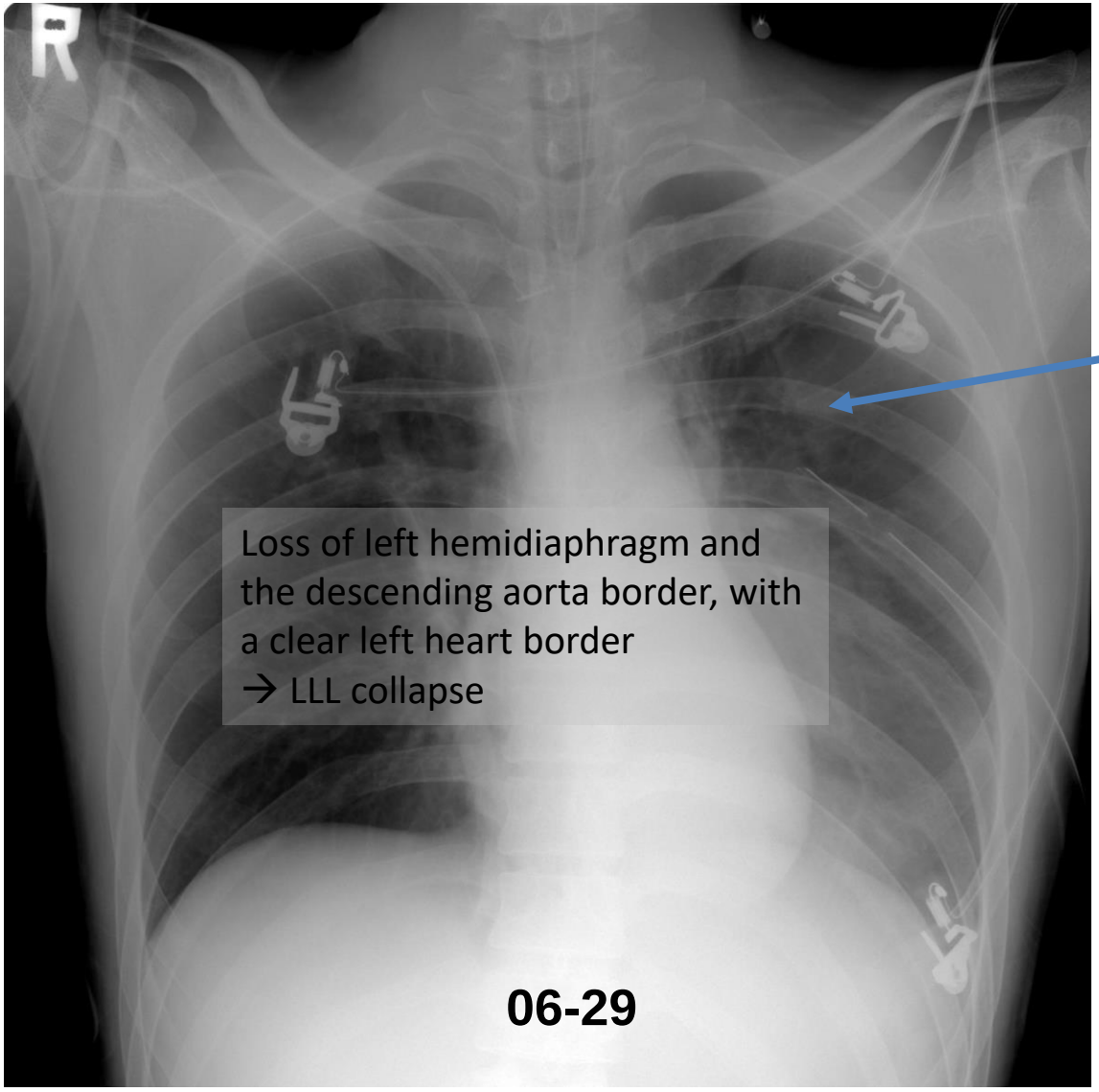


An ICU patient with atelectasis changing rapidly over time





Several days later… LLL collapse



Finally, this patient recovered from respiratory failure. Here is a nodule. Did you see it?

