
بسم الله الرحمن الرحيم

# Imaging in Pulmonary Embolism


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# Background Information

Pulmonary embolism is a life-threatening condition that occurs when a clot of blood or other material blocks an artery in the lungs.

This is an extremely common and highly lethal condition that is a leading cause of death in all age groups.

One of the most prevalent disease processes responsible for in-patient mortality (30%)

Overlooked diagnosis.

# Facts about PE

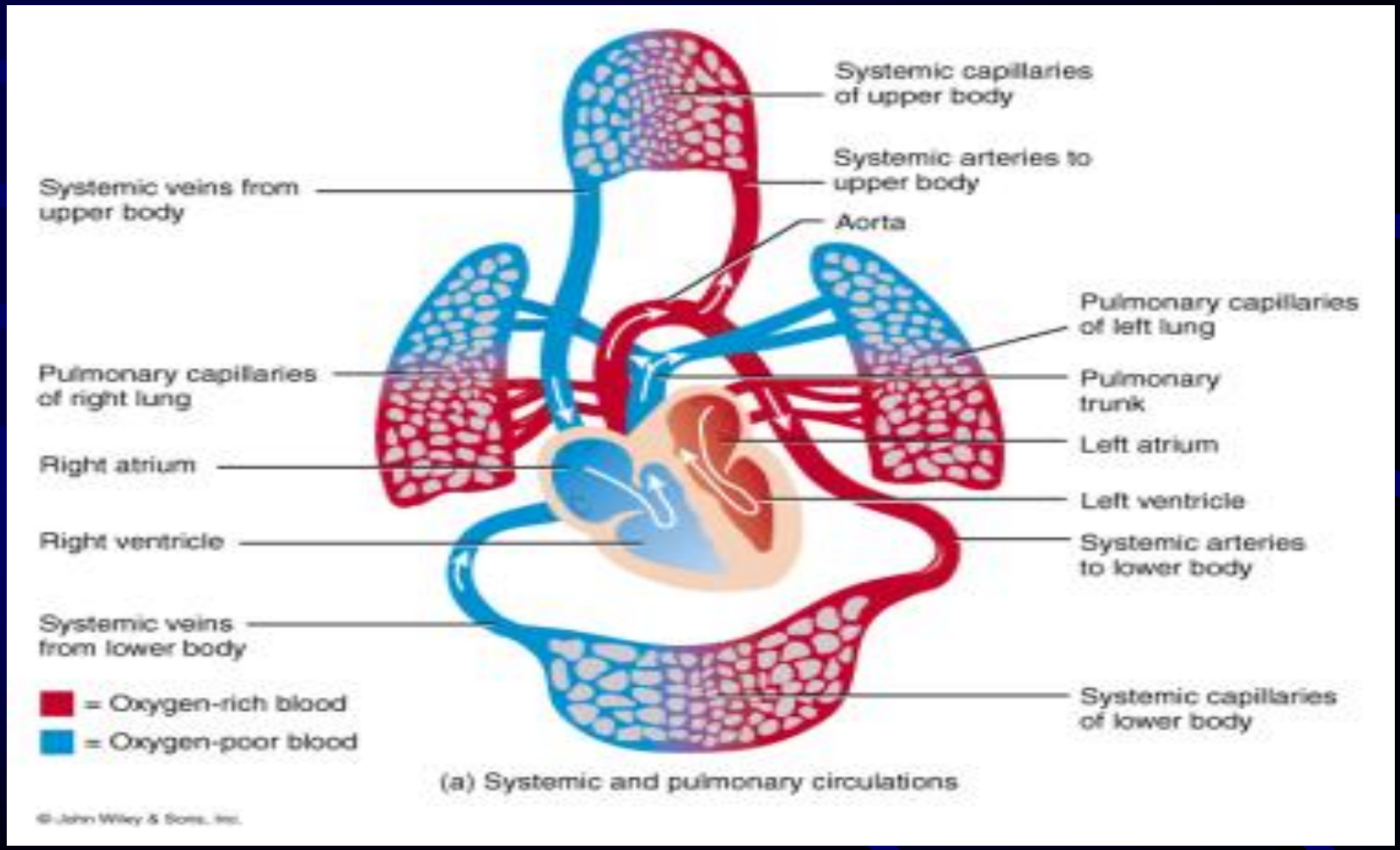
3rd most common cause of death.

2nd most common cause of unexpected death in most age groups.

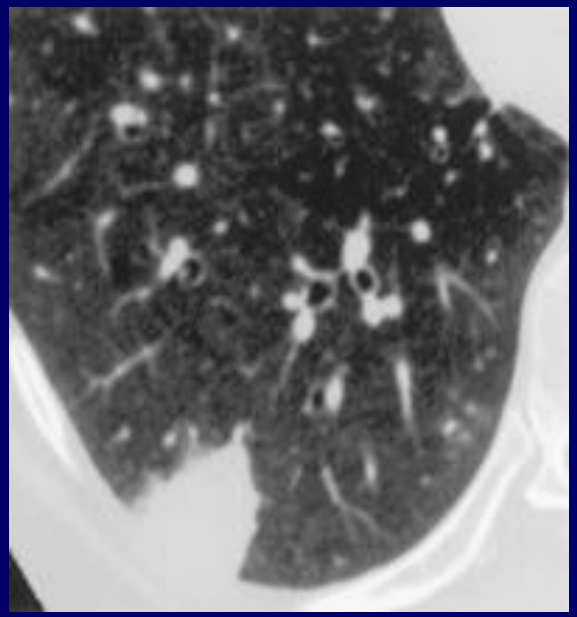
60% of patients dying in the hospital have had a PE.

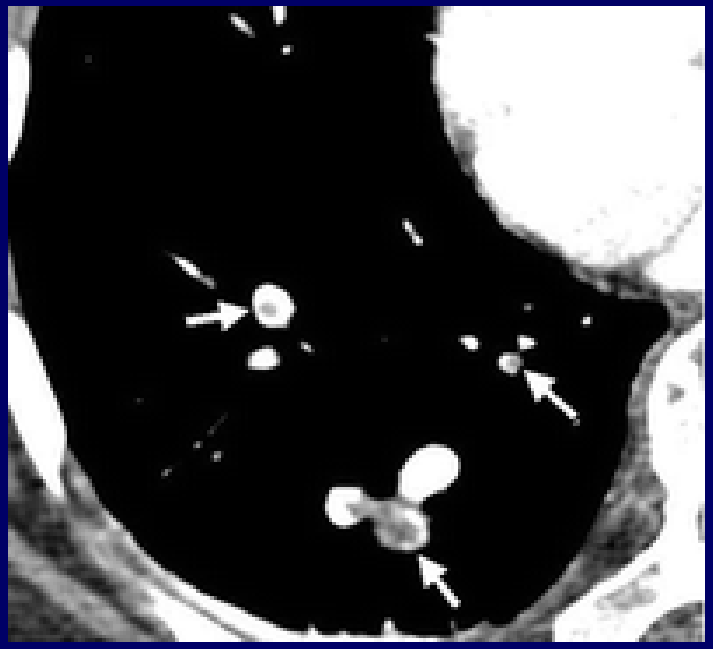
Diagnosis has been missed in about 70% of the cases

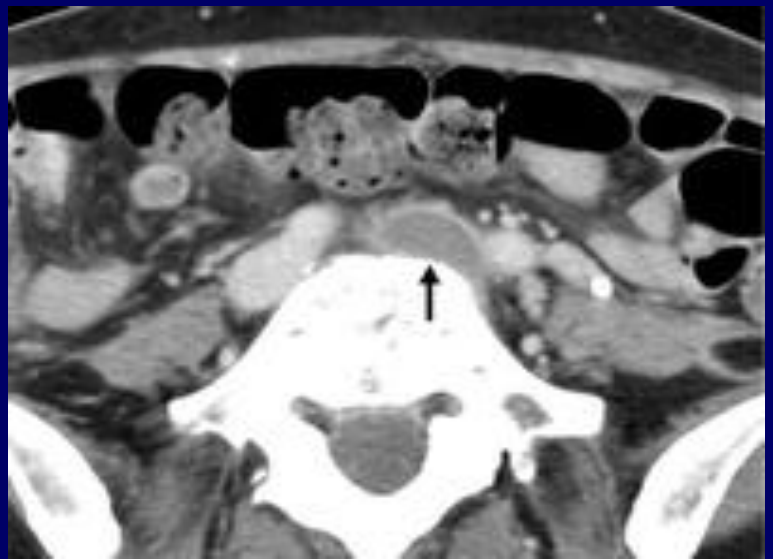
Pulmonary embolism is a life-threatening condition that occurs when a clot of blood or other material blocks an artery the lungs.



# Thrombotic Pulmonary Embolism







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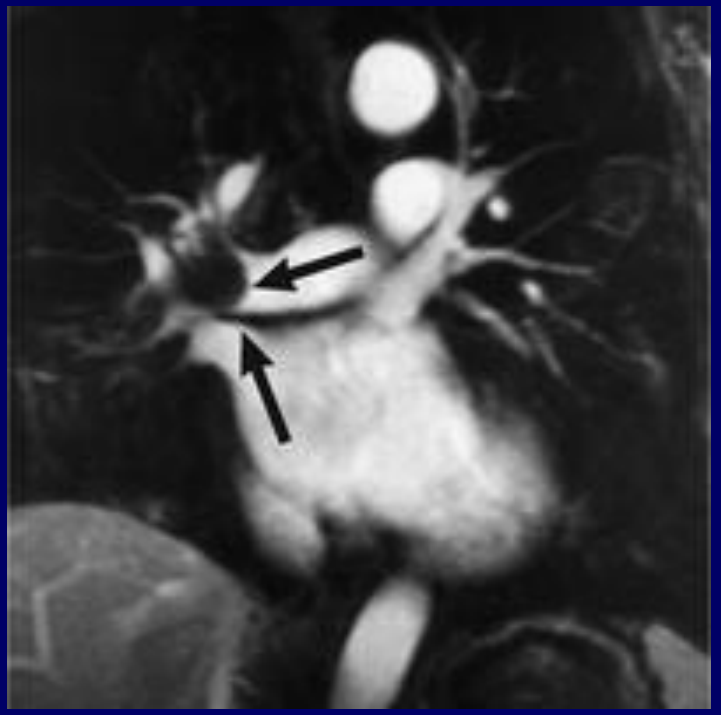

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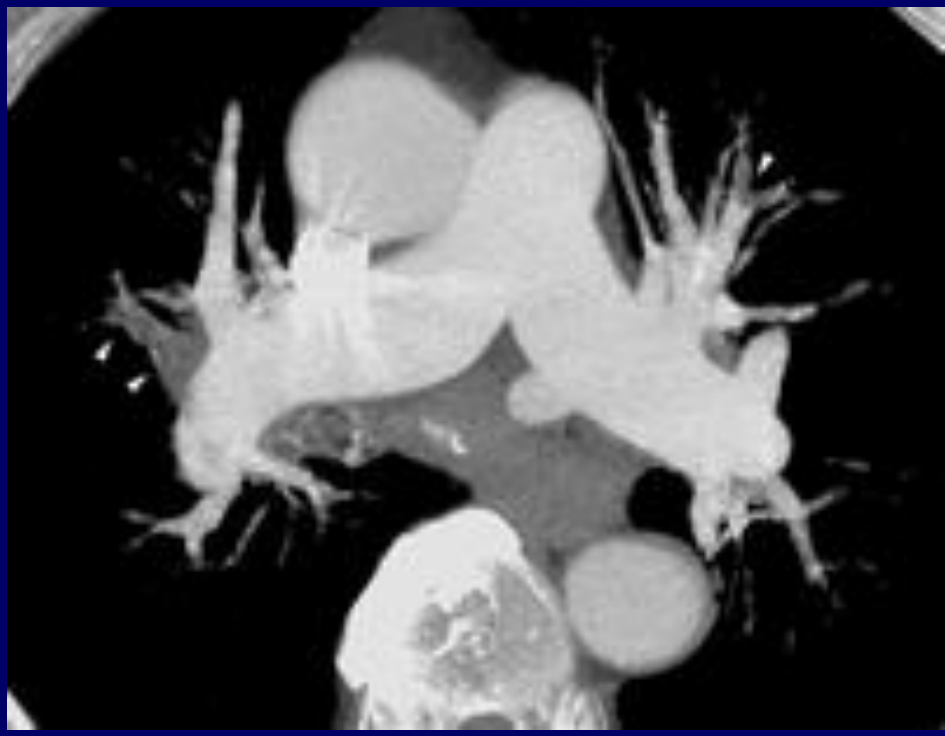
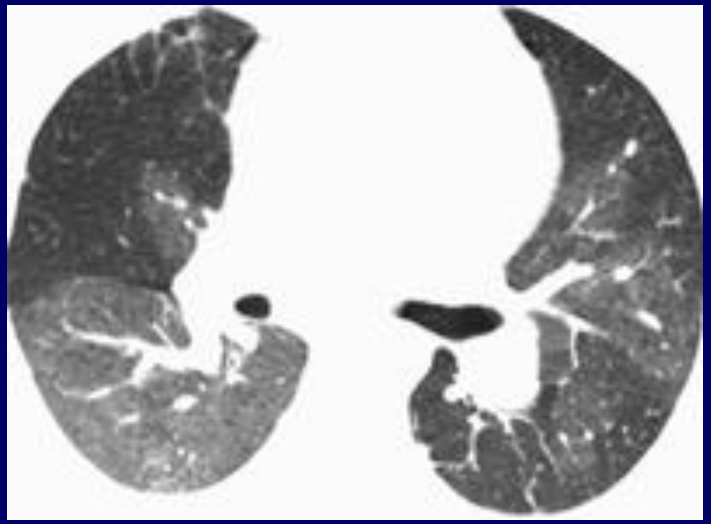
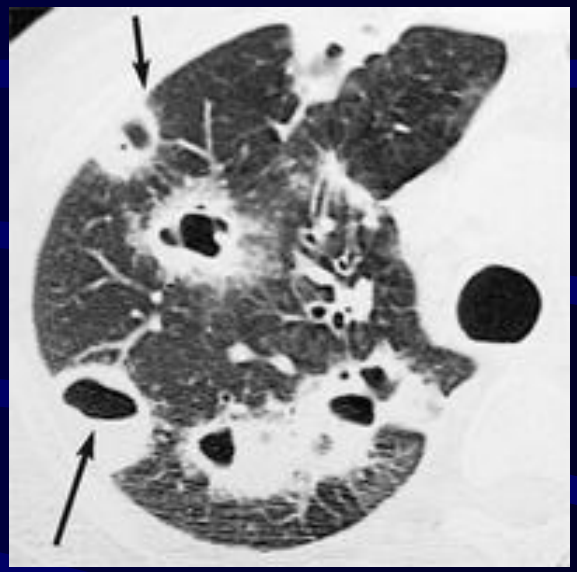
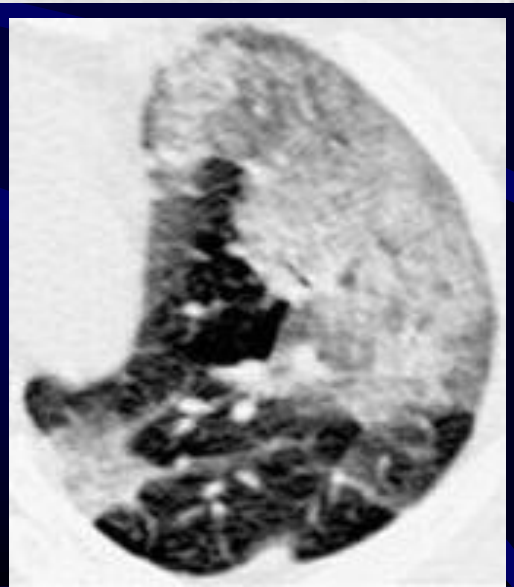




