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May, 19 2003

Pulmonary Embolism: Radiologic Approaches to Diagnosis

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Agenda

- Discuss the pathophysiology and clinical features of pulmonary embolism.
- Present multiple imaging modalities helpful in the diagnosis of pulmonary embolism, as illustrated by cases presenting at the BIDMC.
- Highlight the proper context for the use of the different imaging modalities and the significance of both positive and negative findings.



Pulmonary Embolism: Pathogenesis



- Result of dislodged thrombus, most commonly in the venous system of the lower extremities (90%).
- Emboli lodge in pulmonary vessels too narrow to permit through-flow.
- Morbidity due to:
 - Post-occlusion ischemia
 - Cor pulmonale due to increased pulmonary artery pressures



Urgency of Diagnosis

- Annual U.S. incidence of pulmonary embolism is 300,000
- Annual U.S. mortality from the disease is 50,000
- Untreated disease is associated with 30% mortality
- Treatment reduces mortality to 2-8%



Patient S.I: Clinical Presentation

- 54 year old male presenting with 3-4 days of dyspnea.
- Dyspnea is aggravated by exertion.
- On review of system, patient has cough and palpitations. He denies chest pain and hemoptysis.
- He has noted several days of painful swelling in his right lower extremity
- He was seen earlier in the day at the non-invasive vascular laboratory, where ultrasound demonstrated acute right popliteal venous thrombosis and chronic left popliteal venous thrombosis; he was referred to the emergency department.



S.I: Past Medical History

- Status post craniotomy for brain abscess related to a dental procedure. Recovery complicated by fall, leading to immobility for two weeks.
- Previous history of deep venous thrombosis four years prior to presentation.
- Family history significant for thrombotic events, as well as high incidence of cancer



Physical Exam and EKG

- Vital Signs: Afebrile, normotensive, heart rate of 107, respiratory rate of 18, oxygen saturation of 95%.
- No murmurs, rubs, or gallops on cardiac auscultation
- Lungs clear to auscultation bilaterally
- Dark purple ecchymosis and tenderness of left anterior thigh.
- Palpable clot in right popliteal fossa.
- EKG changes, with tachycardia, T wave inversions



Pulmonary Embolism: Clinical Presentation

Symptoms

- Dyspnea 73%
- Pleuritic chest pain 66%
- Cough 37%
- Hemoptysis 13%

Signs

- Tachypnea 70%
- Rales 51%
- Tachycardia 30%
- S4 24%
- Fever 14%
- Clinical Manifestations of DVT 30%
- EKG changes 70%
- T wave inversions on EKG 49%



Risk Factors for Pulmonary Embolism (PIOPED-1990)

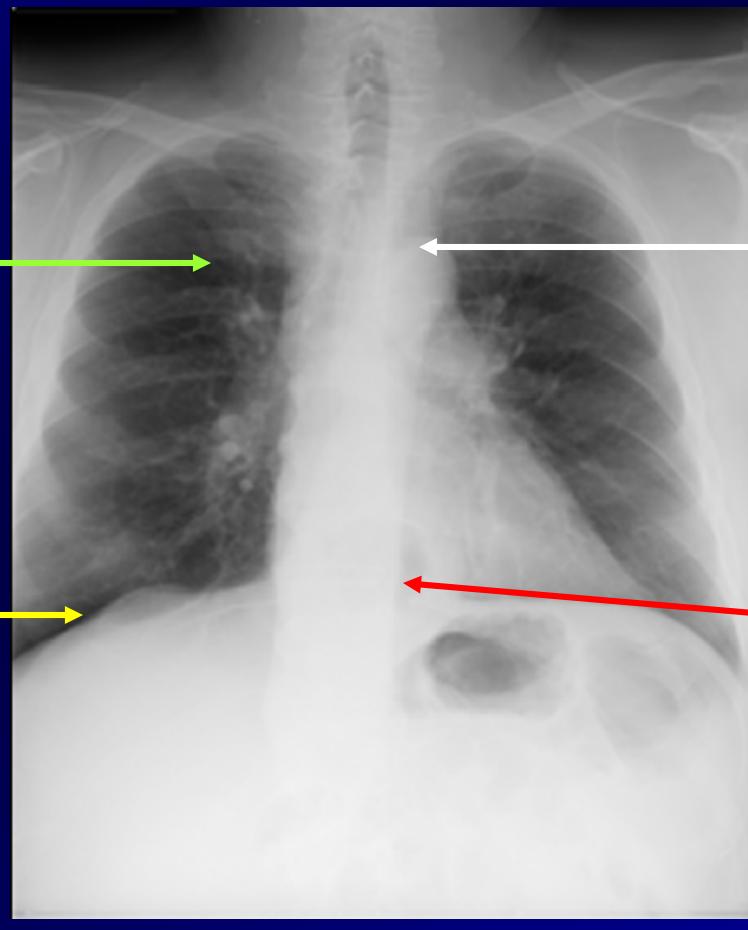
- Immobilization
- Surgery within the last three months
- Stroke
- History of DVT/known hypercoagulable disorder
- Malignancy



S.I: PA Chest X-Ray

Pulmonary
vasculature
unremarkable

No pulmonary
effusion



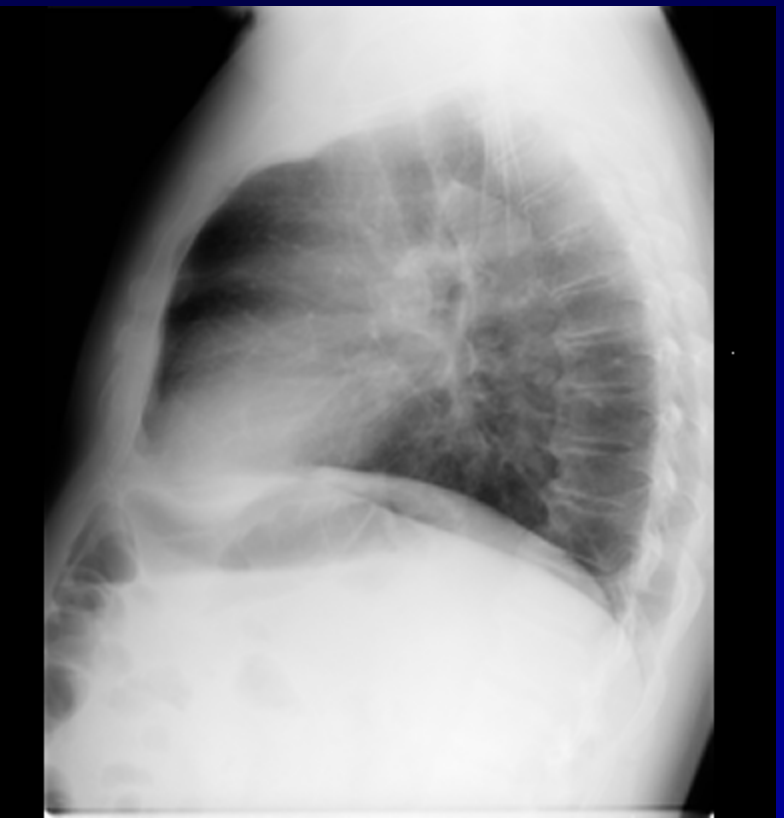
Mediastinal
contours
unchanged
from previous
CXR