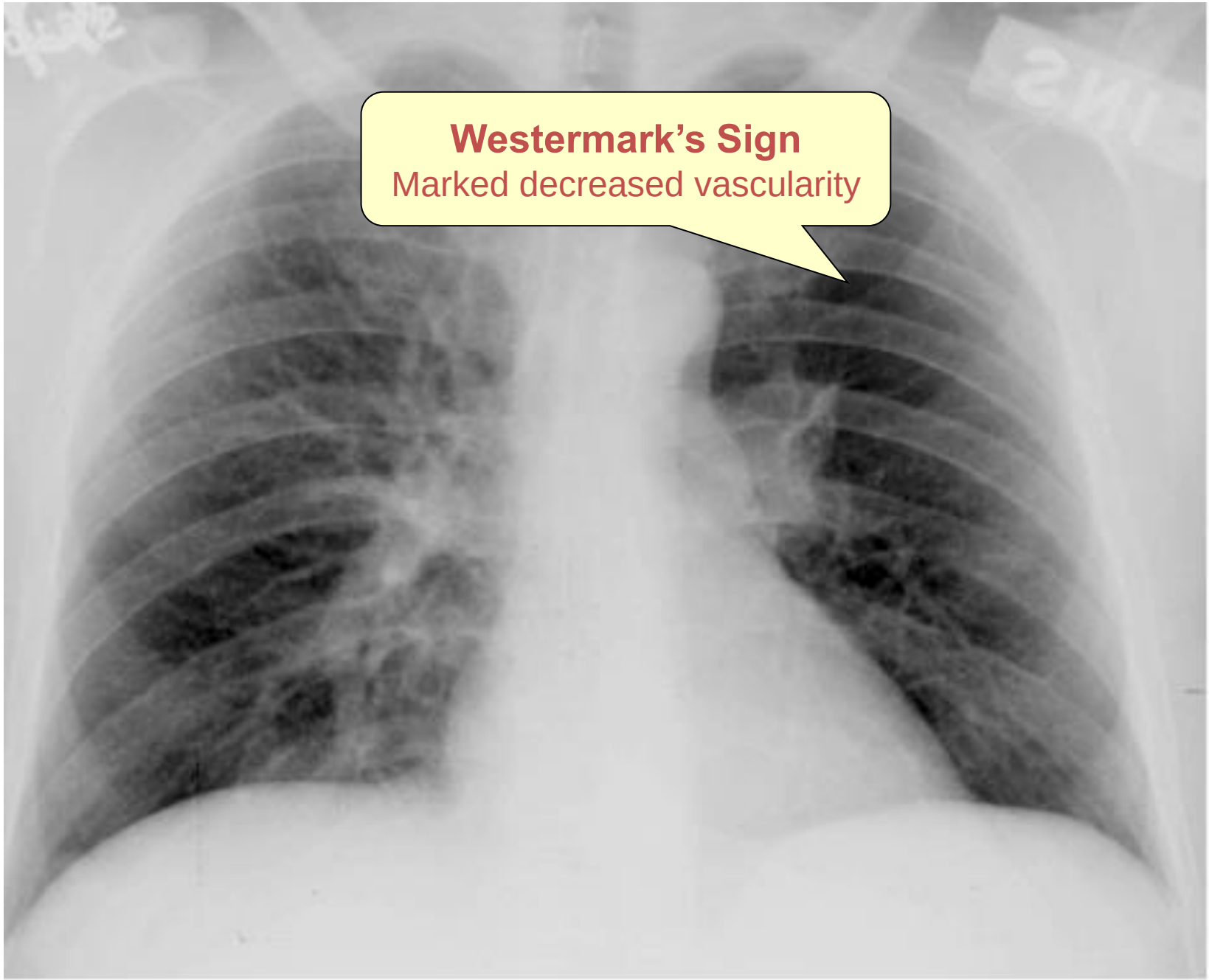
This nodule was pathologically proven to be a lung adenocarcinoma.

Pulmonary Embolism

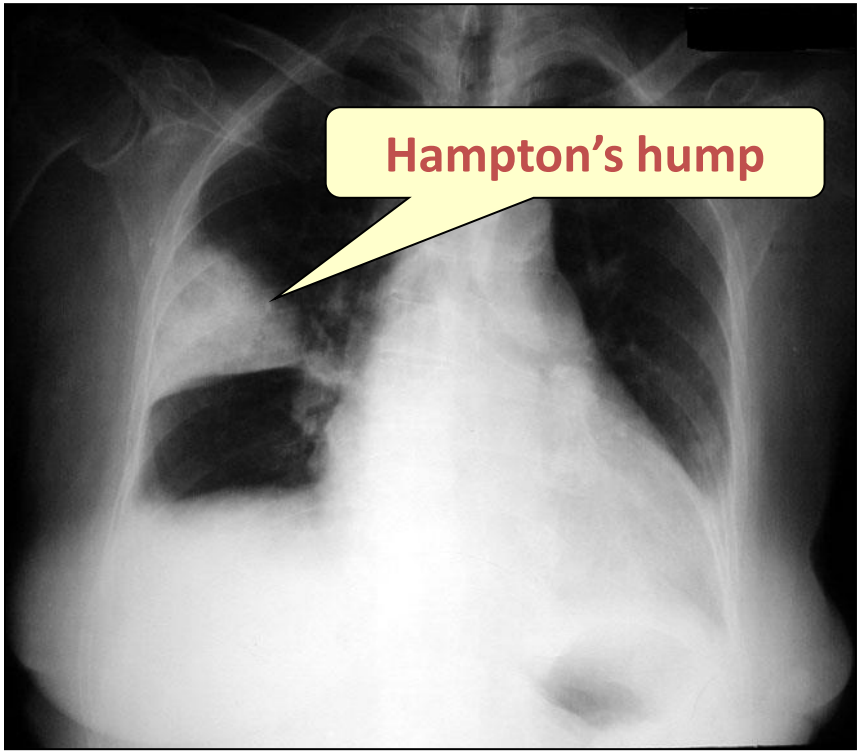
All the signs of PE have poor sensitivity and specificity.
The major role of CXR is to exclude other diagnoses.

CXR of Pulmonary Embolism

- **Normal**
- **Westermark's sign:**
  - Oligemia of the lung beyond the occluded vessel
- **Hampton's hump:**
  - pleural-based, wedge-shape air-space consolidation. Caused by pulmonary hemorrhage or infarction.
- **Signs of right heart failure:**
  - cardiomegaly, engorged PA
- **Pleural effusion:**
  - 50%, small amount, unilateral, transudate or exudate, may be bloody.


Westermark's Sign
Marked decreased vascularity

Pulmonary Infarction



- It takes several months to resolve
- Frequently leaves permanent linear scar
- Cavitation is rare

Summary

- 重症病人何時需照CXR
- 重症病人的CXR判讀要領與一般病人有何不同
- 各種導管的適當位置
- Barotrauma
- ARDS vs Cardiogenic pulmonary edema
- Fluid status evaluation
- Lung atelectasis
- Pulmonary embolism