# Nonthrombotic Pulmonary Embolism





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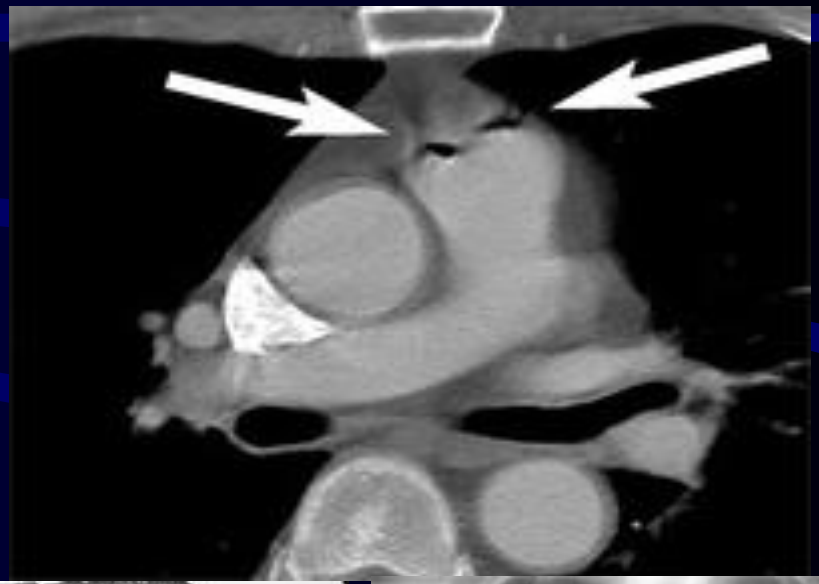

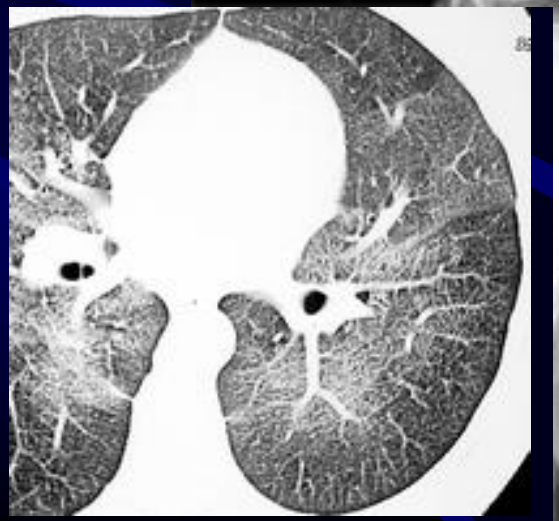

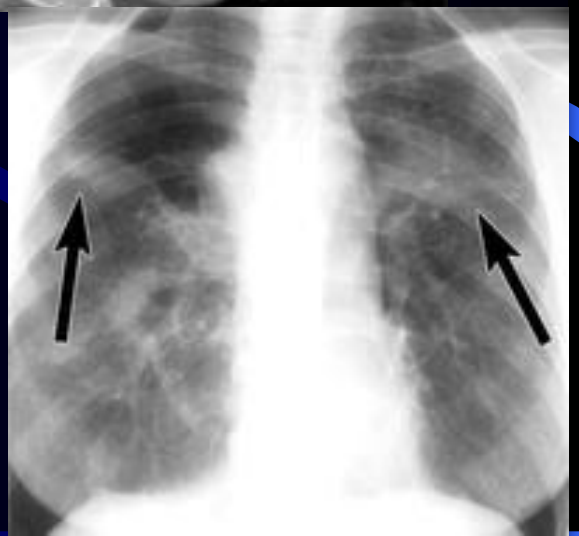

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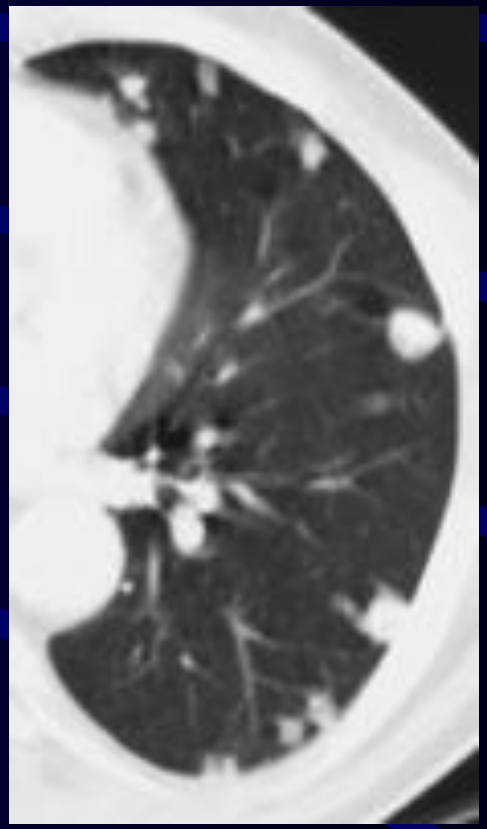

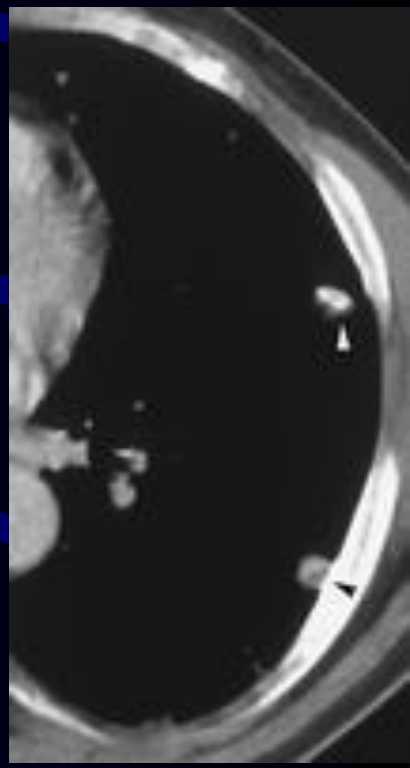

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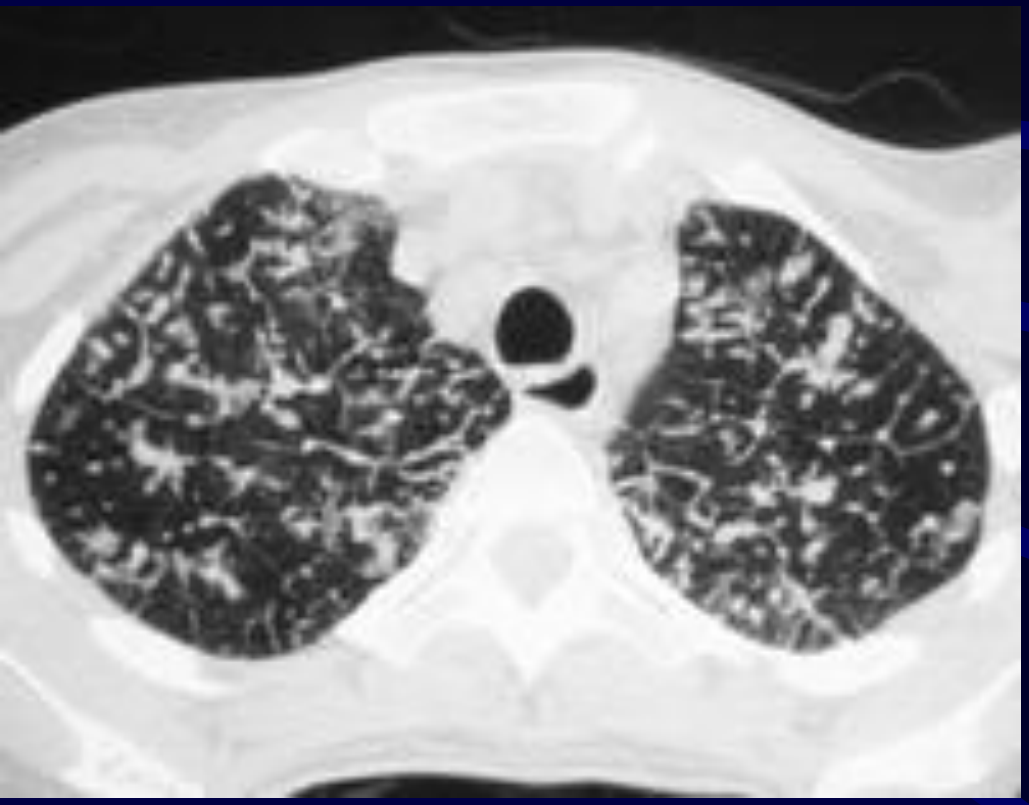

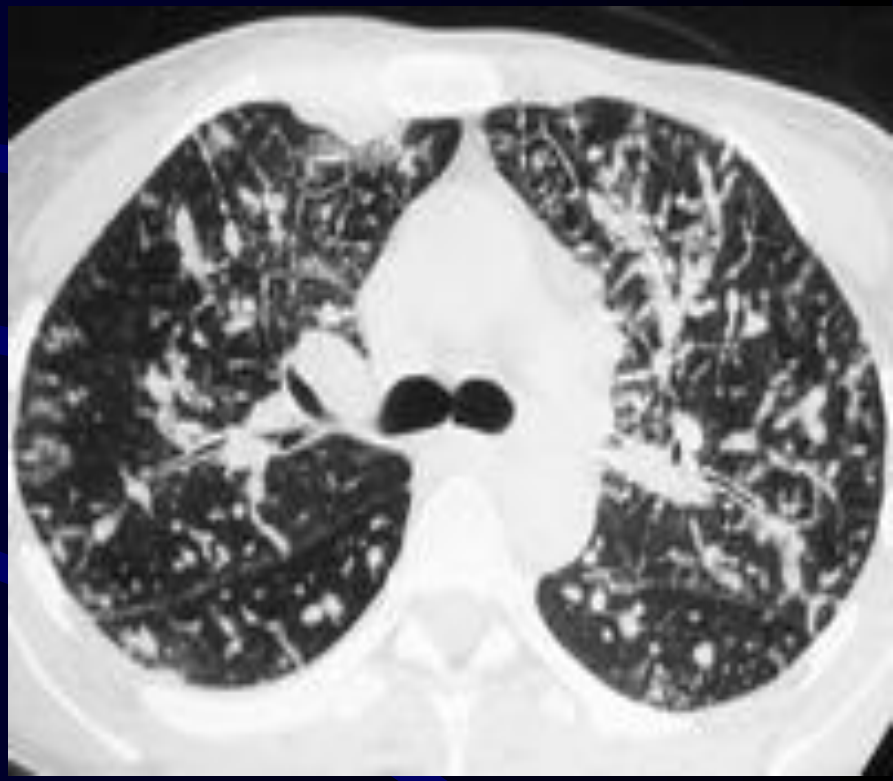

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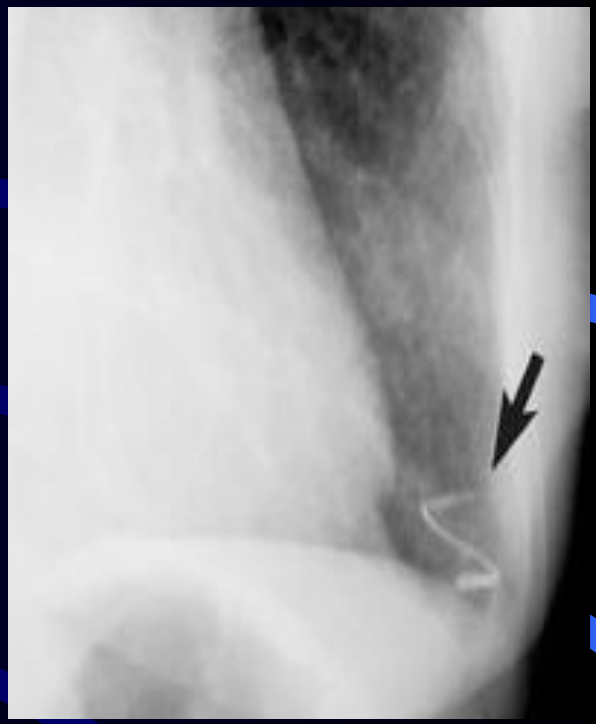


# Chest x-ray findings of a Pulmonary Embolus

14% Normal
68% Atelectasis or parenchymal density
48% Pleural Effusion
35% Pleural based opacity
24% Elevated diaphragm
15% Prominent central pulmonary artery
7% Westermark's sign
7% Cardiomegaly
5% Pulmonary edema

# Plain film radiography **Chest X-ray**

- Initial CxR always **NORMAL**.

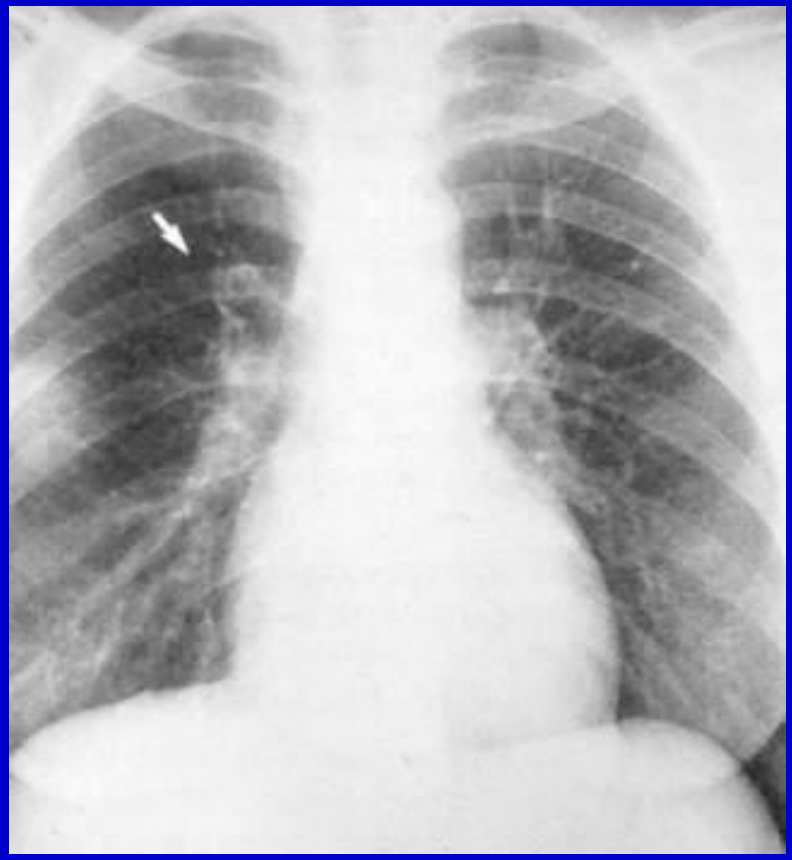
# Plain film radiography **Chest X-ray**

- Initial CxR always **NORMAL**.
- May show – Collapse, consolidation, small pleural effusion, elevated diaphragm.
- Pleural based opacities with convex medial margins are also known as a Hampton's Hump

Gloucestershire Hospitals NHS
NHS Trust
Nick Oldnall, Clinical Practice Developer

# Plain film radiography **Chest X-ray**

- Initial CxR always **NORMAL**.
- May show – Collapse, consolidation, small pleural effusion, elevated diaphragm.
- **Westermark sign** – Dilatation of pulmonary vessels proximal to embolism along with collapse of distal vessels, often with a sharp cut off.