Hiatal
hernia



S.I: Lateral CXR

Lateral chest x-ray is
unremarkable





Differential for Pulmonary Symptoms and Negative Chest X-Ray

- Upper respiratory infection
- Asthma
- Bronchiectasis
- GERD
- Early carcinoma
- Foreign body
- Broncholithiasis
- Extrinsic compression
- Laryngeal lesions
- Pulmonary embolism
- Psychogenic cough/dyspnea



Pulmonary Embolism and Chest X-Ray

- Most chest x-rays are abnormal, but the abnormalities are also consistent with competing diagnoses on the differential
- In PIOPED:
 - Atelectasis found in 69% with embolism, 58% without embolism
 - Pleural effusion found in 47% with embolism, 39% without.
 - Cardiomegaly is commonly seen in PE, CHF, and COPD exacerbations.
- 12% of patients (45/383) have normal chest x-rays.
- A normal chest x-ray in a hypoxemic patient is highly suggestive of pulmonary embolism.

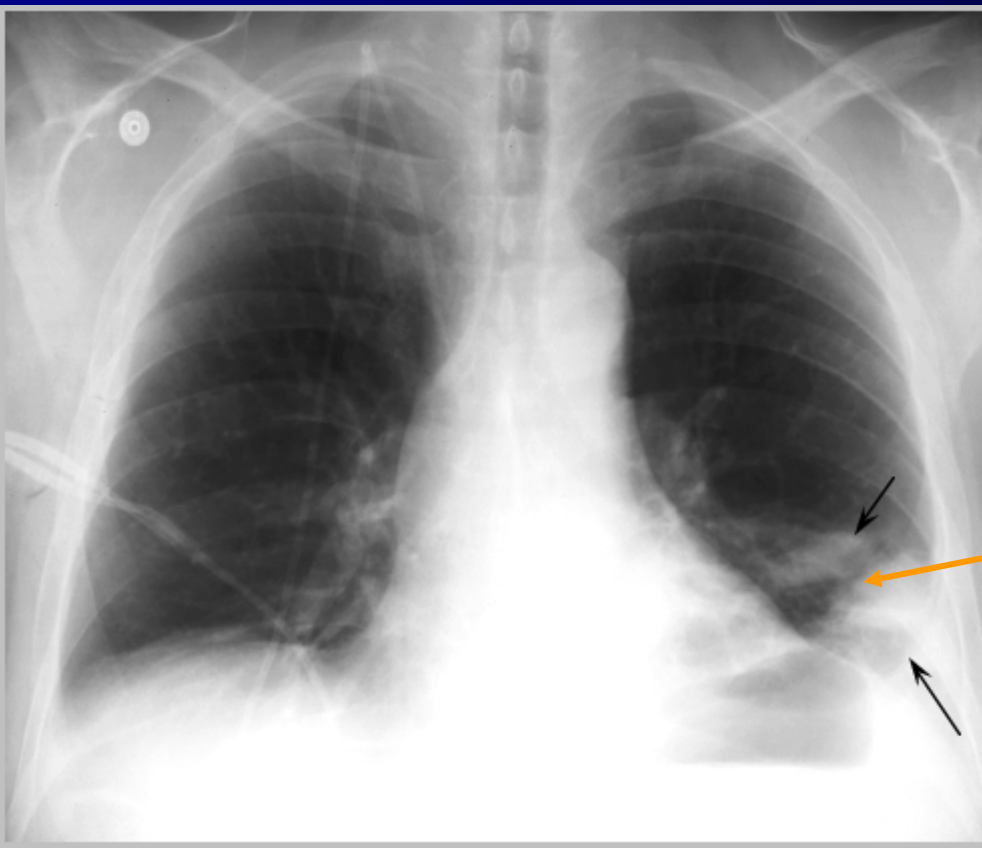


Pulmonary embolism and the Chest X-ray

- Classic radiographic findings that are highly specific (though very insensitive):
 - Hampton's hump: wedge shaped triangular opacity with apex pointing to the hilus
 - Westermark's sign: decreased vascular markings in a localized area
 - Palla's sign: enlarged right descending pulmonary artery
- The chest x-ray cannot prove or exclude pulmonary embolism conclusively, but it may demonstrate alternative pulmonary processes causing dyspnea



Pulmonary Embolism and the Chest X-Ray



Triangular opacity with apex to hilus (Hampton's Hump)



