Pulmonary Embolism.....Diagnostic Approach and Algorithm

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Epidemiology of Pulmonary Embolism

- Pulmonary Embolus (PE): Thrombus originating in the venous system that embolizes to the pulmonary arterial circulation
- PE occurs in up to 50% of patients with proximal DVT and about 79% of patients with a PE have evidence of a DVT
- 600,000 episodes yearly in United States
- 100,000 to 200,000 deaths
- Untreated PE = mortality of 15–30%.
Pathophysiology of PE

- In Acute PE:
  Anatomical obstruction and release of vasoactive and bronchoactive agents e.g. serotonin from platelets contribute to development of ventilation-perfusion mismatching
- Increased pulmonary vascular pressure
- Right ventricular after load increases tension in the right ventricular wall rises and may lead to dilatation, dysfunction, and ischemia of the RV
Diagrammatic Depiction of PE Pathophysiology

- **Origin:** Deep veins, most commonly the calf veins
- **Develop in places of venous stasis** e.g. venous valve pockets of lower extremity veins
- **Risk of embolism is increased** if clot propagates to or originates in popliteal veins or more proximally
- **Thrombi travel to right side of heart then to pulmonary arteries**
**Risk factors** for Deep Vein Thrombosis

Virchow’s Triad:
- Endothelial Injury: Trauma, surgery
- Stasis: Inactivity/ Immobility
- Hypercoagulability:
  - Inherited: Protein C or S deficiencies, Anti - phospholipid syndrome, Factor V Leiden mutation, Prothrombin gene mutation
  - Acquired: Pregnancy, Malignancy, OCPs, Smoking
Clinical Symptoms of PE (PIOPED II study)

Clinical symptoms suggestive of PE:
- Dyspnea
- Chest pain (Pleuritic or non pleuritic)
- Cough
- Orthopnea
- Calf and/or thigh pain or swelling
- Wheezing

Common signs:
- Tachypnea
- Tachycardia
- Rales
- Decreased breath sounds
- Jugular venous distension
- Accentuated pulmonic component of second heart sound

Symptoms/ signs of lower extremity DVT include edema, erythema, tenderness or a palpable cord.
Menu of Tests

- Chest X-Ray (CXR)
- ECG and D-Dimer
- Computed Tomography: Multiple detector CT pulmonary angiography (MDCT-PA)
- Ventilation- Perfusion Scan
- Pulmonary Arteriography
- MRI
- ECHO (not used for diagnosis)

Imaging Lower Extremities:
- Ultrasound
Step one in evaluation: CXR

- CXR is always the first imaging modality to obtain when evaluating a patient with chest pain
- CXR often not diagnostic
- Non specific findings that may be present:
  Cardiac enlargement, pleural effusions, elevated hemidiaphragm, pulmonary artery enlargement, discoid atelectasis
- Classic Findings on CXR:
  - Westermark Sign
  - Hampton’s hump
Companion Patient #1: CXR with Discoid Atelectasis

- CXR in a patient with a PE showing some areas of discoid atelectasis
- This does not rule in or rule out a PE
- Remember: A normal CXR never rules out a PE!

Frontal CXR: Boxes indicate areas of discoid atelectasis
Companion Patient #2: Westermark Sign on CXR

Watermark Sign: Dilatation of pulmonary vessels proximal to embolism along with collapse of distal vessels, often with a sharp cut off as shown by white arrow.

Frontal CXR: Arrow indicates abrupt cut off in pulmonary vasculature

http://www.e-radiography.net/technique/chest/cxreval22.jpg
Hampton’s Hump:
Peripheral wedge shaped opacity representing pulmonary infarction and atelectasis secondary to a pulmonary embolus as shown by white arrow

Frontal CXR: Arrow indicates Wedge shaped infarct
ECG and D-Dimer

ECG: Not specific
- Tachycardia
- Axis deviation
- Right bundle branch block
- S₁Q₃T₃ pattern

D-Dimer:
- Good sensitivity but poor specificity
- Best to use this in conjunction with clinical probability.
We have discussed the preliminary tests that are usually obtained in evaluating a patient with a PE. Now we will discuss the main diagnostic imaging modalities for PE.
Preferred Diagnostic Modality Today: MDCT-PA

- Contrast enhanced MDCT –PA is currently the preferred method of diagnosis

- Sensitivity (83%) and specificity (96%) of MDCT-PA for the detection of PE (PIOPED II)

- Typical findings on CTPA include:
  - Complete arterial occlusion: Low attenuation on CT
  - Non obstructive intraluminal filling defects
  - Evidence of right heart strain
  - Polo mint sign and Rail track sign
  - Can see peripheral wedge shaped infarcts
We will see images of the CT findings of PE later, when we discuss our index patient MH.
Advantages and Disadvantages of CTA

Advantages:
- Readily available
- Fast
- Minimally invasive
- Can provide prognostic information by assessing the size of the right ventricle
- Can detect alternative diagnoses

Disadvantages of CTA:
- Expensive
- Radiation dose
- Contraindicated in those with renal failure, contrast allergies and pregnant women
Why Should We Take Non Contrast Images When Performing a CT?