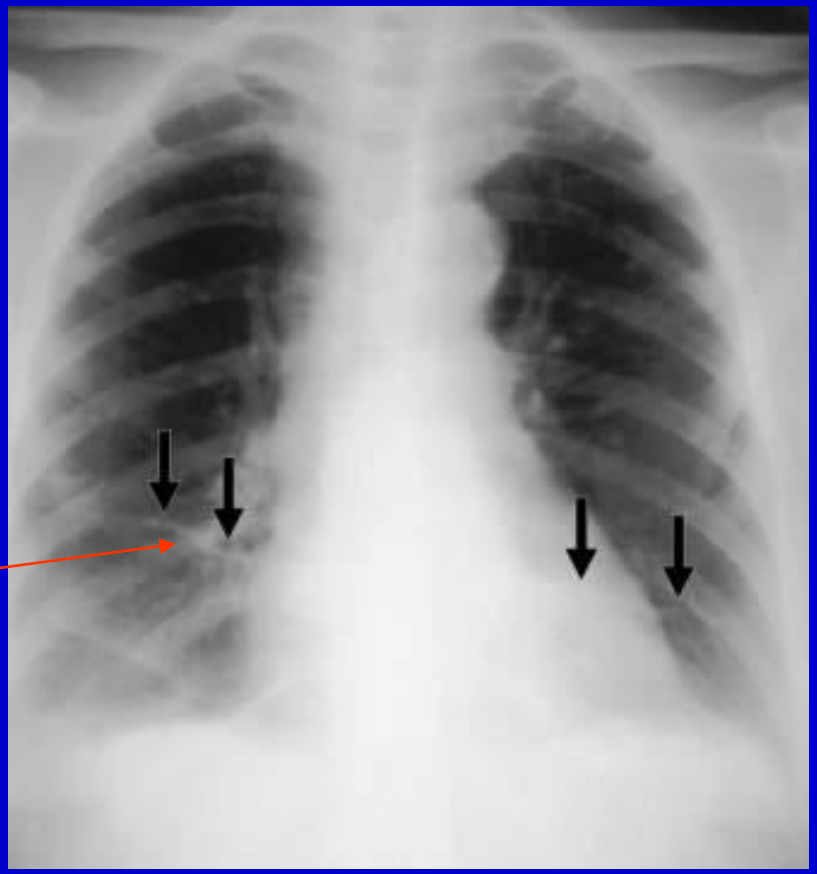


# Embolism without Infarction

- Most PEs (90%)
- Frequently normal chest x-ray
- Pleural effusion
- Westermark's sign
- "Knuckle" sign abrupt tapering of an occluded vessel distally
- Elevated hemidiaphragm

# Embolism with Infarction

- Consolidation
- Cavitation
- Pleural effusion (bloody in 65%)
- No air bronchograms
- "Melting" sign of healing
- Heals with linear scar



# Hampton's Hump

- Pleural based opacities with convex medial margins are also known as a Hampton's Hump. _ This may be an indication of lung infarction. However, that rate of resolution of these densities is the best way to judge if lung tissue has been infarcted. Areas of pulmonary hemorrhage and edema resolve in a few days to one week. The density caused by an area of infarcted lung will decrease slowly over a few weeks to months and may leave a linear scar

## Wedge Shaped Density

The wedge's base is pleural and the apex is towards the hilum, giving a triangular shape. You can encounter either of the following:

**Vascular wedges :**

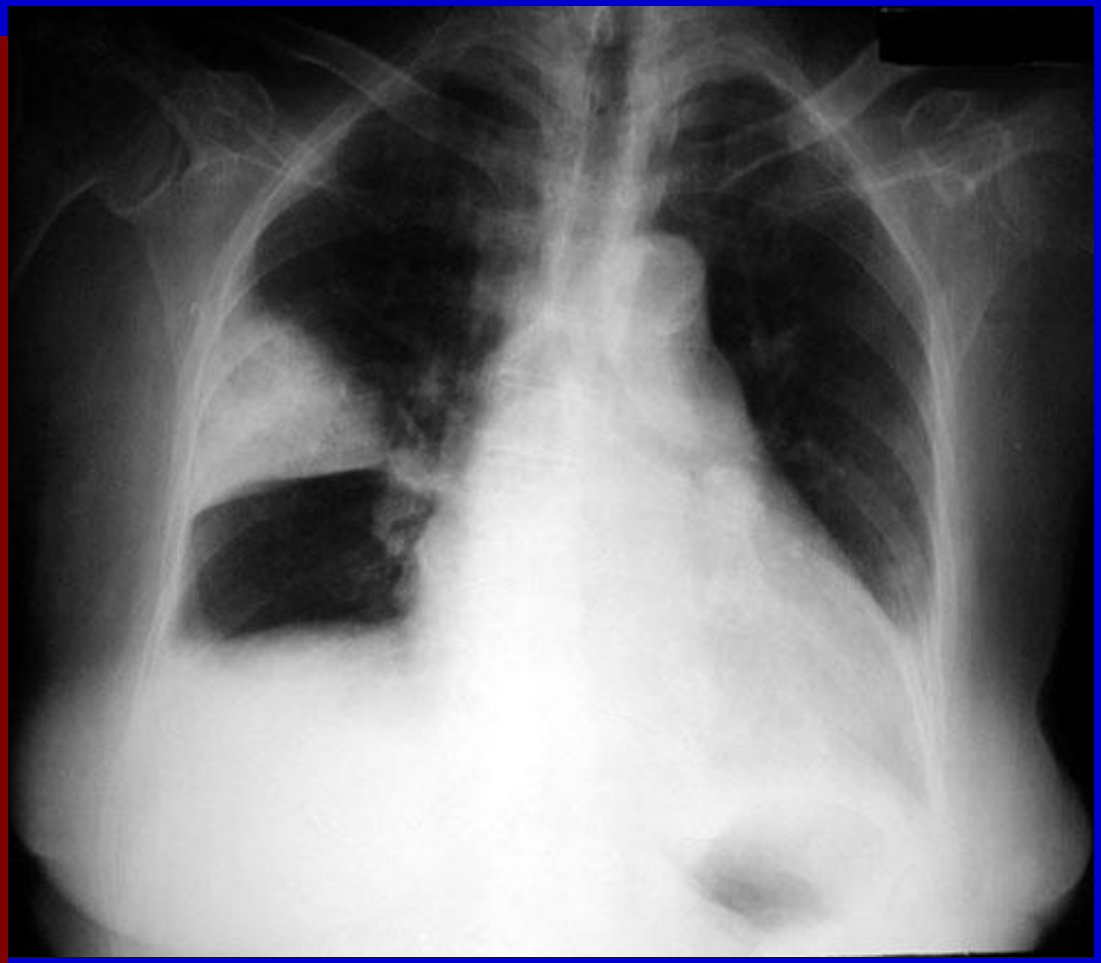
Infarct

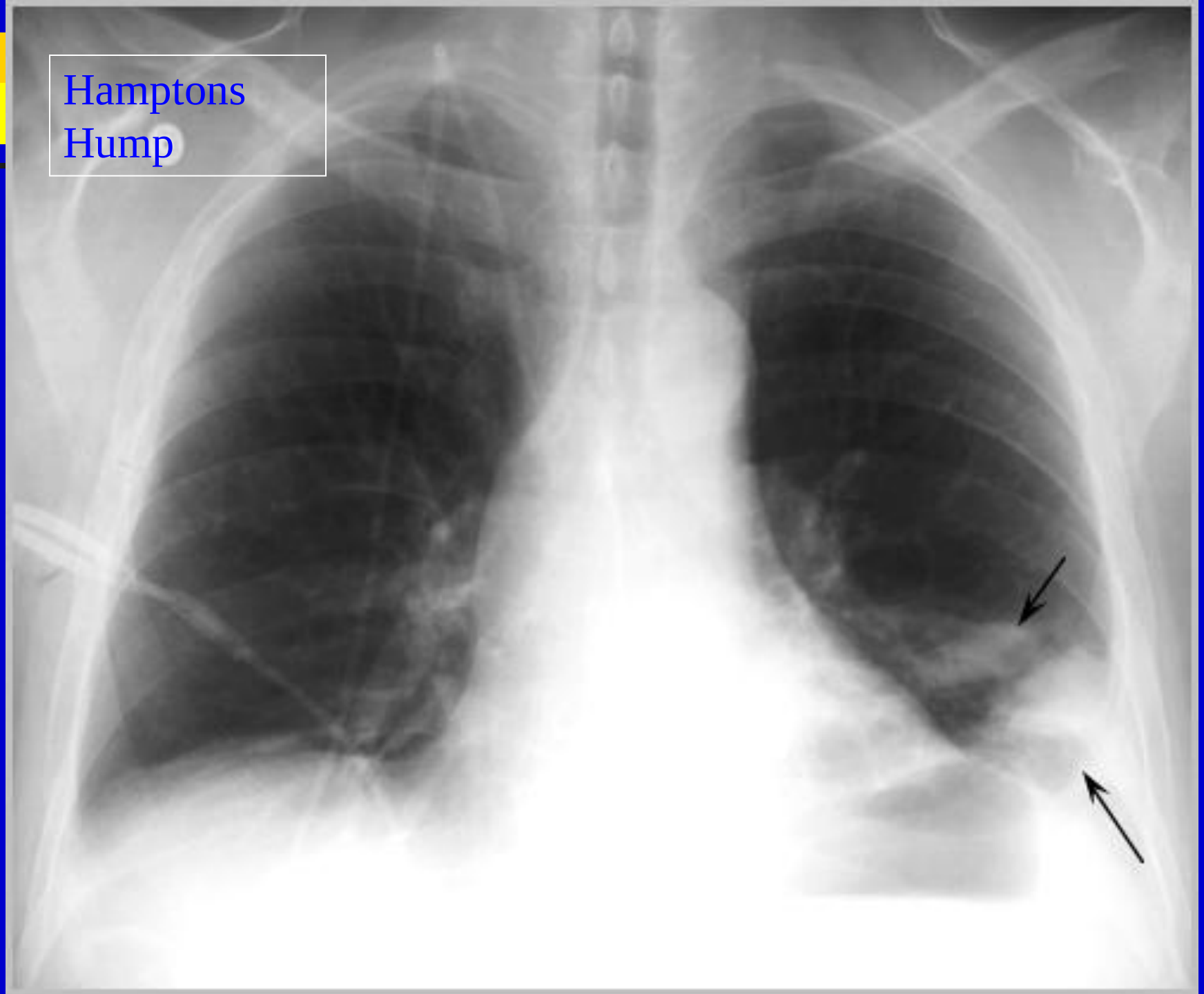
Invasive aspergillosis

**Bronchial wedges :**

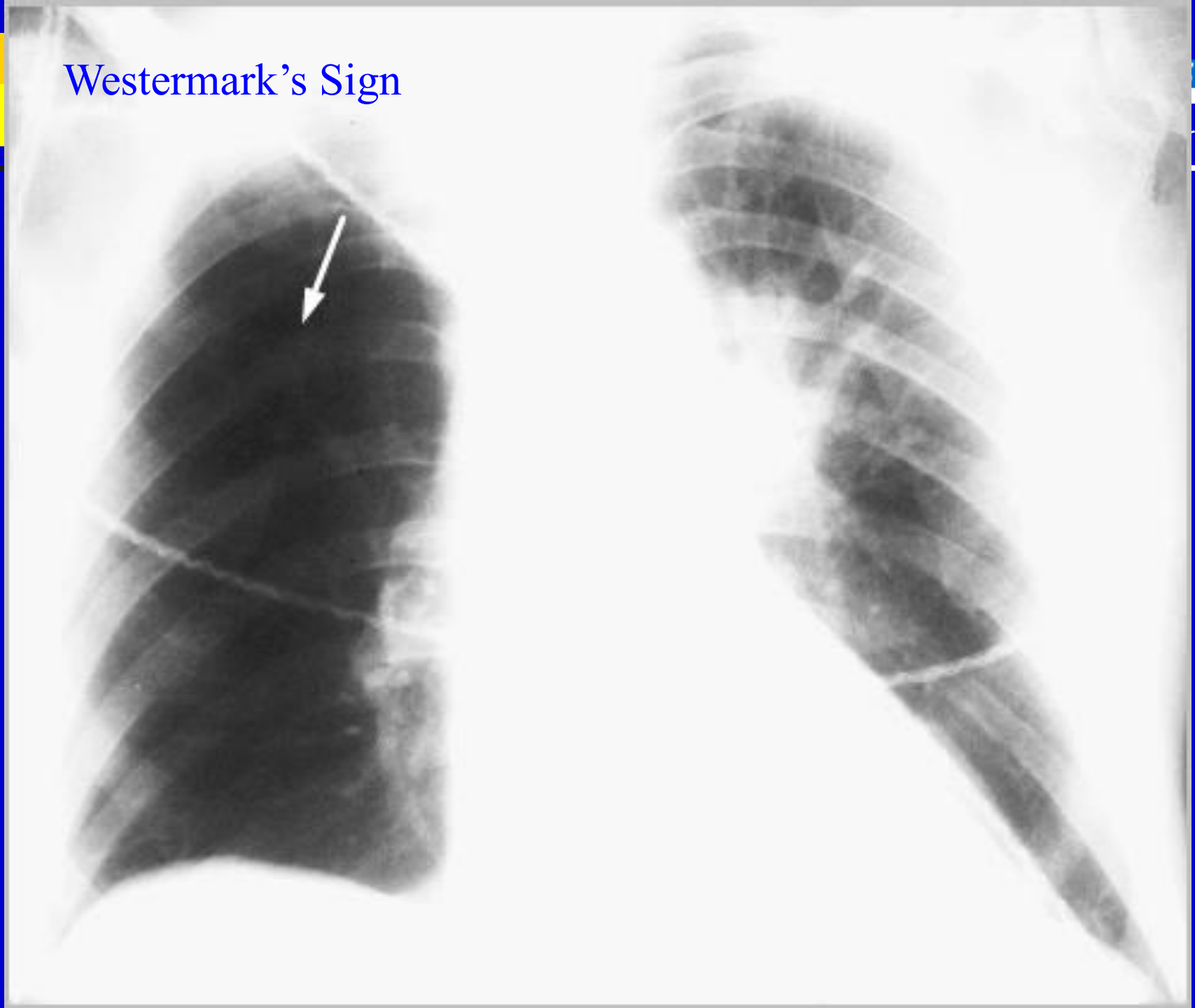
Consolidation

Atelectasis

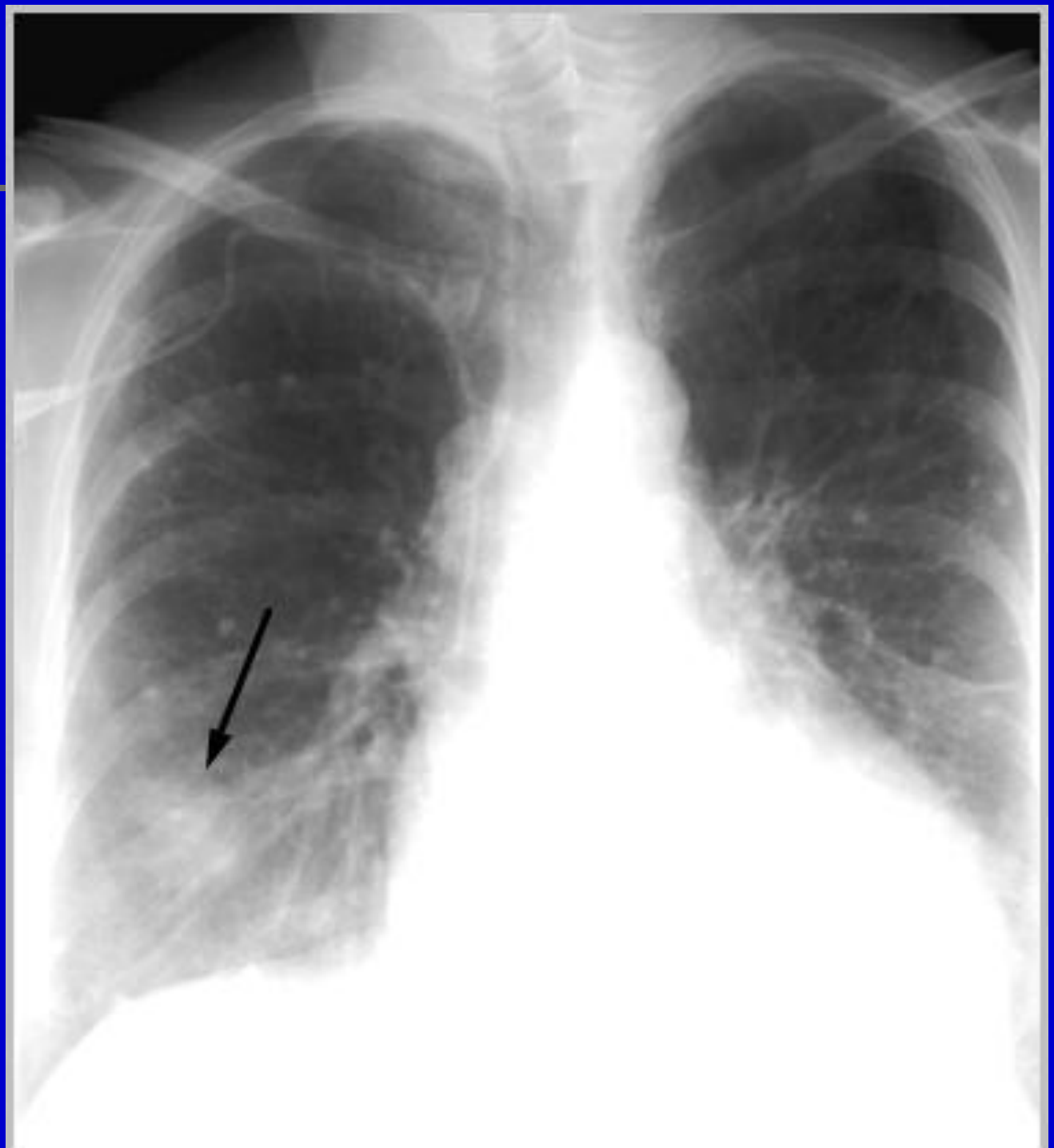


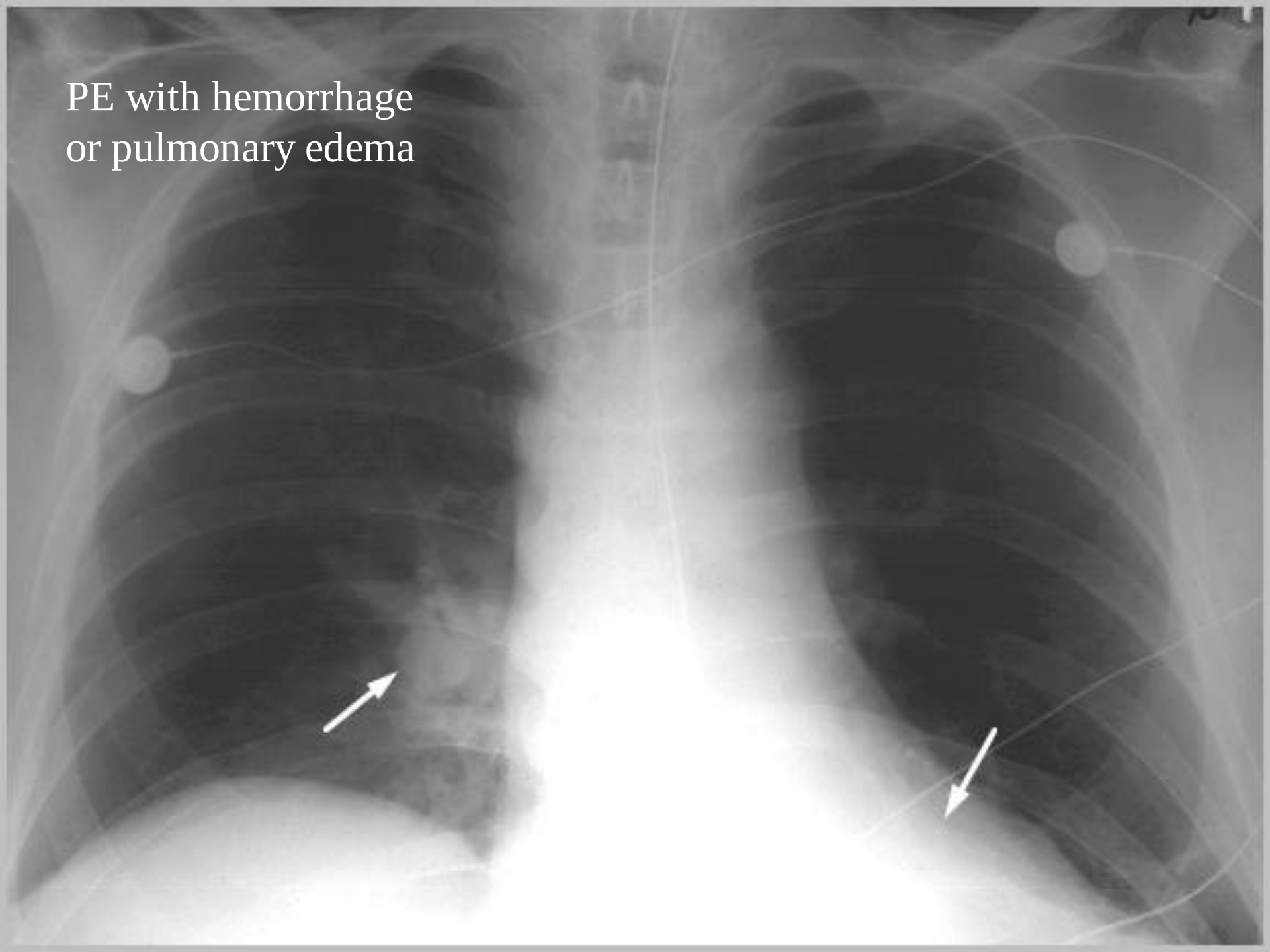

Hamptons
Hump

# Westermark's Sign



PE which appears like a mass.




PE with hemorrhage
or pulmonary edema

PE with effusion
and elevated diaphragm

# Echocardiographic features of PE

- RV dilatation
- RV size does not change from diastole to systole = hypokinesis
- D-shaped LV
- 40% of pts. W/ PE have RV abnormalities seen by ECHO

Goldhaber, S. Pulmonary embolism.NEJM.1988.339(2):93-104.

# *Lower extremity venous ultrasonography*

- Compression U/S = B-mode imaging only
- Duplex U/S = B-mode plus Doppler waveform analysis
- Limited vs.complete exam
  - Illiac, common femoral, femoral, popliteal, greater saphenous, calf veins

Advantages

- Cost
- Portability
- May avoid further diagnostic imaging if positive

Limitations

- Low sensitivity and risk of false positives
- No consistent protocol for technique
- Operator dependant

Turkstra F; Kuijer PM; van Beek EJ; Brandjes DP; ten Cate JW; Buller HR. Ann Intern Med. 1997 May 15;126(10):775-81.

# *Venous Ultrasonography*

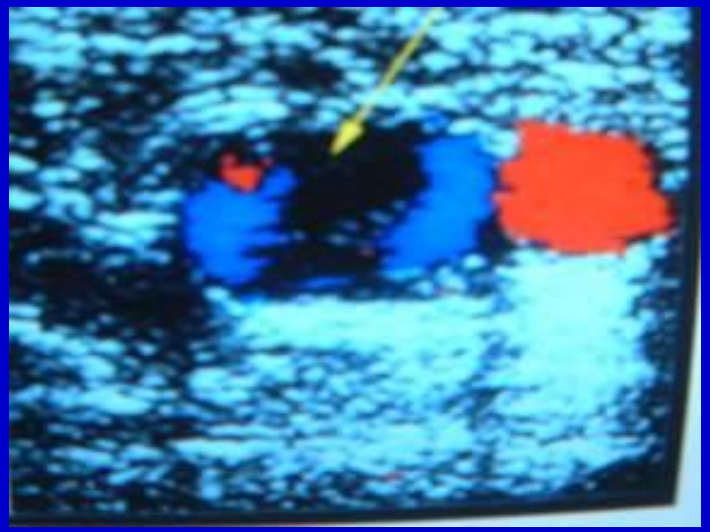
Recommendations of Use

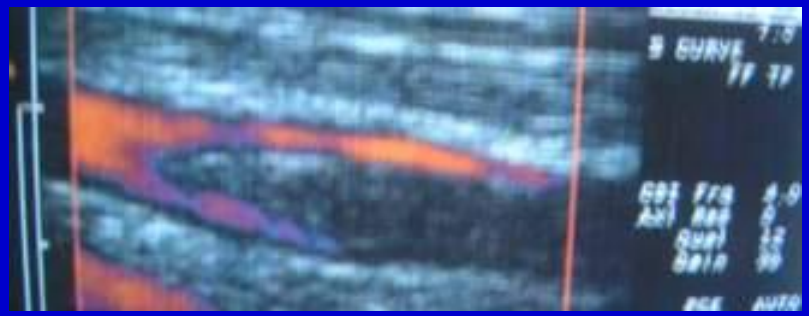
- First-line if radiographic imaging contraindicated or not readily available
- Not likely required in patient with negative CT-PA
- Helpful to rule out DVT in patient with non-diagnostic V/Q scan

Anderson DR; Barnes D. Semin. Nucl. Med. 2008 Nov;38(6)412-7.

# Ultrasound

- Duplex scanning with compression will aid to detect any thrombus.
  Highly sensitive and specific for diagnosing DVT.
  Look for loss of flow signal, intravascular defects or non collapsing vessels in the venous system





# V/Q Scanning.

- Single most important  diagnostic modality for detecting PE.
- Always indicated when PE is suspected and there is no other diagnosis.
- Non diagnostic V/Q scan is not an acceptable end point in the workup of PE.
- 1 in every 25 pts sent home after a normal V/Q scan actually has a PE that has been **MISSED.**

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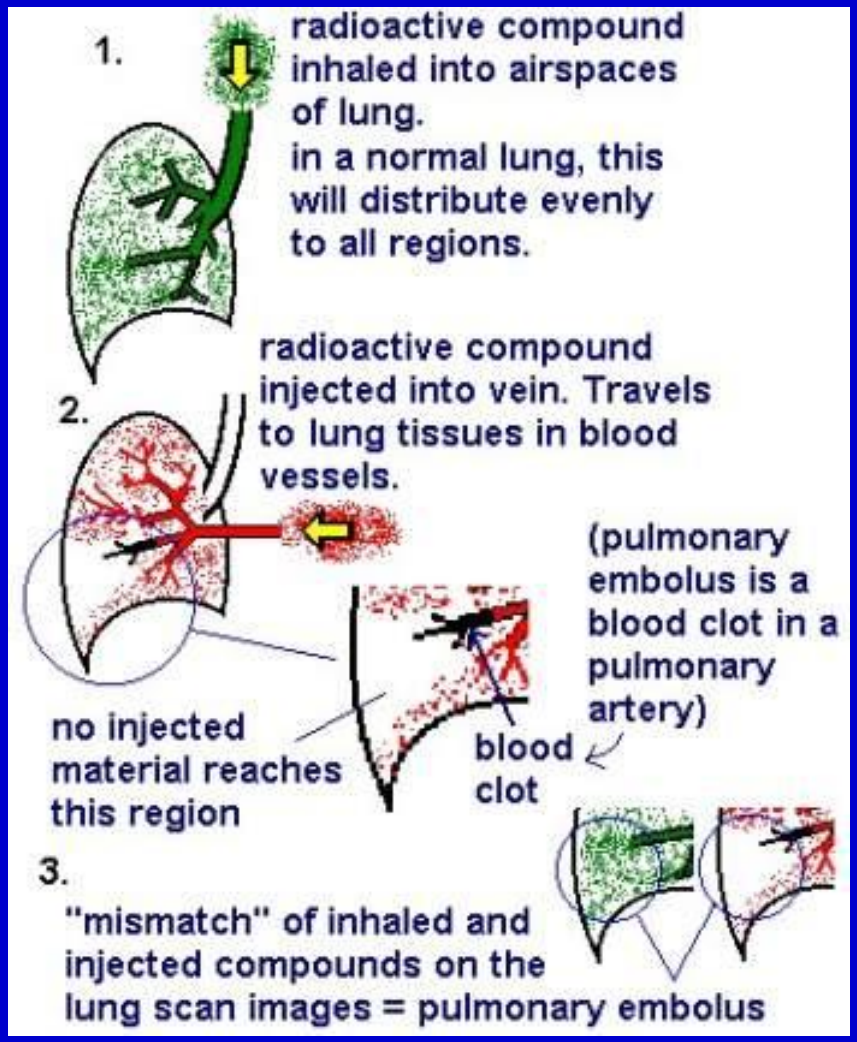
# V/Q Scanning



# The Lung Scan Perfusion

## Perfusion

- IV injection of human serum albumin labelled w/ technetium-99m
- Particles are same size as pulmonary capillaries and become trapped
- Lung peripheral to a clot is not perfused and will show defect