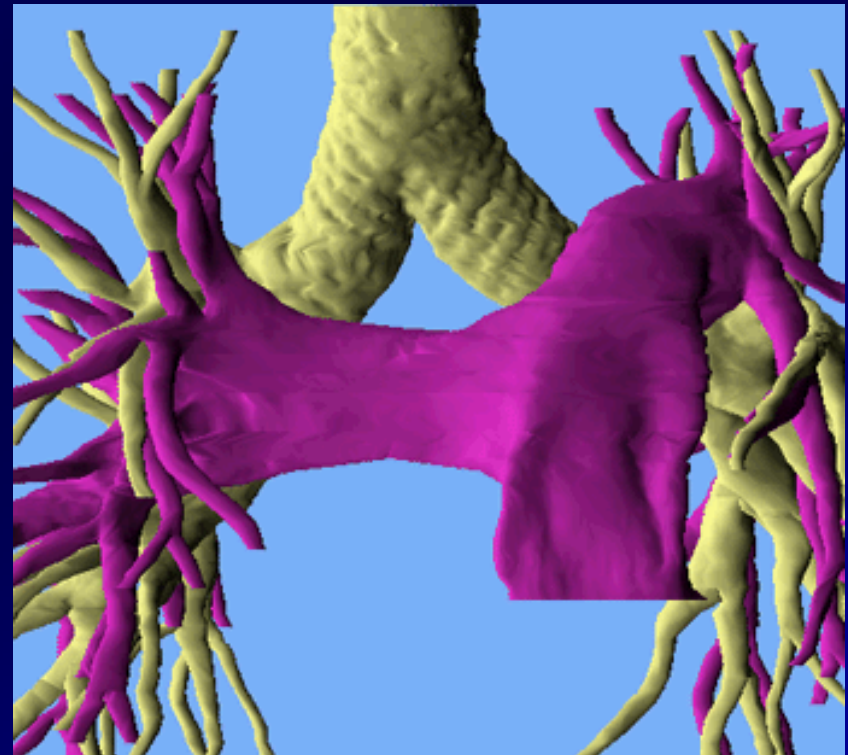
CT Angiography

- Procedure:
 - Contrast-enhanced spiral CT to evaluate pulmonary vessels
 - Iodinated contrast media is injected intravenously
- Helical CT allows for the evaluation of the entire chest in a single breath hold.
- For main, lobar, and segmental arteries: sensitivity of 90% (60%-100% range in various studies) and specificity of 90% (80%-100% range).
- For subsegmental arteries, sensitivity is reduced (sensitivity range of 53%-100% for all pulmonary emboli).



CTA: Anatomical Considerations

- Interpretation of CTA involves opacification of pulmonary arteries.
- A systematic evaluation of all arteries is necessary.
- Arteries accompany branches of the bronchial tree, and one vessel is associated with each segment of the lung (ten on right, eight on left).



<http://sig.biostr.washington.edu/projects/da/>



CTA Findings for Pulmonary Embolism

- Acute Embolism
 - Centrally located filling defect
 - Vessel occlusion
 - Vessel distension
- Chronic Embolism
 - Eccentric filling defect, often contiguous with vessel wall
 - (+/-) calcifications



