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

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Signs</th>
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<tbody>
<tr>
<td>Dyspnea 73%</td>
<td>Tachypnea 70%</td>
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<tr>
<td>Pleuritic chest pain 66%</td>
<td>Rales 51%</td>
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<tr>
<td>Cough 37%</td>
<td>Tachycardia 30%</td>
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<tr>
<td>Hemoptysis 13%</td>
<td>S4 24%</td>
</tr>
<tr>
<td></td>
<td>Fever 14%</td>
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<td></td>
<td>Clinical Manifestations of DVT 30%</td>
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<td></td>
<td>EKG changes 70%</td>
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<td>T wave inversions on EKG 49%</td>
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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

- No pulmonary effusion
- Mediastinal contours unchanged from previous CXR
- Pulmonary vasculature unremarkable
- 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

Right and left main stem bronchi

Main Pulmonary Artery

Right pulmonary artery embolus

Non-obstructive saddle embolus

Embolus extension into left pulmonary artery
Upper lobe branch occluded by embolus

Ascending aorta

Embolus in right upper lobe arterial tree

Trachea

Descending aorta

S.I CTA
S.I: CTA (Coronal Reconstruction)

Emboli in the left main pulmonary artery

Emboli in the descending right 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.

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 defects.
- Low probability scan: Non-segmental defect or or defect accompanied by large radiographic abnormality

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.

## Likelihood of Pulmonary Embolism following V/Q Scan

<table>
<thead>
<tr>
<th></th>
<th>High Clinical Probability</th>
<th>Intermediate Clinical Probability</th>
<th>Low Clinical Probability</th>
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</thead>
<tbody>
<tr>
<td>High Likelihood Scan</td>
<td>95</td>
<td>85</td>
<td>56</td>
</tr>
<tr>
<td>Intermediate Likelihood Scan</td>
<td>66</td>
<td>28</td>
<td>15</td>
</tr>
<tr>
<td>Low Likelihood Scan</td>
<td>40</td>
<td>15</td>
<td>4</td>
</tr>
<tr>
<td>Normal Scan</td>
<td>0</td>
<td>6</td>
<td>2</td>
</tr>
</tbody>
</table>

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

Perfusion

Ventilation

Courtesy: Kevin Donohoe, MD BIDMC
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

Common femoral vein

Compressed common femoral vein

BIDMC PACS
Lower Extremity Non-Invasive Study: Deep Venous Thrombosis

Poîlitéal 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

SI: Pulmonary Angiogram

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

Courtesy Elvira Lang, MD BIDMC
SI: Pulmonary Angiogram

Embolus in left main pulmonary artery

Courtesy Elvira Lang, MD BIDMC
SI: Pulmonary Angiogram

Lung perfusion status post suction embolectomy

Courtesy Elvira Lang, MD BIDMC
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

**Magnetic Resonance Angiography:**
- Remains experimental, becoming more sensitive with advancing technology
- Like CTA, least sensitive in localizing subsegmental emboli

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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
References


References


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