## Ventilation:

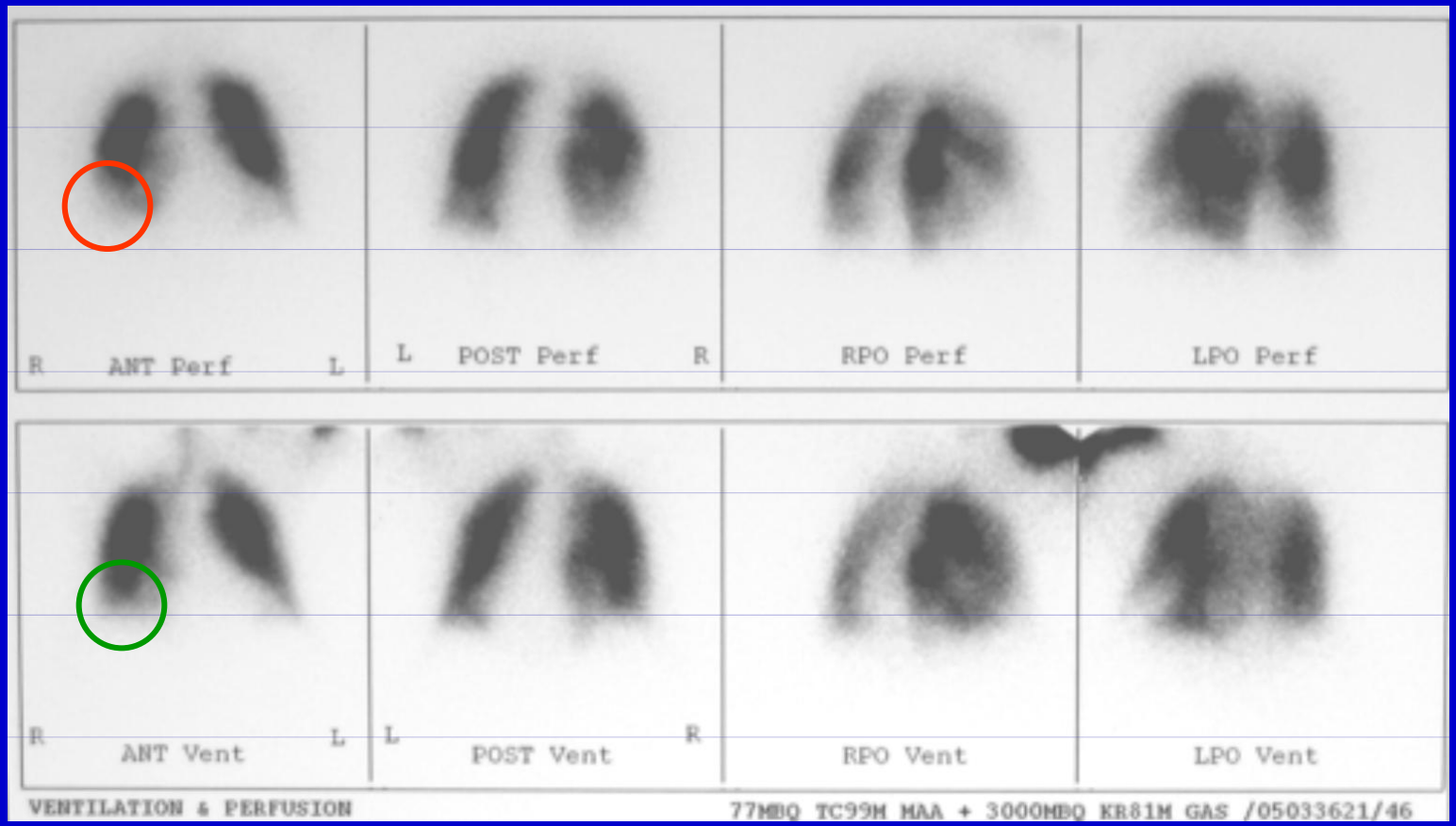
- Inhalation of xenon-133 radioactive gas
- Degree of ventilation of all lung areas can be assesed
- Pneumonia, emphysema, tumors can cause defects
- Pulmonary embolism does not cause ventilation defect

**Therefore, patients w/ a perfusion defect w/out a ventilation defect is suggestive of a pulmonary embolus.**

# V/Q Scanning.

- The perfusion part of the scan is achieved by injecting the patient with technetium 99m, which is coupled with macro aggregated albumin (MAA). This molecule has a diameter of 30 to 50 micrometres, and thus sticks in the pulmonary capillaries. Sufficiently few molecules are injected for this not to have a physiological effect. An embolus shows up as a cold area when the patient is placed under a gamma camera. The MAA has a half life of about 10 hours

# VQ Scan results 1



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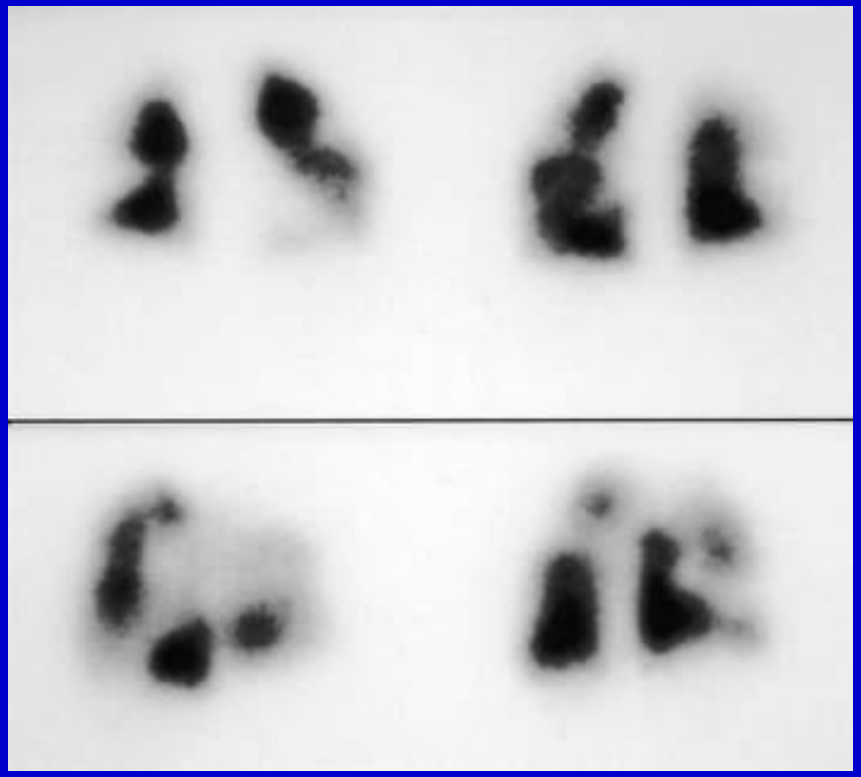
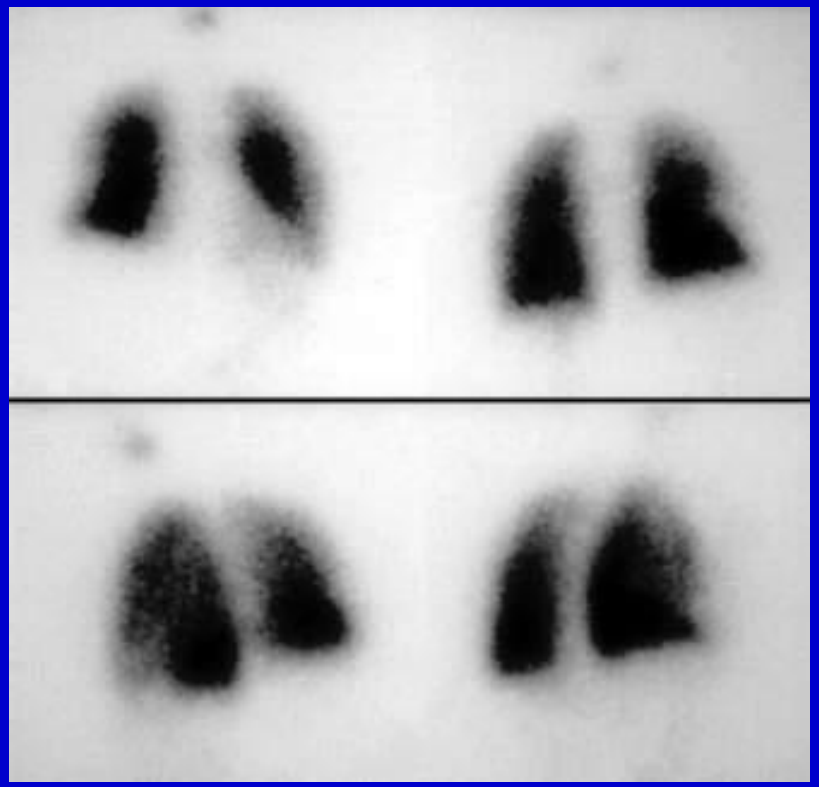
# VQ Scan results 2





Perfusion

Mismatch

Ventilation

# VQ Scan results

- Presence of several large focal perfusion defects not matched by ventilation defects indicates a high probability of PE !!!!!
- Normal scan basically excludes PE and indicates for other explanations for the pts condition.
- High probability – start Rx.
- Low probability – withhold Rx – can do CT / angiogram.
- Intermediate probability – can do CT / angio

# *Ventilation-perfusion scintigraphy*

- PIOPED Study: Accuracy of V/Q scan versus reference standard (pulmonary angiogram)

Table: Likelihood of pulmonary embolism according to scan category and clinical probability in PIOPED study

| Scan Probability | Clinical Probability of Pulmonary Emboli | | |
|---|---|---|---|
| | High | Intermediate | Low |
| High | 95 | 86 | 56 |
| Intermediate | 66 | 28 | 15 |
| Low | 40 | 15 | 4 |
| Normal or near normal | 0 | 6 | 2 |

The PIOPED Investigators. JAMA. 1990 May 23-30;263(20):2753-9.

# V/Q Scan

- Advantages
  - Excellent negative predictive value (97%)
  - Can be used in patients with contraindication to contrast medium
- Limitations
  - 30-50% of patients have non-diagnostic scan necessitating further investigation

Sostman HD et al. Radiology. 2008;246:941-6.

# CT-PA vs. V/Q scan

- Directly compared in trial of 1417 patients with suspected PE
- Randomized to CT-PA or V/Q scan
- Main outcome measure was development of symptomatic VTE post-negative test
- Result: CT-PA not inferior to V/Q scan for ruling out pulmonary embolism

- PIOPED II
  - higher rate of non-diagnostic tests with V/Q Scan vs. CT-PA (26.5% vs. 6.2%)

Anderson DR et al. JAMA. 2007 Dec 19;298(23):2743-53.
Sostman DH et al. Radiology. 2008 Jan 14;246:941-946.

# *Multidetector helical CT pulmonary angiography*

- Increasingly the first-line imaging modality
- PIOPED-II Study: 824 patients evaluated prospectively with multidetector CTA versus composite reference test
  - Sensitivity 83%
  - Specificity 96%
  - PPV = 96% with concordant clinical assessment

Stein PD et al. N. Engl. J. Med. 2006 Jun 1;354(22):2317-27.

# *Multidetector helical CT pulmonary angiography – Advantages*

- Diagnosis of alternative disease entities
- Coverage of entire chest with high spatial resolution in one breath hold
- High interobserver correlation
- Availability
- Improved depiction of small peripheral emboli

Schoepf J; Costello P. Radiology. 2004 Feb; 230:329-337.

# *Multidetector helical CT pulmonary angiography – Limitations*

- Reader expertise required
- Expense
- Requires precise timing of contrast bolus
- Radiation exposure
- Not portable
- Contraindications to contrast
  - Renal insufficiency
  - Contrast allergy

Schoepf J; Costello P. Radiology. 2004 Feb; 230:329-337.

# Multidetector-CT Technique

- Parameters vary by scanner equipment
- Contrast material bolus
  - Duration of injection should approximate duration of scan
  - Desired flow rate 3-5ml/s
  - Usually 50-80ml
- Best results achieved if:
  - Thin sections
  - High and homogenous enhancement of pulmonary vessels
  - Data acquisition in single breath hold

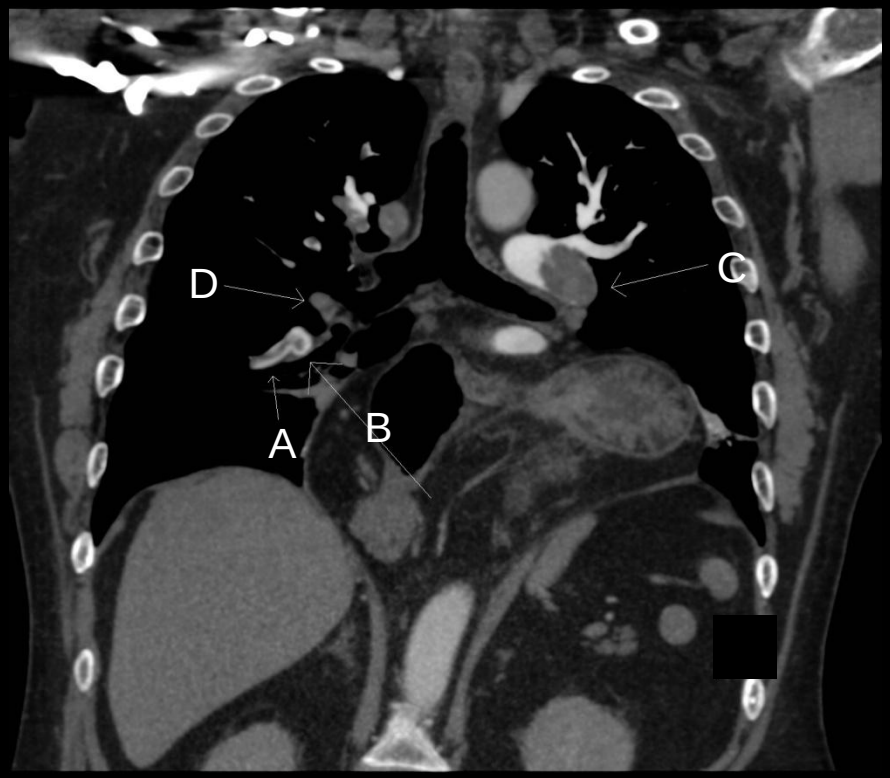
Schaefer-Prokop C; Prokop M. Eur. Radiol. Suppl. 2005;15(4):d37-d41.

# Multidetector-CT Findings

- Partial or complete filling defects in lumen of pulmonary arteries
  - Most reliable sign is filling defect forming acute angle with vessel wall with defect outlined by contrast material
  - “Tram-track sign”
    - Parallel lines of contrast surrounding thrombus in vessel that travels in transverse plane
  - “Rim sign”
    - Contrast surrounding thrombus in vessel that travels orthogonal to transverse plane
- RV strain indicated by straightening or leftward bowing of interventricular septum

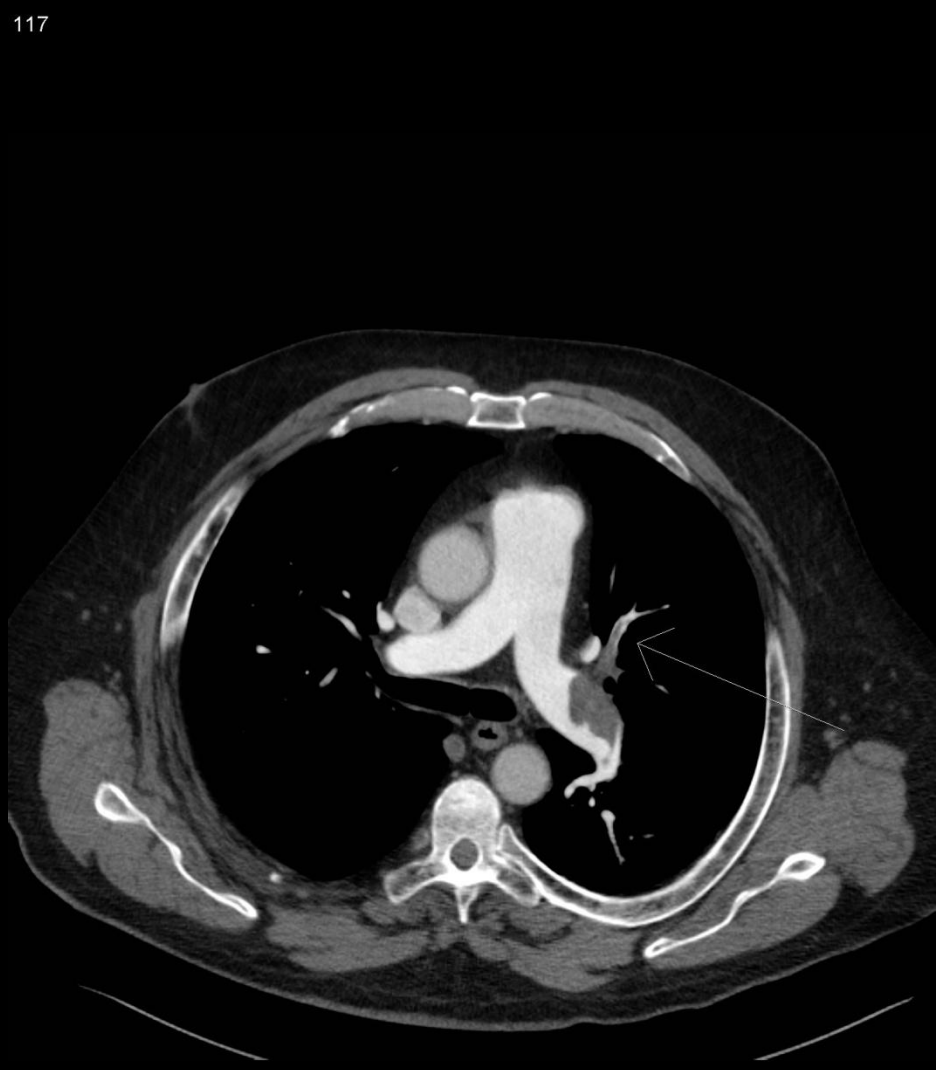
Macdonald S; Mayo J. Semin. Ultrasound CT. 2003;24(4):271-231.