S.I CTA

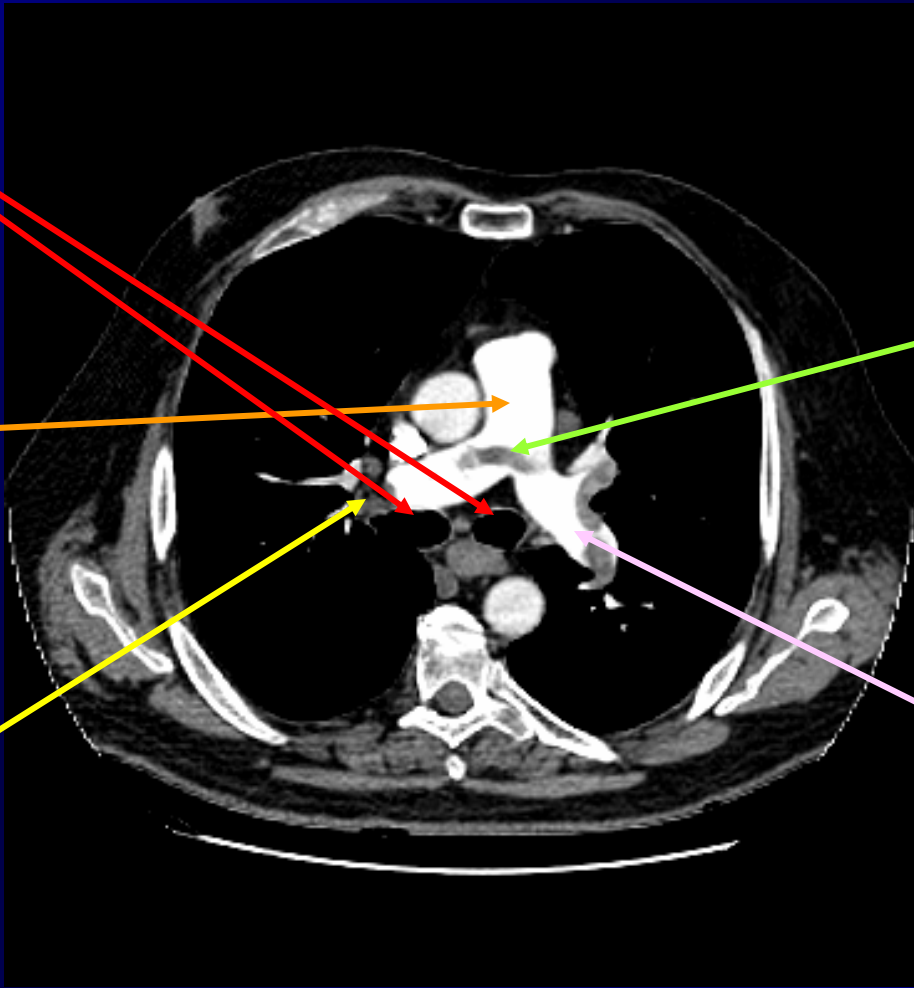
Right and left
main stem bronchi

Main Pulmonary
Artery

Right pulmonary
artery embolus

Non-
obstructive
saddle
embolus

Embolus
extension into
left pulmonary
artery



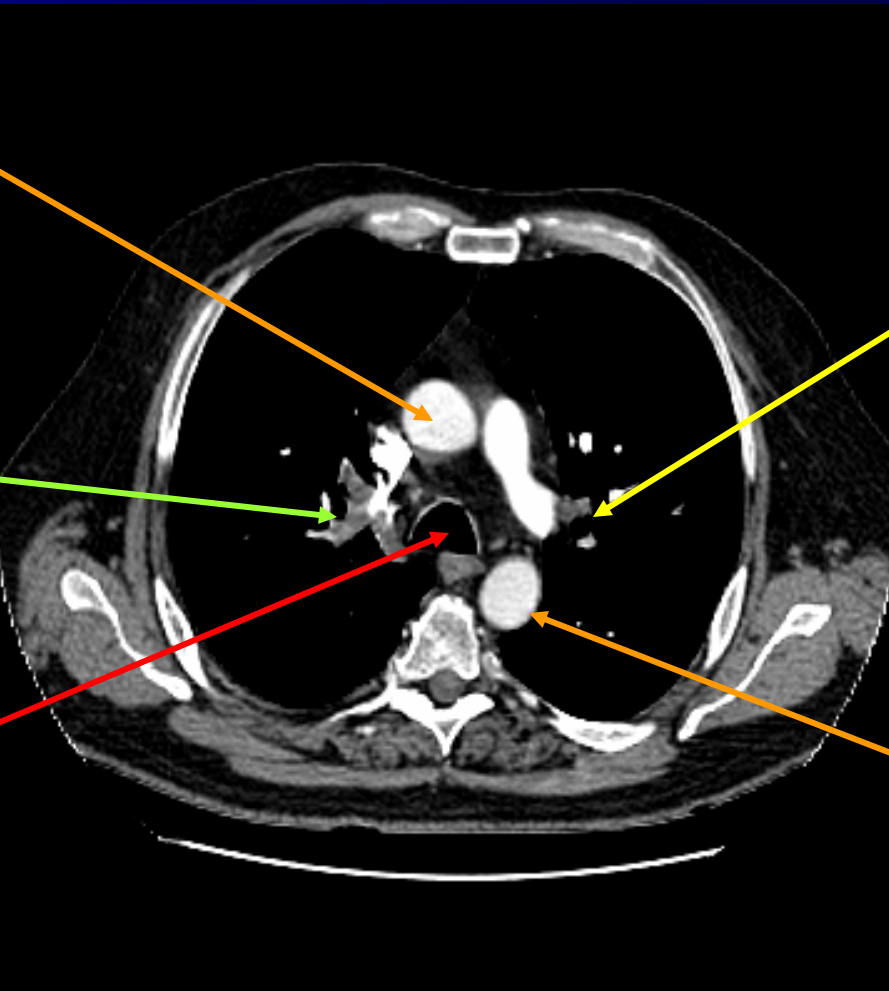


S.I CTA

Ascending
aorta

Embolus in
right upper
lobe arterial
tree

Trachea



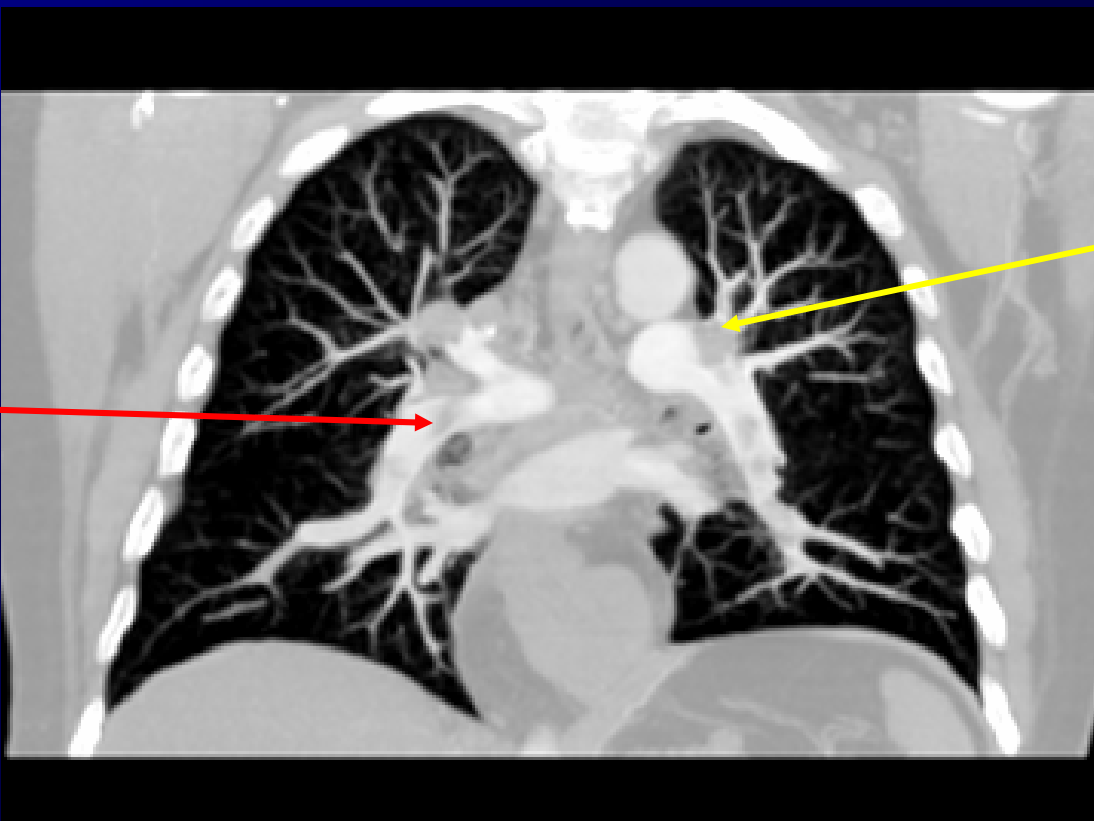
Upper lobe
branch
occluded by
embolus

Descending
aorta



S.I: CTA (Coronal Reconstruction)

Embolus in
descending
right
pulmonary
artery



Embolus in
left main
pulmonary
artery



CTA: Discussion

- Recent data has demonstrated low morbidity (<2.0%) in patients untreated after negative CTA.
- Role of subsegmental emboli in causing morbidity is still undefined.
- Multi-head CT scanners now allow for faster scanning and better demonstration of segmental and subsegmental pulmonary vessels.
- Along with imaging of pulmonary arteries, CT angiography can-in the same exam-perform CT venography of the lower extremities, correlating well with lower extremity ultrasound examination of legs for DVT.
- Currently pending are the results of the PIOPED II study, designed to assess spiral CTA in detecting PE.

Goodman, LR, Lipchik, RJ, Kuzo, RS et. al. "Subsequent Pulmonary embolism: Risk after a negative helical CT pulmonary angiogram. Prospective comparison with scintigraphy. Radiology 2000, 215: 535.

Ryu, JH, Swensen, SJ, Olso, EJ, Pellikka, PA, "Diagnosis of Pulmonary Embolism With Use of Computed Tomographic Angiography." Mayo Clinical Proceedings 2001, 76(1): 59-65.

Stein, GA, Goodman, LR, "Overview of Prospective Investigation of Pulmonary Embolism Diagnosis II," Semin Nucl Med 2002, ²²32(3): 173-82.