- To rule out other pathologies such as Intramural Hematomas which would not be well visualized on contrast enhanced images.

- Remember the radiologist is responsible for ruling out other possible etiologies of the patient’s symptoms and not just a PE.
Before CTAs became so popular VQ scans were in vogue.
Ventilation Perfusion (VQ) Scan

- Non invasive nuclear study: Identifies areas of VQ mismatch indicative of a PE

- Scans categorized as high, intermediate, low, very low probability or normal

- Largely replaced by CT but is still useful in situations where CT is contraindicated as previously mentioned
Technique and Limitations of VQ Scans

- CXR used as adjunct in interpretation

- Ventilation phase: Radioactive gas, usually xenon, is inhaled by patient. Normal scan would show homogenous bilateral distribution of the tracer

- Perfusion phase: Clusters of human albumin with a radioactive particle are injected into the patient’s vein. Normal scan would show homogenous bilateral distribution of tracer

- Limitations:
  - Many scans are indeterminate and thus non diagnostic.
  - Difficult to interpret in patients with certain underlying lung diseases e.g. COPD
The ventilation series demonstrates uniform distribution of tracer throughout both lung fields.

Generalized reduced trace uptake seen in the right lung

Multiple segmental and sub segmental perfusion defects throughout both lung fields.

These findings have a high probability for recent pulmonary embolism.

VQ scan: Purple circles indicate areas of decreased perfusion
Less Frequently Used Imaging Modalities:

- Pulmonary Angiography: Previously gold standard for diagnosing of acute PE, no longer in common use due to advances in CT and invasive nature of angiography.

- MR Angiogram: Non invasive, but takes longer to perform and more technically challenging.

- ECHO is not used for diagnosis but can show evidence of heart strain such as RV enlargement or ventricular dysfunction.
As previously mentioned lower extremity ultrasounds are used to evaluate for clots in the lower extremity. We will now see examples of a normal ultrasound and an abnormal one.
Companion Patient #5: Normal Left Common Femoral Vein

Lower Extremity Ultrasound: Arrow indicates compressed femoral vein
Companion Patient # 6: Non Compressible Left Popliteal Vein with DVT

Lower Extremity Ultrasound: Purple star shows non compressed popliteal vein
Companion Patient # 6: Lack of Flow in Left Popliteal Vein Filled With Clot

Doppler Ultrasound: Star indicates lack of flow in popliteal vein secondary to obstruction by clot
Interim Summary

- We have spoken about the pathophysiology and presentation of pulmonary embolism

- We have discussed the menu of tests at our disposal to guide our diagnosis

- We have seen examples of CXR, VQ scan and lower extremity ultrasound findings of PE and DVT

- We will now discuss our index patient MH and view examples of the CT findings that accompany PEs
Index Patient MH

HPI: 47 yo F with a history of left upper arm DVT who was on a recent flight. She presented to the ED with complaints of sudden worsening of her baseline tachypnea and pleuritic chest pain.

PMH: History of Left UE DVT, HTN.

Soc HX: No tobacco use, no OCP use, travels weekly.

Pertinent PE:
- Vitals: Systolic BP in the 130’s, HR 110, O2 Sat 92-93% on RA on arrival
- Gen: Respiratory distress speaking in short sentences
- CV: RRR no heaves, loud P2. No murmurs, rubs.
- Lungs: CTAB
- Ext: No edema, no palpable cords/calf tenderness

Ultrasound showed chronic non obstructive clot of the right popliteal vein with no extension into the upstream venous system.

MDCT performed to rule out PE given presentation and history
Our patient: Normal CXR

Frontal CXR: Normal
Our Patient: Bilateral Emboli in Distal Pulmonary Arteries

Axial C+ CT: Purple stars indicate clots in bilateral pulmonary arteries
Our patient: Emboli in Segmental Branches

Axial C+ CT: Yellow boxes indicate bilateral clots
Our patient: Emboli in Sub segmental Arteries!

Axial C+ CT: Yellow boxes indicate bilateral clots
Our patient: Enlargement of Pulmonary Artery to 3.3 cm

Axial C+ CT: Enlarged PA indicating pulmonary hypertension
Our patient: RV Enlargement and Bowing of Interventricular Septum

Axial C+ CT: Blue lines indicate RV dilation and arrow shows bowing of septum
Our patient: Reflux into Inferior Vena Cava

Axial C+ CT: Reflux into IVC indicating severely increased RV pressure
Our Patient: Bilateral Pulmonary Emboli

Axial C+ CT Coronal views: Stars Indicate bilateral emboli
Our Patient’s course

- The patient was treated with Heparin IV, monitored for a few days in the ICU, before being transferred to the floor. She was then transitioned to Coumadin before discharge.

- Follow up scan three months later showed complete resolution of the PE and no residual evidence of heart strain.
Summary Algorithm

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References