# MDCT Findings




Large saddle thrombus with extensive clot burden. Arrows demonstrating tram-track sign (A), rim sign (B), complete filling defect (C), and a fully non-contrasted vessel (D)


Arrow indicating rim sign




Arrow indicating tram-track sign

# Multidetector-CT: Artifacts

- Pseudo-filling defects or “pseudo-emboli” caused by:
  - Suboptimal contrast enhancement
  - Motion artifact – respiratory and cardiac
  - Volume averaging of obliquely oriented vessels
  - Non-enhanced pulmonary veins
  - Hilar lymph nodes
  - Asymmetric pulmonary vascular resistance

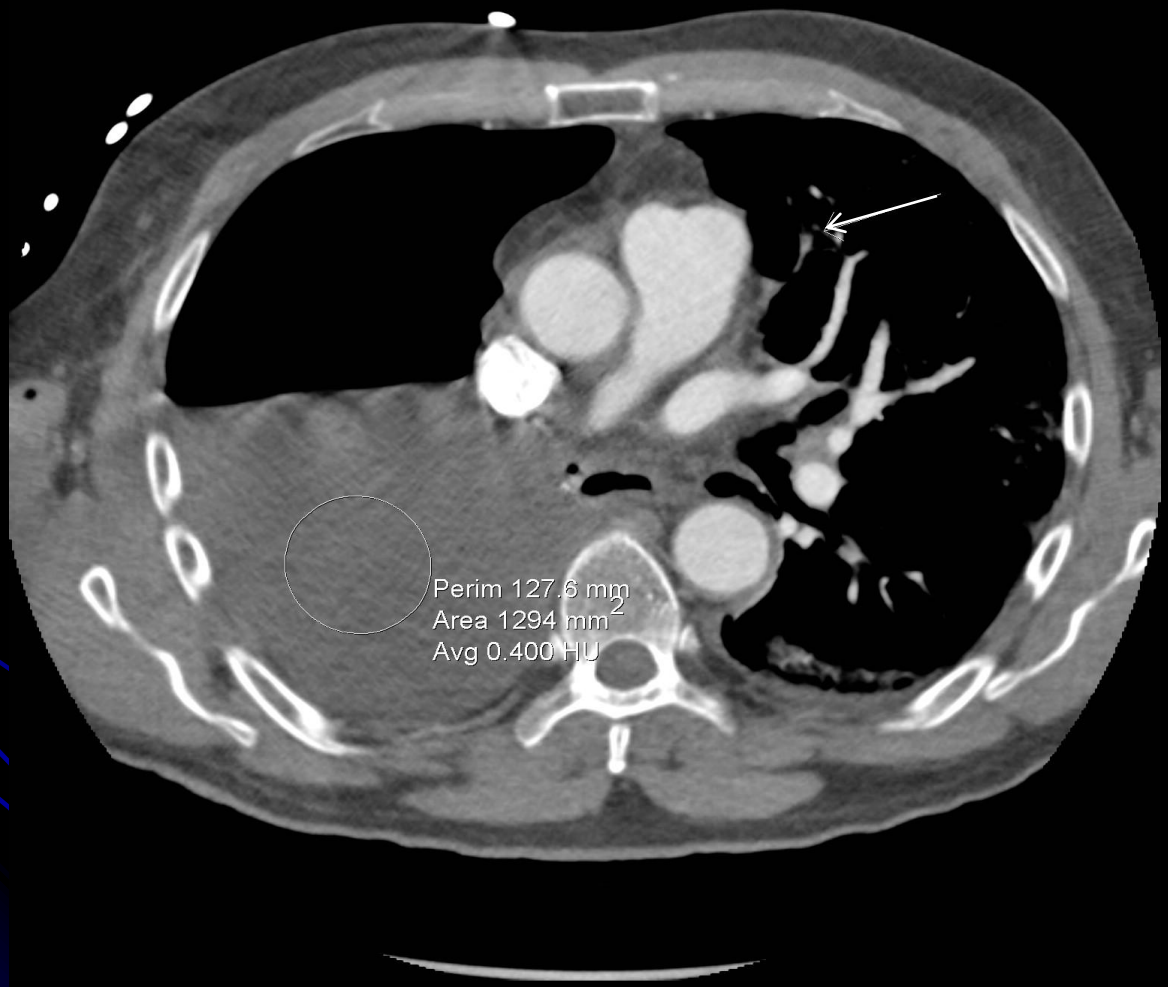
Macdonald S; Mayo J. Semin. Ultrasound CT. 2003;24(4):231-271.

# Clinical relevance of MDCT findings I. Subsegmental Emboli

- Natural history largely unknown
- Lack of evidence to guide management
- Some suggest isolated subsegmental PE may not require treatment in appropriately selected subset of patients
- Currently treat on case-by-base basis

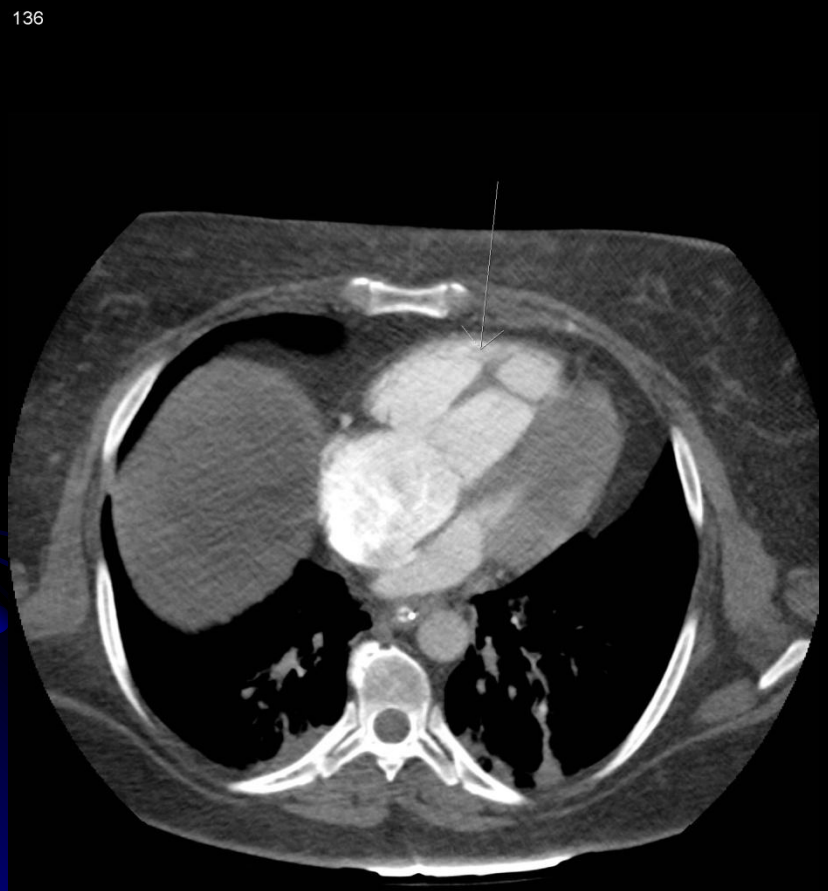
Le Gal G et al. 2006;4(4):724-731.
Goodman LR. Radiology. 2005;234(3)654-658.
Glassroth J. JAMA. 2007;298(23):2788-2789.

# Patient with pneumonectomy




Lingular subsegmental pulmonary embolism (arrow)

# Clinical Relevance of MDCT findings II. RV Strain




Massive bilateral PE with signs of RV strain. Dilated RV with visible thrombus (arrow).

- Increased RV:LV ratio correlated with increased thrombus load
- Increased RV diastolic dimensions on axial CT correlate with worse outcome in acute PE

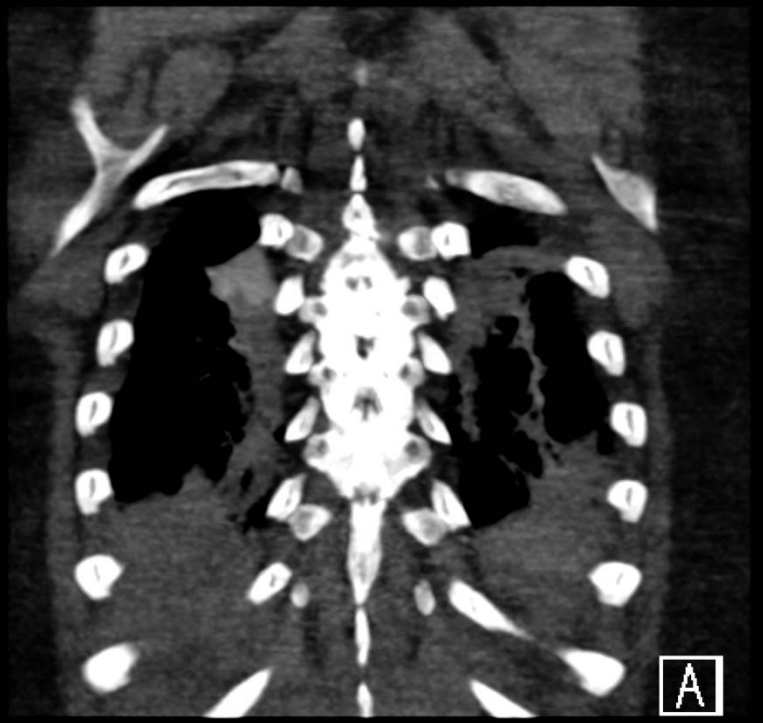
Sanchez O et al. Eur. Heart J. 2008;29:1569–77.

184

Contrast seen in IVC, indicating RV strain

W 784 : L 121

205



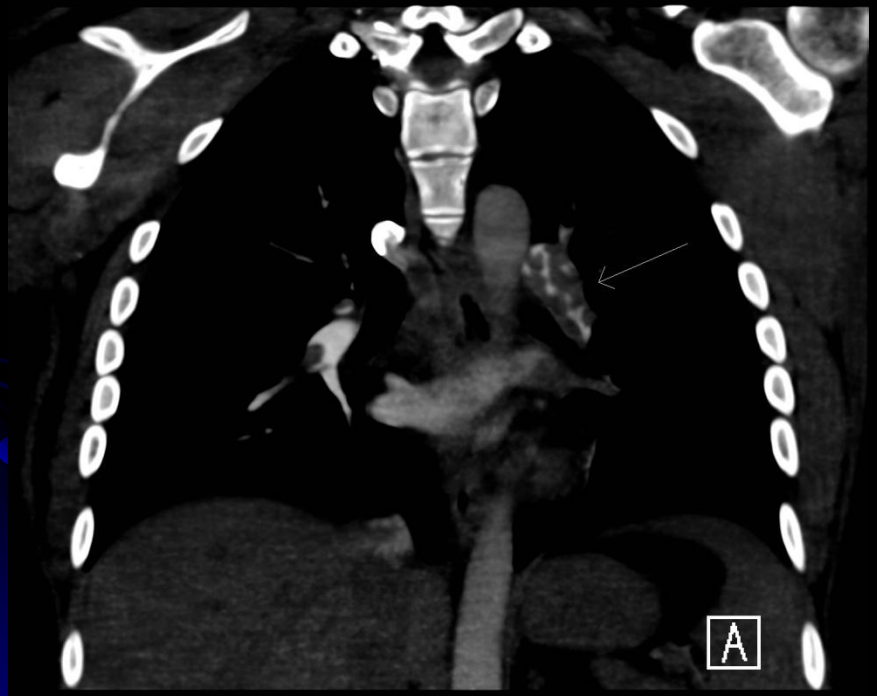

Bilateral mosaic attenuation

W 788 : L 226

# Clinical Relevance of MDCT findings III. Clot Burden

- Clot burden = pulmonary arterial obstruction index
- Conflicting evidence re: clinical relevance
- Prospective study of 105 patients with PE found no correlation between clot burden and all-cause mortality at 12 months
  - Possible selection bias – patients with large clot burden may have died prior to CTPA
  - Single-detector CTPA used

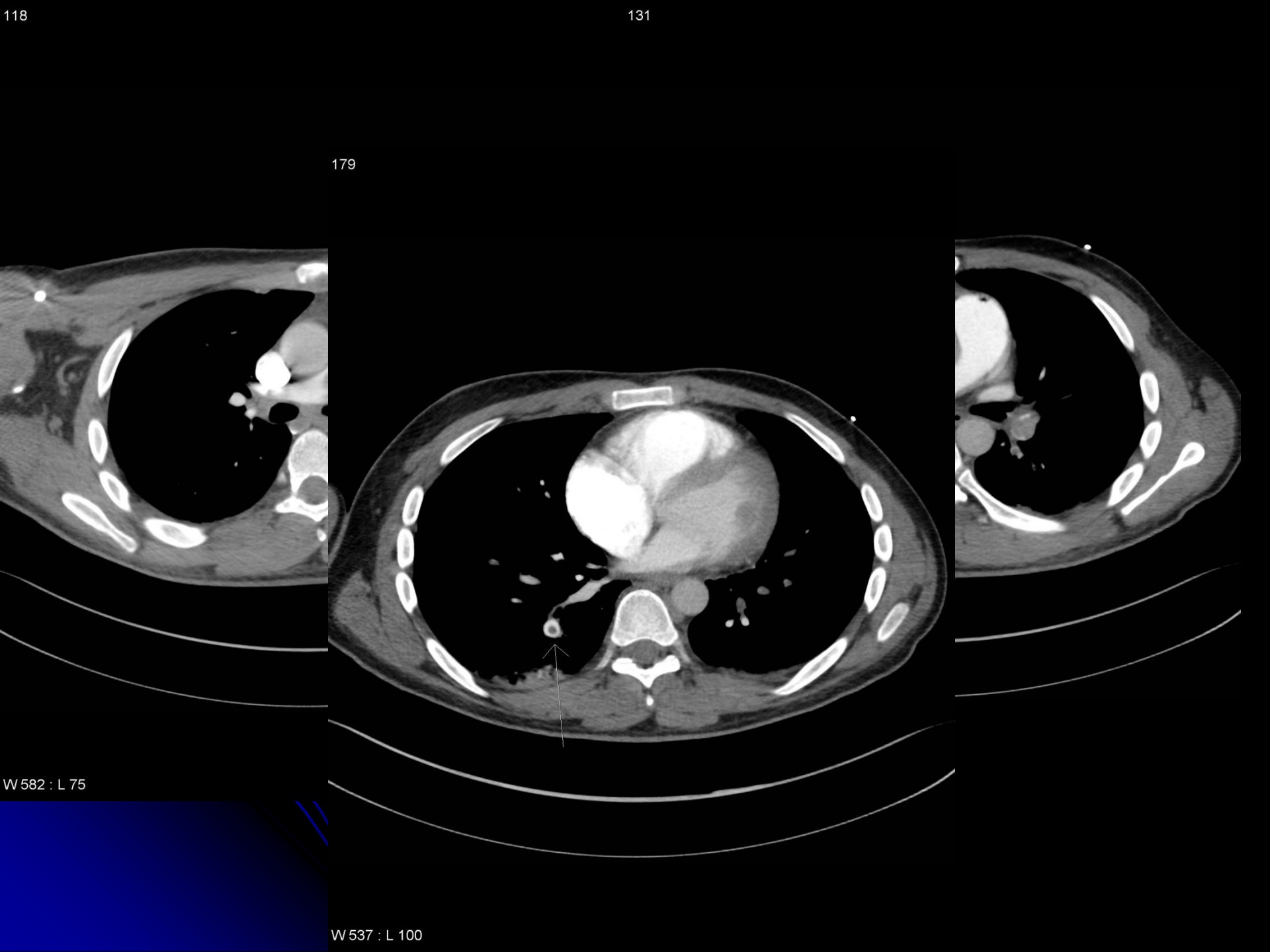
# Clinical Relevance of MDCT findings iv. Mosaic Perfusion




Massive PE with RV strain and mosaic attenuation (arrow)

- Mosaic perfusion is an indirect sign of nonuniform pulmonary arterial perfusion
  - Non-specific for acute PE
  - DDx = chronic PE, emphysema, infection, compression/invasion of pulmonary artery, atelectasis, pleuritis, and pulmonary venous hypertension
  - No evidence demonstrating clinical relevance

Wittram C et al. AJR 2006;186:S421-S429.