Ventilation/Perfusion Scans

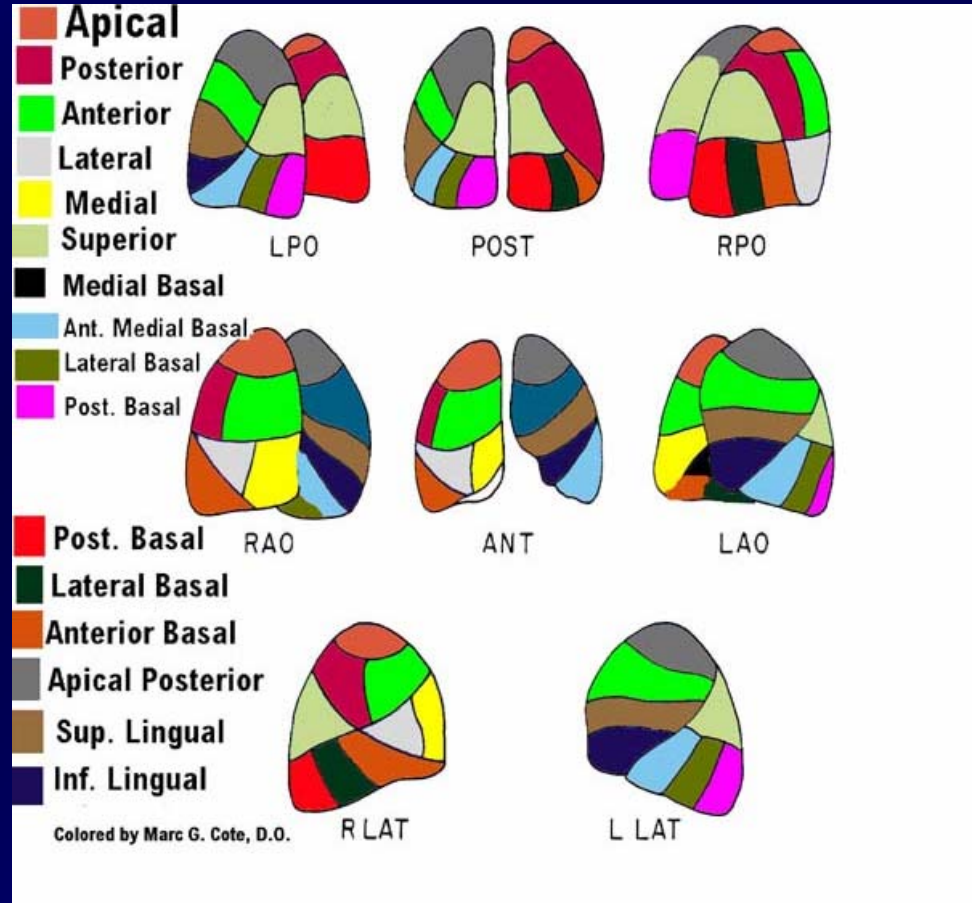
- Most frequently used test in diagnosis of pulmonary embolism.
- Studies are interpreted as normal or high/intermediate/low likelihood of embolism
- Perfusion imaging via Tc 99m-labeled macroaggregated albumin or Tc 99m-labeled human albumin macrospheres.
- Ventilation imaging via Xe 133, Xe 127, Kr 81m, Tc 99m aerosols.



Ventilation-Perfusion: Anatomic Considerations

- High probability scan: Equivalent of two or more large (>75%) segmental mismatched perfusion deficits.
- Intermediate scan: Less than 2 segmental perfusion deficits.
- Low probability scan: Non-segmental defect or or defect accompanied by large radiographic abnormality

Value of the ventilation/perfusion scan in acute pulmonary embolism. Result of the prospective investigation of pulmonary embolism diagnosis (PIOPED). The PIOPED Investigators. JAMA 1990, 263: 2753

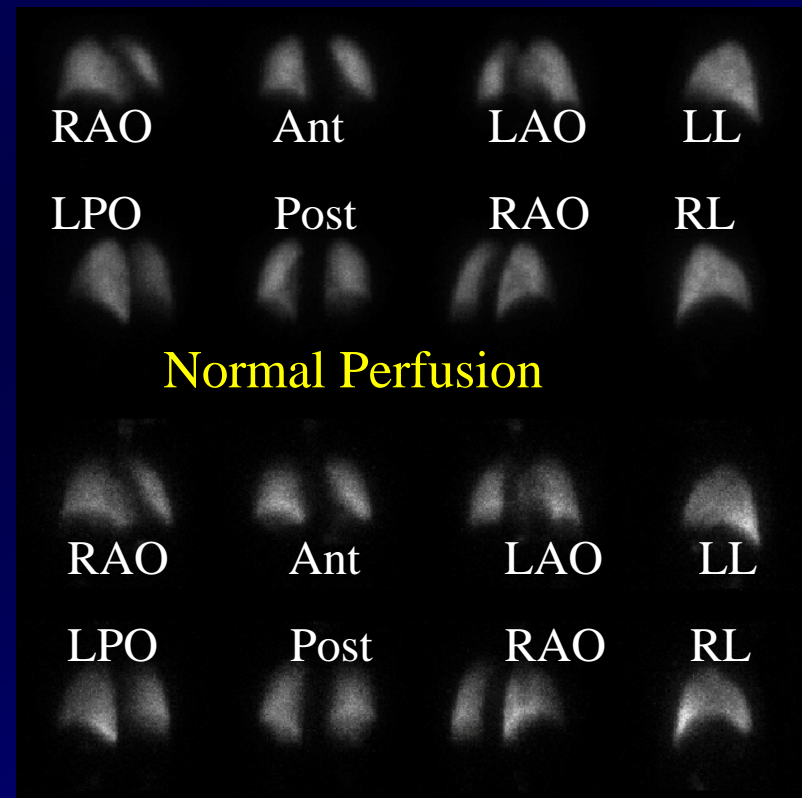




PIOPED and the Significance of the V/Q Scan

- Normal V/Q scan rules out pulmonary embolism in all presenting patients, regardless of clinical suspicion.
- 72% of the PIOPED population were not definitively diagnosed or ruled out for pulmonary embolism with lung scan.
- Initial recommendation was for indeterminate results to be followed up with pulmonary angiography

Value of the ventilation/perfusion scan in acute pulmonary embolism. Result of the prospective investigation of pulmonary embolism diagnosis (PIOPED). The PIOPED Investigators. JAMA 1990, 263: 2753





Likelihood of Pulmonary Embolism following V/Q Scan

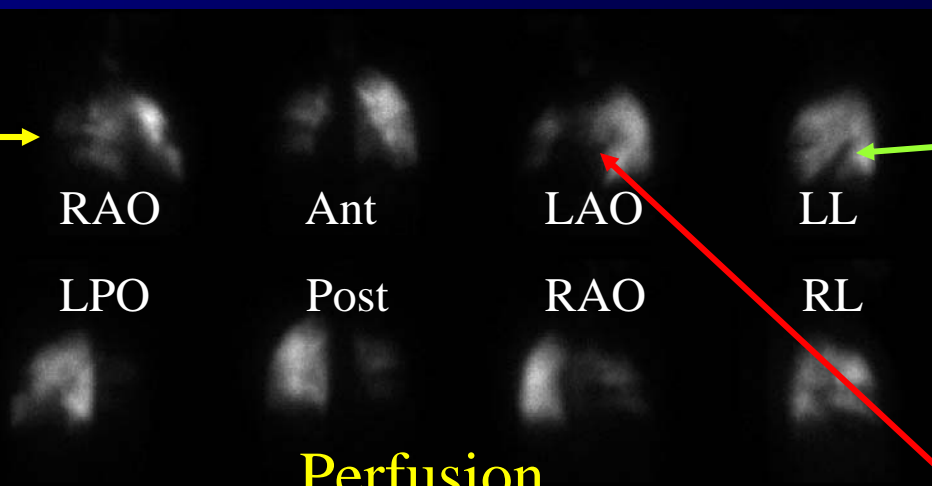
	High Clinical Probability	Intermediate Clinical Probability	Low Clinical Probability
High Likelihood Scan	95	85	56
Intermediate Likelihood Scan	66	28	15
Low Likelihood Scan	40	15	4
Normal Scan	0	6	2

Value of the ventilation/perfusion scan in acute pulmonary embolism. Result of the prospective investigation of pulmonary embolism diagnosis (PIOPED). The PIOPED Investigators. JAMA 1990; 263: 2753



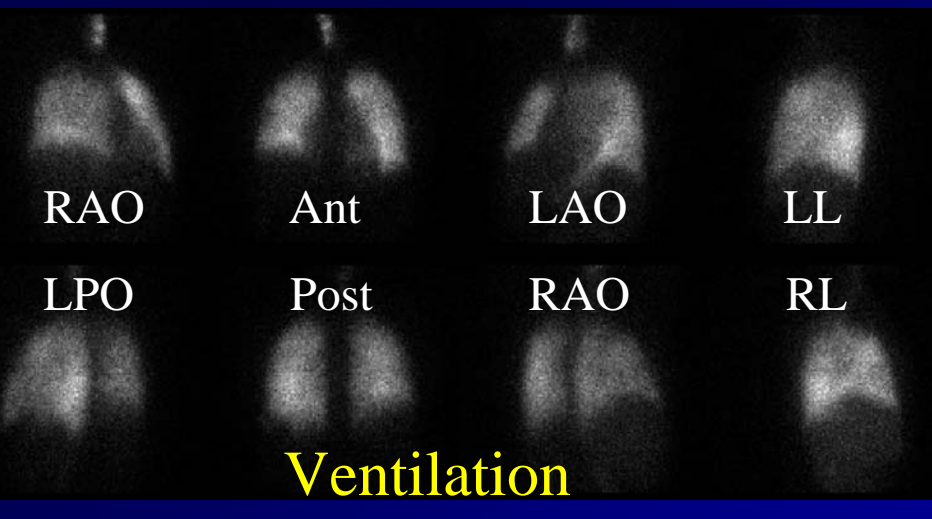
High Likelihood V/Q Scan

Decreased perfusion of right lung



Decreased perfusion of anterior medial basilar segment

Decreased perfusion of lingula



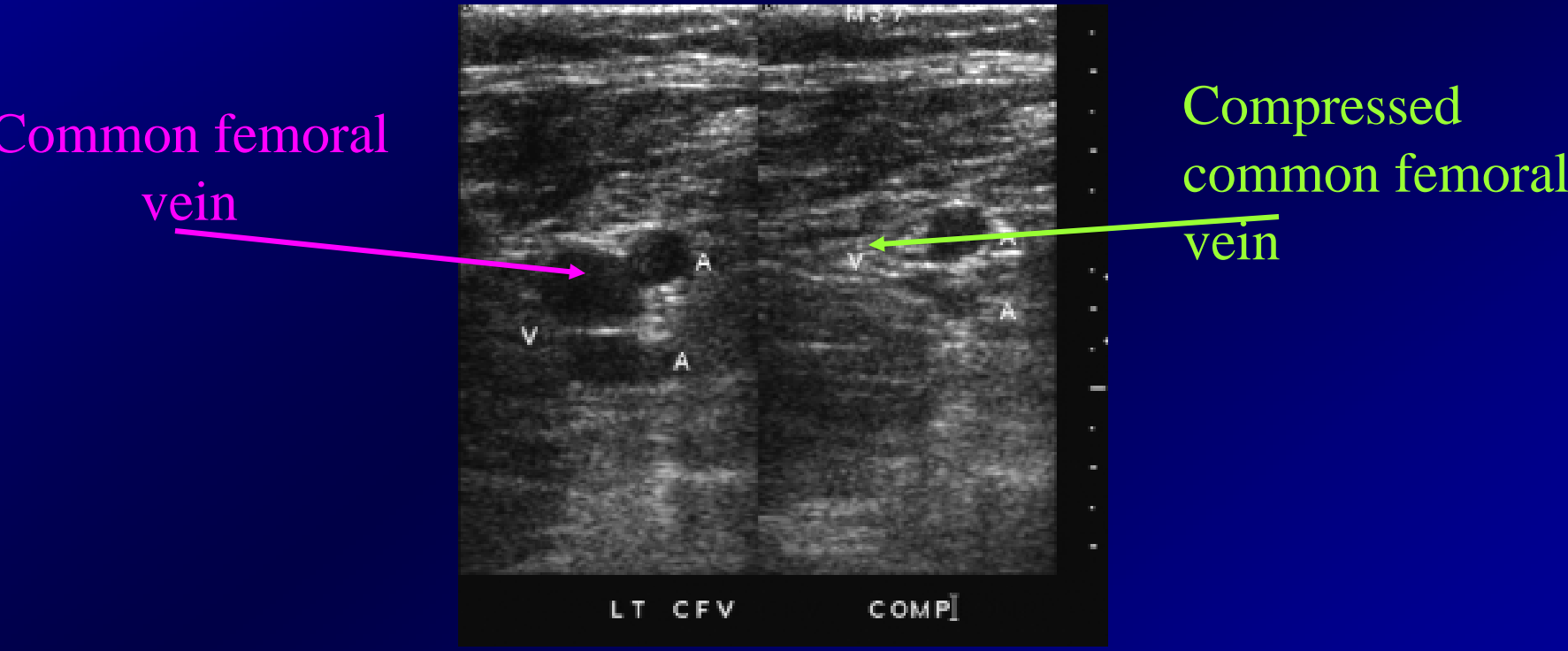


Minimizing the Uncertainty

- Multiple algorithms have been established to confirm or rule out PE in patients whose diagnosis is uncertain based on V/Q scan and clinical presentation, thereby minimizing the need for diagnostic pulmonary angiography.
- D-dimer measurements:
 - Measurements are highly sensitive but very non-specific.
 - One study of 517 patients demonstrated a 98% negative predictive value.
- Noninvasive lower extremity ultrasound
 - Ultrasound has a high sensitivity (89%-100%) and specificity (89%-100%) for DVT
 - Anticoagulation of patients positive for DVT would be therapeutic for an undiagnosed PE