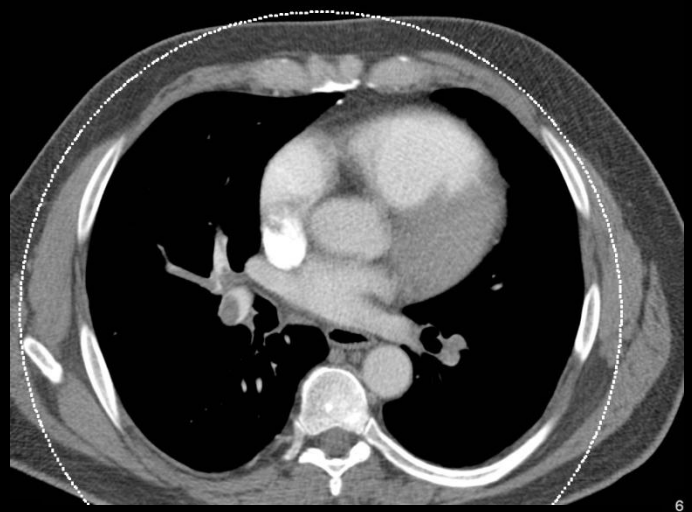

118
131
179
W 582 : L 75
W 537 : L 100

# New Imaging Approaches

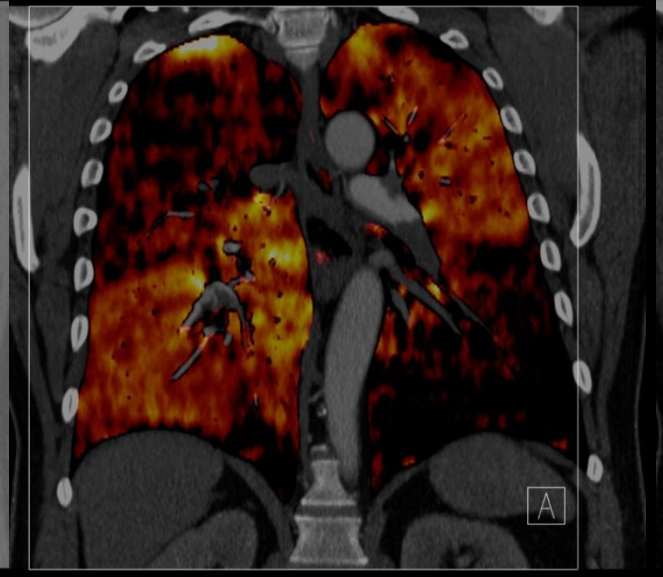
- Dual Energy Iodine Distribution Maps
  - Provides functional and anatomic lung imaging
  - Demonstrates perfusion defects beyond obstructive and non-obstructive clots
  - Diagnostic accuracy and inter/intra-observer variability requires further research
  - Advantages
    - Indirect evaluation of peripheral pulmonary arterial bed
  - Disadvantages
    - Longer data acquisition time
    - Increased radiation exposure

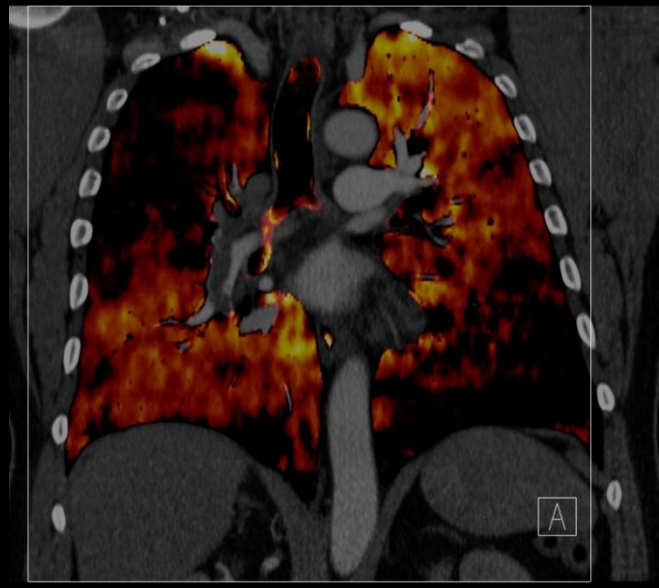

Multiple thrombi in main PA with extensive clot burden. Perfusion defects seen on iodine mapping

Pontana F et al. Acad. Radiol. 2008;15(12):1494.







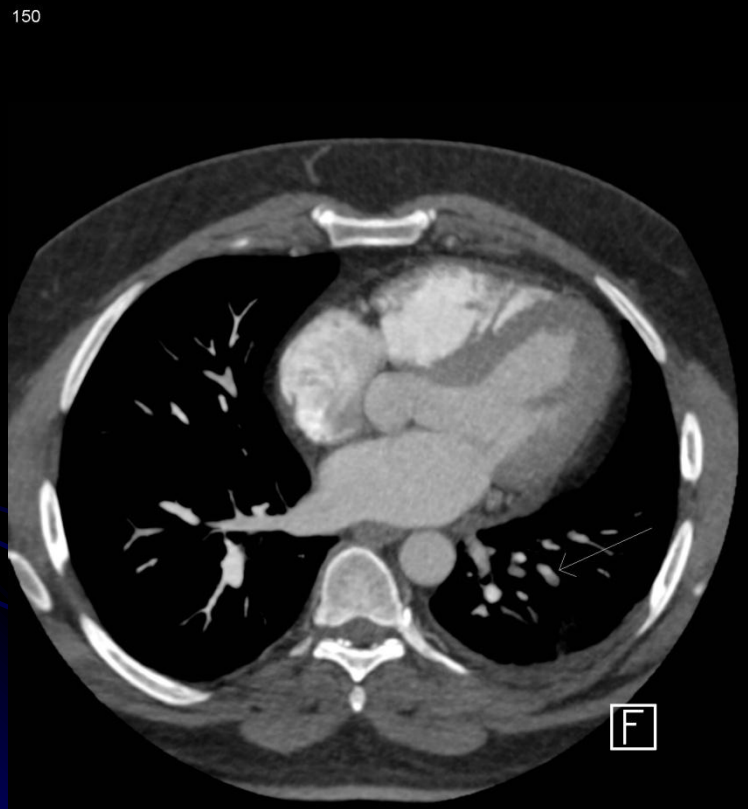




W 255 : L 127

W 255 : L 127

W 255 : L 127

# New Imaging Approaches




Left lower lobe subsegmental embolism (arrow) with associated atelectasis using high-pitch technique

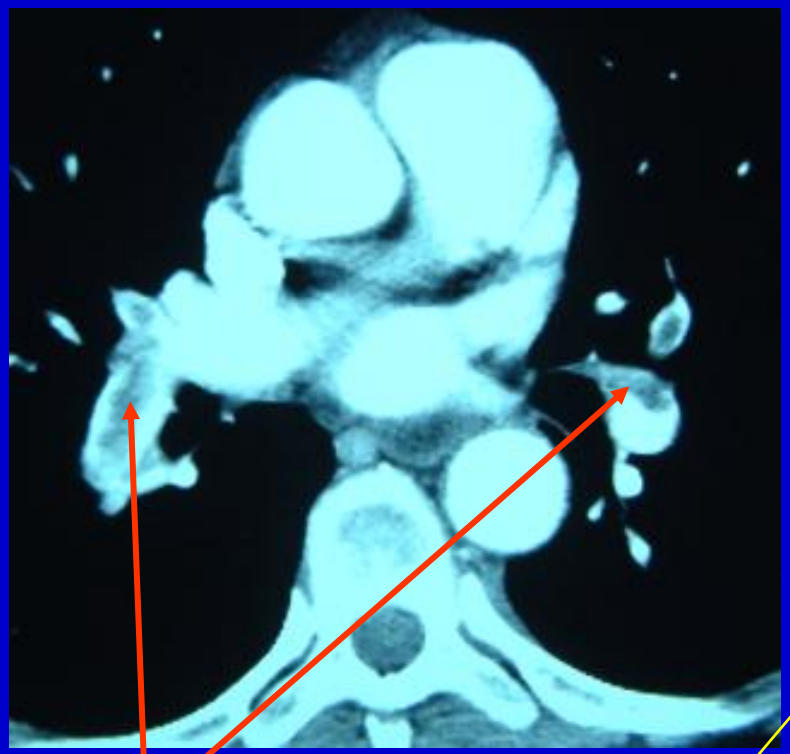
- Low dose MDCT using ultra high pitch technique
- Useful in patients who are unable to hold their breath
- Timing of contrast bolus even more critical

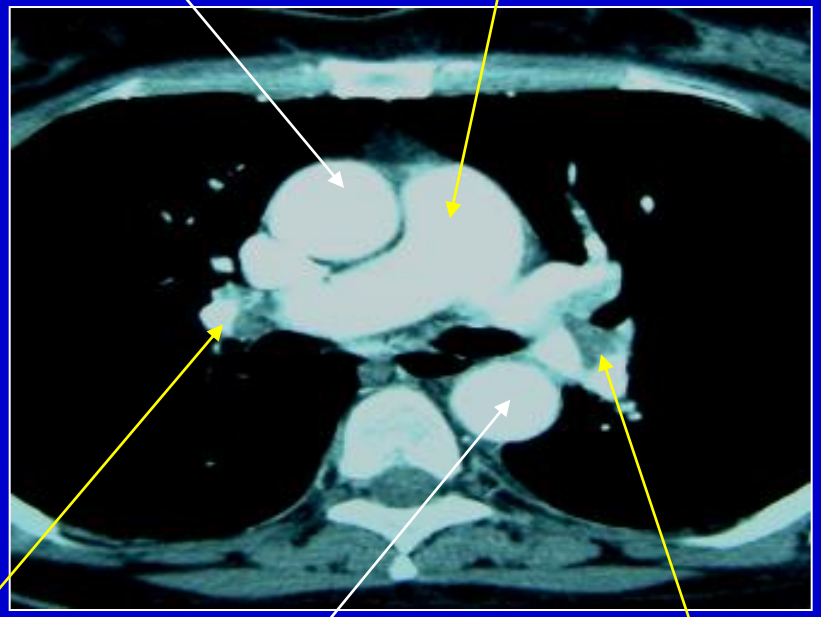
145


W 1212 : L 68

Gloucestershire Hospitals NHS
NHS Trust
Nick Oldnall, Clinical Practice Developer

# Spiral / Multislice CT Results





Ascending Aorta

Main Pulmonary Artery

Descending Aorta

Rt Pulmonary Artery

Lt Pulmonary Artery

Thrombus

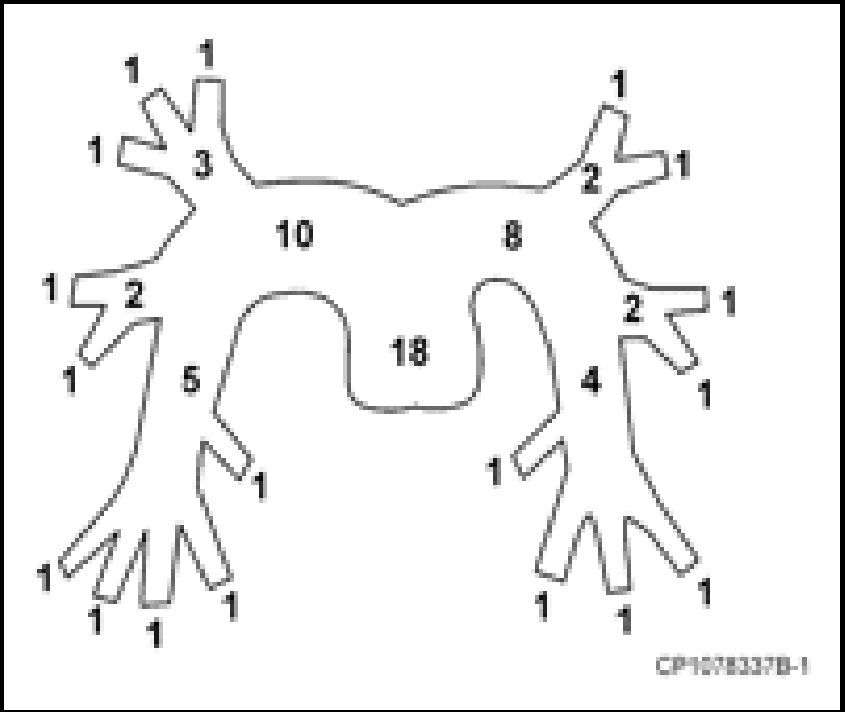
# CT prognostic factors

Transverse contrast material–enhanced chest CT scan shows that ventricular septum bows leftward (arrow) into the left ventricular lumen. Small pulmonary emboli are visible in left lower lobe basal segmental pulmonary arteries.

RV/LV diameter ratio. (a)Transverse contrast-enhanced chest CT scan at level where the tricuspid valve is widest. RV diameter is measured at this level from inner wall to inner wall. (b) LV diameter is measured at the level where the mitral valve is widest. Small pulmonary emboli are visible in basal segmental pulmonary arteries bilaterally.

RV/LV diameter ratio. (a)Transverse contrast-enhanced chest CT scan at level where the tricuspid valve is widest. RV diameter is measured at this level from inner wall to inner wall. (b) LV diameter is measured at the level where the mitral valve is widest. Small pulmonary emboli are visible in basal segmental pulmonary arteries bilaterally.

**Embolic burden scoring system. Schematic of the pulmonary arterial tree with scores for nonocclusive emboli according to vessel. Emboli in a segmental pulmonary artery are given a score of 1. Emboli in more proximal pulmonary arteries are given a score based on the total number of segmental pulmonary arteries supplied.**



# MRI MR Angiogram

- Very good to visualize the blood flow.
- Almost similar to angiogram

3D Pulmonary MRA

# MRI

- PIOPED III Trial
  - Accuracy of gadolinium-enhanced MR angiography in combination with venous phase venography in diagnosing acute PE
  - Insufficient sensitivity
  - High rate of technically inadequate images

Image: 59 y.o. male with severe dyspnea

MR angiogram depicts large amounts of embolic material (*arrowheads*) in right pulmonary artery, in right upper and lower lobes, and in left lingual pulmonary artery. Nonenhancing masses (*arrow*) are present in liver.