Lower Extremity Non-Invasive Ultrasound: No Evidence of Thrombosis

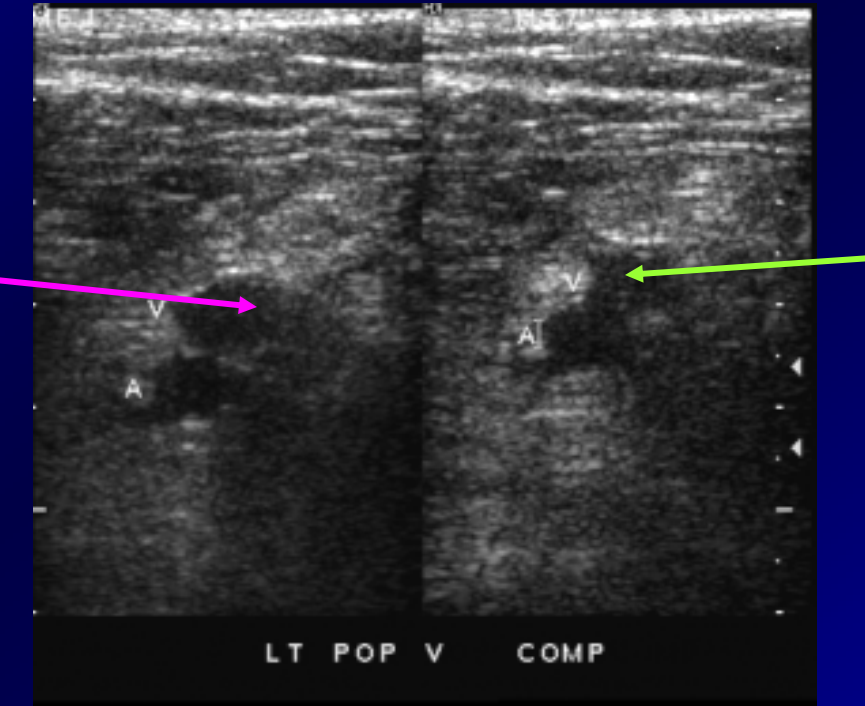
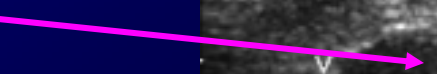


BIDMC PACS



Lower Extremity Non-Invasive Study: Deep Venous Thrombosis

Popliteal vein



Non-compressing popliteal vein





Lower Extremity Non-Invasive Ultrasound: DVT Criteria

- Primary diagnostic criteria is non-compressible vein
- Secondary criteria:
 - Echogenic thrombus in lumen
 - Venous distension
 - Lack of Doppler signal
 - No response to Valsalva with backwards flow or augmentation with forward flow



Pulmonary Angiography

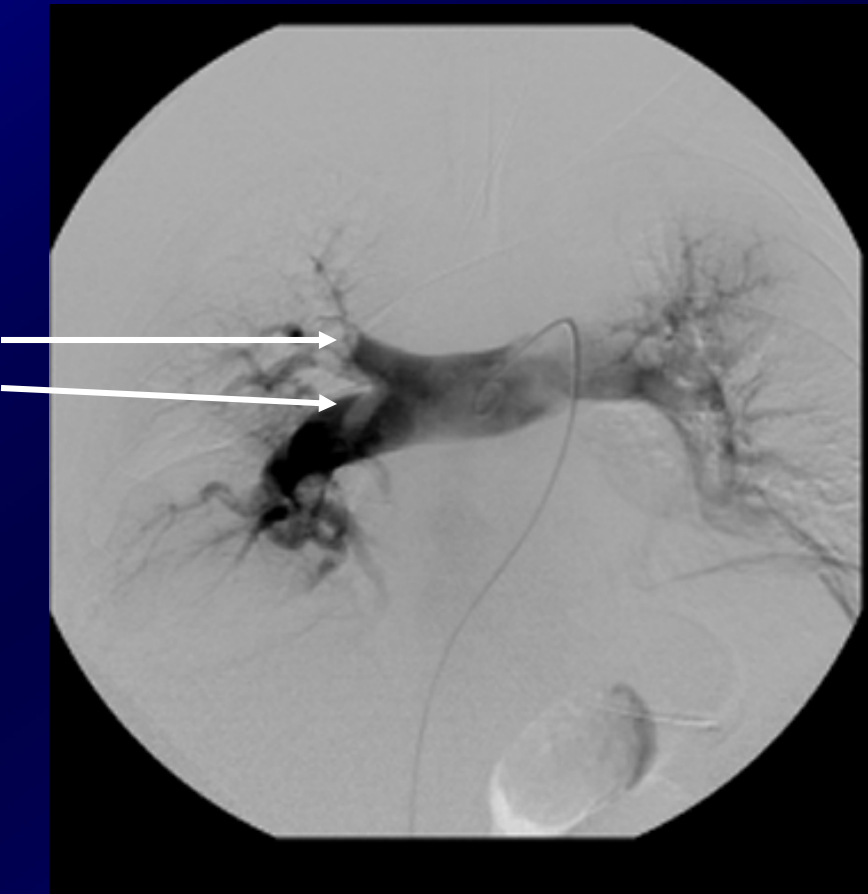
- Considered the gold standard in diagnosis of pulmonary embolism.
- Iodinated contrast is injected within the pulmonary vasculature after percutaneous catheterization, usually transfemorally.
- Mortality of 0.5% and morbidity of 5%
- Used in unstable patients, who require interventional management of pulmonary embolism:
 - Suction embolectomy
 - Intrapulmonary thrombolytic therapy

Lang, EV, Barnhart, WH, Walton, DL, Raab, SS, "Percutaneous Pulmonary Thrombectomy," SCVIR, 1997, 8: 427.
Value of the ventilation/perfusion scan in acute pulmonary embolism. Result of the prospective investigation of pulmonary embolism diagnosis (PIOPED). The PIOPED Investigators. JAMA 1990, 263: 2753



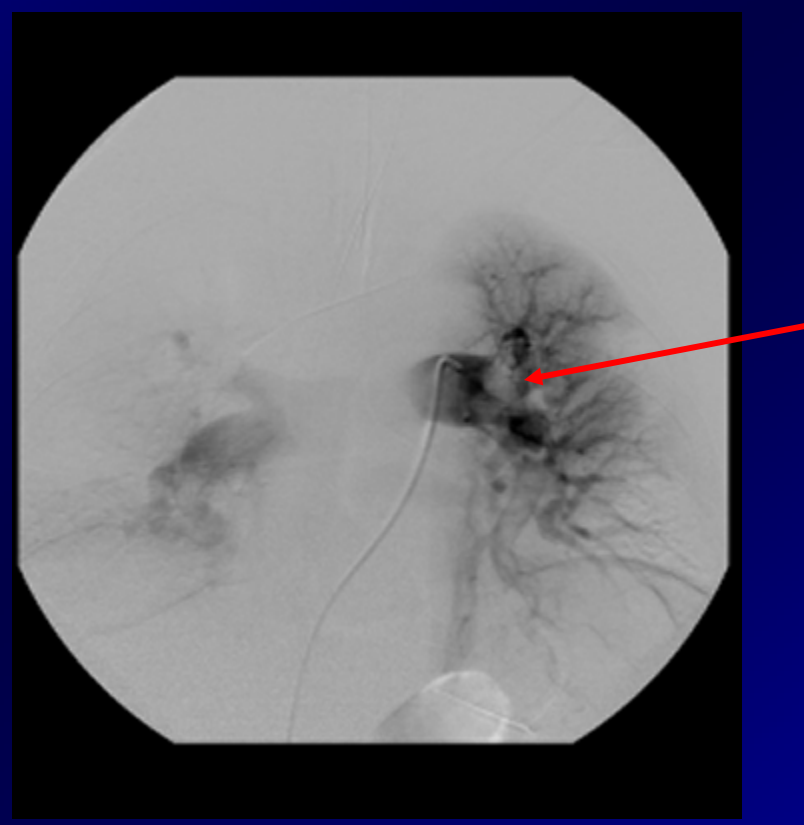
SI: Pulmonary Angiogram

Filling defects,
consistent with
emboli in upper
lobe circulation
and right
descending
pulmonary
artery





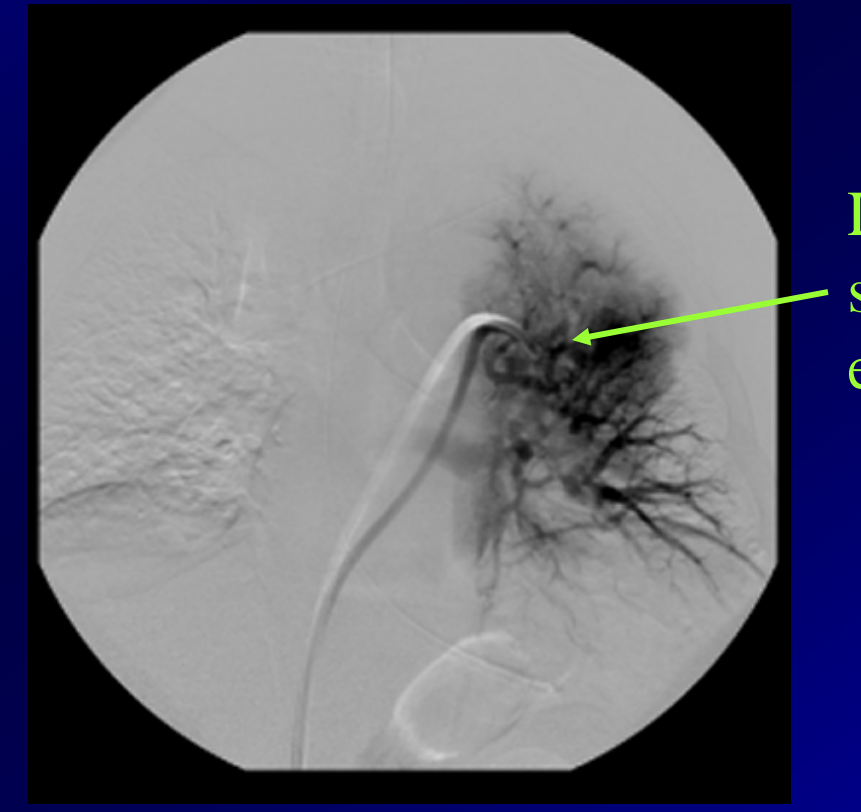
SI: Pulmonary Angiogram



Embolus in
left main
pulmonary
artery



SI: Pulmonary Angiogram



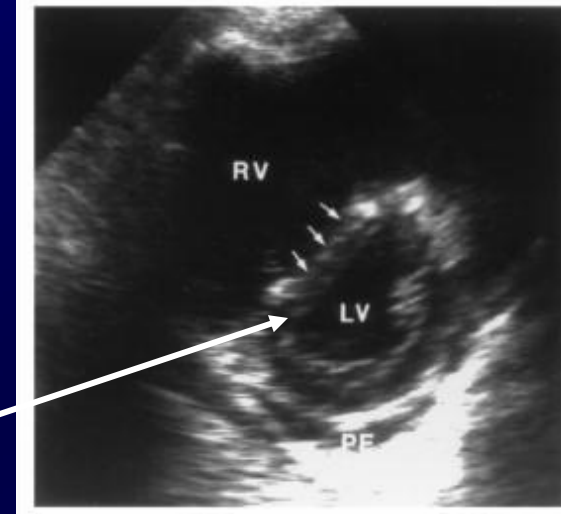
Lung perfusion
status post suction
embolectomy



Imaging Modalities Under Investigation

Echocardiography:

- Non-sensitive
- May provide information on PE's effect on right heart and therefore prognosticate
- Findings include right ventricular hypokinesis and septal bulging towards left ventricle
- Currently being examined as a tool for risk assessment and for management with thrombolytics and embolectomy



Goldhaber, SZ, "Echocardiography in the Management of Pulmonary Embolism." *Annals of Internal Medicine* 136(9): 691-700, 2002

Magnetic Resonance Angiography:

- Remains experimental, becoming more sensitive with advancing technology
- Like CTA, least sensitive in localizing subsegmental emboli

Meaney, JF, Weg, JG, Cheenevert, TL et. al. Diagnosis of pulmonary embolism with magnetic resonance angiography," *NEJM* 336: 1422, 1997.



Conclusions

- Pulmonary embolism diagnosis and treatment significantly improve patient survival.
- Diagnosis incorporates history, exam, and radiologic studies
- Multiple radiologic studies have a place in PE diagnosis, including chest x-rays, CT angiography, lower extremity non-invasive ultrasound studies, ventilation/perfusion scintigraphy, and pulmonary angiogram



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Acknowledgments

- Raja Kyriakos, MD
- Elvira Lang, MD
- Kevin Donohoe, MD
- Larry Barbaras
- Cara Lyn D'amour
- Gillian Lieberman, MD
- Pamela Lepkowski