Kluge, A. et al. Am. J. Roentgenol. 2006;187:W7-W14

Stein PD et al. Ann Intern Med. 2010;152:434-43.

# MRI

Advantages

- Lack of ionizing radiation

Limitations

- Respiratory and cardiac motion artifact
- Suboptimal resolution for peripheral pulmonary arteries
- Complicated blood flow patterns

- Experimental technology may have role in future
  - Real-time MR sequence without breath hold
  - Molecular MRI with fibrin-specific contrast agent

Tapson, VF. N. Engl. J. Med. 1997; 336:1449.

Haage P et al. Am. J. Respir. Crit. Care Med. 2003 Mar 1;167(5):729-34. Epub 2002 Nov 21.

Spuentrup E et al. Am. J. Respir. Crit. Care Med. 2005 Aug 15;172(4):494-500. Epub 2005 Jun 3.

# Pulmonary Angiogram

- **GOLD STANDARD**.
- Positive angiogram provides 100% certainty that an obstruction exists in the pulmonary artery.
- Negative angiogram provides > 90% certainty in the exclusion of PE.

# Pulmonary Angiogram

- Catherterisation of the subclavian vein
- Catheter
- Subclavian vein – Superior vena cava – right atrium – right ventricle – main pulmonary artery
- Contrast
- DSA

Nick Oldnall, Clinical Practice Developer

# Pulmonary Angiogram

# Pulmonary Angiogram

# Pulmonary Angiogram


- **Westermark sign** – Dilatation of pulmonary vessels proximal to embolism along with collapse of distal vessels, often with a sharp cut off.

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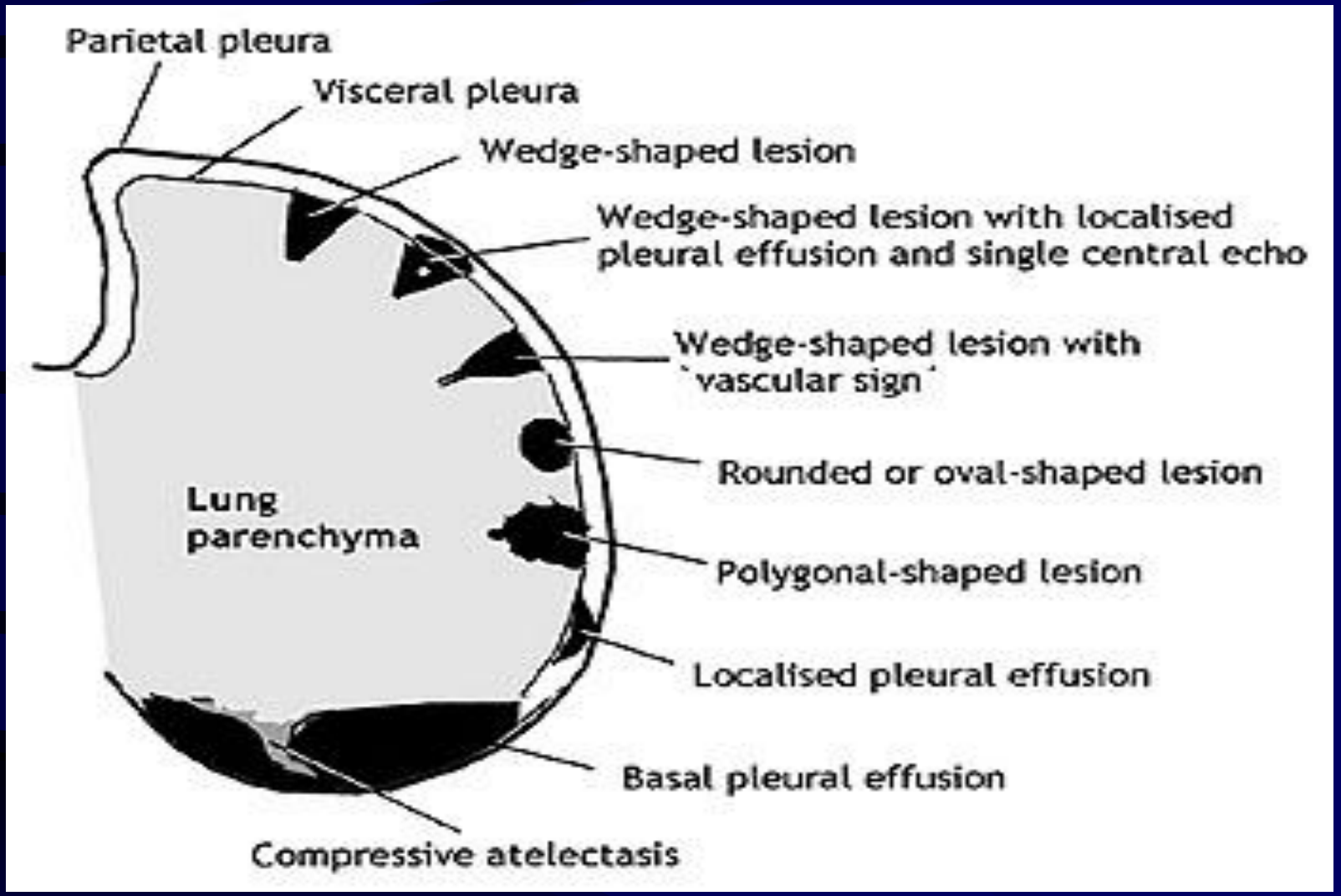
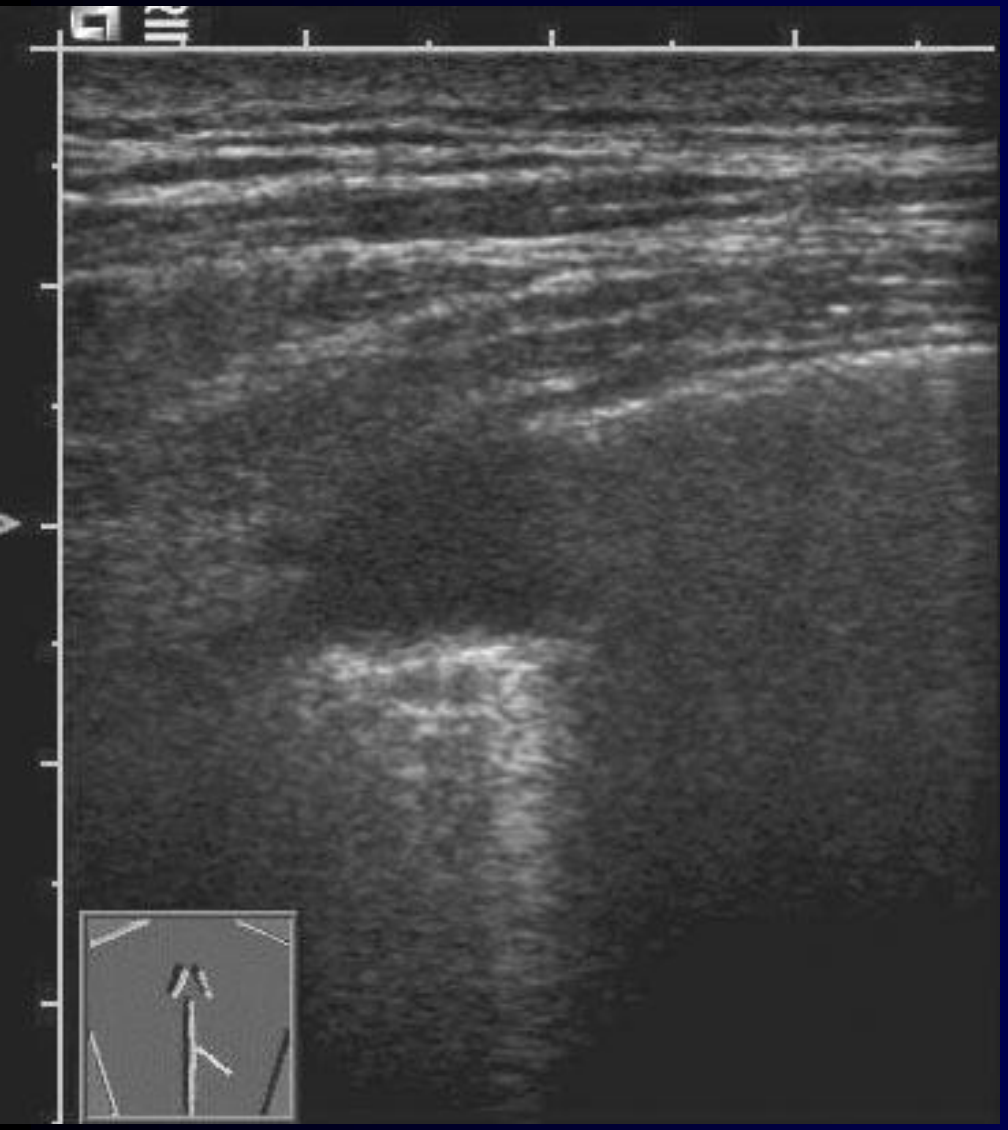
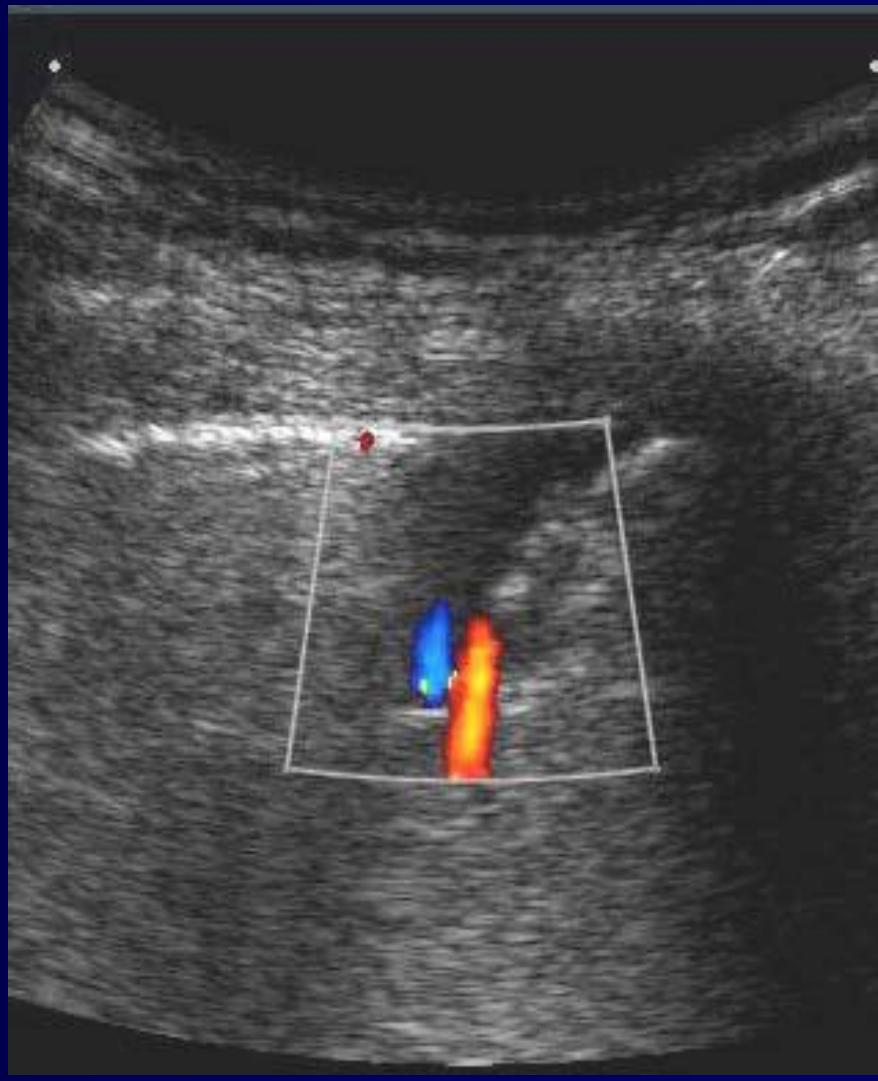
# Transthoracic sonography

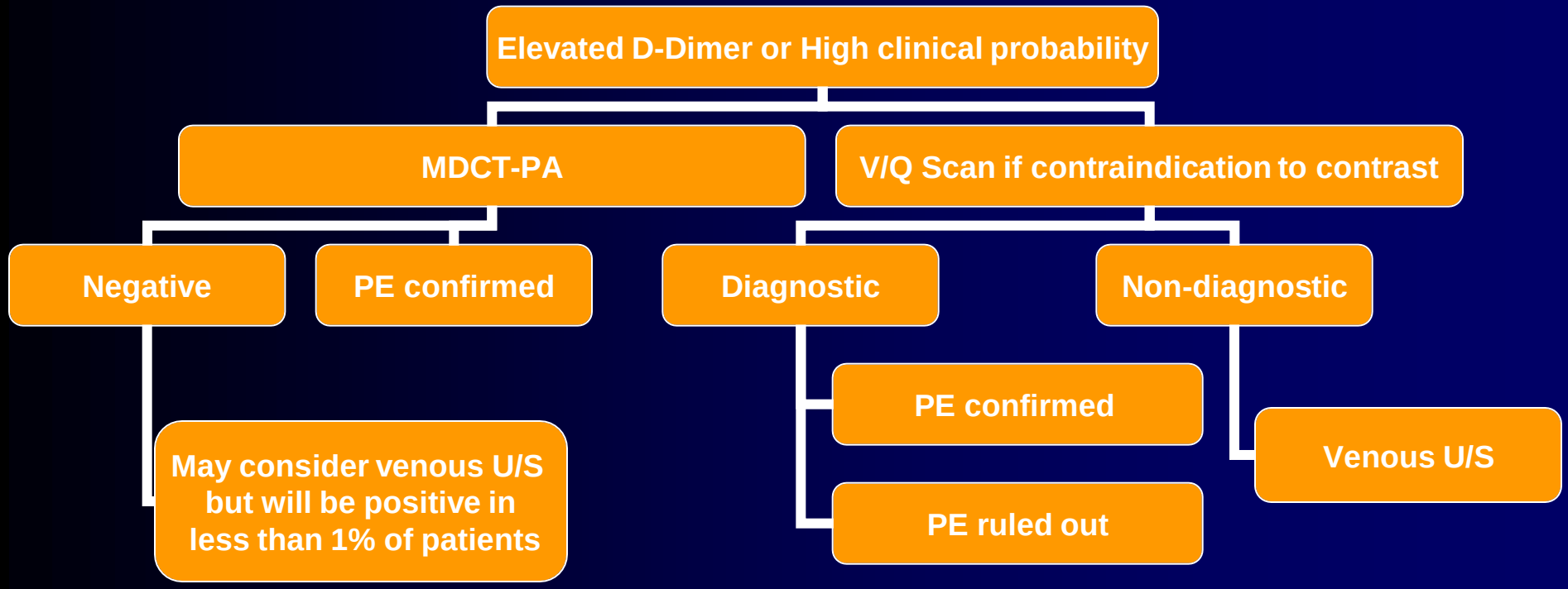



Schematic representation of the parenchymal, pleural and vascular features associated with pulmonary embolism.(Angelika Reissig, Claus Kroegel. *Respiration* 2003;70:441-452)





# Diagnostic Imaging Algorithm




Adapted from Agnelli G; Becattini C. N. Engl. J. Med. 2010;363:266-74.


Thank You