Role of imaging in the diagnosis of pulmonary embolism

By
Dr, Mohamed Abdelaal Khalfallah
Lecturer of cardiology, Tanta

Pulmonary embolism

- pulmonary embolism:
  An obstruction of the pulmonary artery or one of its branches by a thrombus or embolus.
- The majority of cases result from thrombotic occlusion

Other embolic sources include:
- Fat embolism
- Air embolism
- Amniotic fluid embolism
Risk factors for pulmonary embolism

- recent surgery
- pregnancy
- prolonged bed rest/immobility
- malignancy
- oral contraceptive use
- known or previous DVT
- presence of certain venous aneurysms

Risk factors for pulmonary embolism

- Pacemaker, implantable cardiac defibrillator leads, or central venous catheter.
- Advance age.
- Obesity
- Congestive heart failure
- hypercoagulable states including:
  - protein C deficiency
  - protein S deficiency
  - antithrombin III deficiency
  - lupus anticoagulant
Diagnosis of pulmonary embolism
The most common modalities used:

- ECG
- Chest X Ray
- Echocardiography
- V/Q scan
- Pulmonary Angiography
- MRI
- Duplex of veins of lower limbs
- Spiral CT

Key ECG findings include:

- Sinus tachycardia
  the most common abnormality
- Complete or incomplete RBBB
- Right ventricular strain pattern
- Right axis deviation
- Dominant R wave in V1
- \( S_I, Q_{III}, T_{III} \) pattern
  deep S wave in lead I, Q wave in III, inverted T wave in III.
Key ECG findings include

- Right atrial enlargement (P pulmonale)
- Clockwise rotation shift of the R/S transition point towards V6 with a persistent S wave in V6
- **Atrial tachyarrhythmias** AF, flutter, atrial tachycardia. Seen in 8% of patients.

Non-specific ST segment and T wave

- Sinus tachycardia
- RBBB
- T-wave inversions in the right precordial leads (V1-3) as well as lead III
ECG:

- The main value of ECG is exclusion of other diagnoses, such as MI or pericarditis rather than diagnosis of pulmonary embolism.

Chest X ray

- A chest x-ray is neither sensitive nor specific for a pulmonary embolism. It is used to assess for differential diagnostic possibilities such as pneumonia and pneumothorax rather than for the direct diagnosis of PE.

Some described chest radiographic signs include:

- Fleischner sign: enlarged pulmonary artery (20%)
- Hampton hump: A peripheral wedge-shaped density above the diaphragm and implies lung infarction (20%)
- Westermark sign: regional oligaeamia indicates massive central embolic occlusion with marked decrease in vascularity
- pleural effusion (35%)
- Elevated diaphragm
Chest x-ray showing pulmonary infarction in right lower lobe.
Westermark sign

Hampton’s hump
Incidence of chest x ray finding in pulmonary embolism

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

Echocardiographic Signs of Pulmonary Embolism

- Right ventricular enlargement or hypokinesis, especially free wall hypokinesis, with sparing of the apex (the McConnell sign)
- Interventricular septal flattening and paradoxical motion toward the left ventricle, resulting in a D-shaped left ventricle in cross section
- Tricuspid regurgitation
Echocardiographic Signs of Pulmonary Embolism

- Pulmonary hypertension with a tricuspid regurgitant jet velocity >2.6 m/sec
- Dilated inferior vena cava
- Loss of respiratory-phasic collapse of the inferior vena cava with inspiration
- Direct visualization of thrombus (more likely with transesophageal echocardiography)
V/Q scan

• Test is used to identify areas of the lung not receiving air flow or blood flow.
• Ventilation without perfusion suggests the probability of a pulmonary embolus.
• Two parts of the test:
  1. **Perfusion scan**: Radioisotope IV injection. Scans to detect anything in the pulmonary circulation.
  2. **Ventilation scan**: Inhale radioactive gas (xenon). This displays how the gas within the lungs distributes.
V/Q scan

• There is still some indications to obtain a lung scan:
  (1) renal insufficiency,
  (2) anaphylaxis to intravenous contrast agent that cannot be suppressed with high-dose corticosteroids
  (3) pregnancy (lower radiation exposure to the fetus).
Pulmonary angiography

- This is an invasive procedure, a catheter is inserted via the femoral vein to pulmonary artery
- The dye is injected through the left or the right branch of the pulmonary artery.
- Normal Findings: Pulmonary vessels fill symmetrically and quickly with no defects or obstruction.
Pulmonary angiography

- Invasive pulmonary angiography was formerly the reference standard for diagnosis of PE, but it is now rarely performed.
- However, pulmonary angiography is required when interventions are planned, such as
  1. suction catheter embolectomy,
  2. mechanical clot fragmentation, or
  3. catheter directed thrombolysis.
• Left-sided pulmonary angiogram showing Extensive filling defects within the left pulmonary artery and its branches.
Magnetic Resonance Imaging

- Gadolinium-enhanced magnetic resonance angiography (MRA) is far less sensitive than CT for the detection of PE.
- However, unlike chest CT or catheter-based pulmonary angiography, MRA does not require ionizing radiation or injection of iodinated contrast agent.
- In addition, magnetic resonance pulmonary angiography can assess right ventricular size and function.
### MRA

![MRA images](image)

### Diagnosis

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower limb CUS in search of DVT may be considered in selected patients with</td>
<td>IIb</td>
<td>B</td>
</tr>
<tr>
<td>suspected PE to obviate the need for further imaging test if the result is</td>
<td></td>
<td></td>
</tr>
<tr>
<td>positive.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CUS showing a proximal DVT in a patient with clinical suspicion of PE confirms</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>PE.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If CUS shows only a distal DVT, further testing should be considered to</td>
<td>IIa</td>
<td>B</td>
</tr>
<tr>
<td>confirm PE.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pulmonary angiography</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulmonary angiography may be considered in cases of discrepancy between</td>
<td>IIb</td>
<td>C</td>
</tr>
<tr>
<td>clinical evaluation and results of non-invasive imaging tests.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MRA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MRA should not be used to rule out PE.</strong></td>
<td>III</td>
<td>A</td>
</tr>
</tbody>
</table>


[www.escardio.org/guidelines](http://www.escardio.org/guidelines)
Duplex on veins of lower limbs

- A noninvasive test known as a duplex venous ultrasonography, uses high-frequency sound waves to check for blood clots in lower limb veins.
- 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
Spiral CT

• Spiral CT is similar to the regular CT, but the spiral CT actually spirals around the body giving a 3D image.
• Detect size, location, and extent of thrombus
• Detect other diagnoses that may coexist with PE: Pneumonia, Pericardial effusion or Pneumothorax.

Spiral CT

• Detect right ventricular enlargement
• Detect contour of the interventricular septum
• Detect incidental masses or nodules in the lung
• Risks: exposure to radiation, allergic reaction to contrast medium
Spiral CT

A

Spiral CT

A
Spiral CT

Diagnosis

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT angiography</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>Normal CT angiography safely excludes PE in patients with low or intermediate clinical probability or PE-unlikely.</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>Normal CT angiography may safely exclude PE in patients with high clinical probability or PE-likely.</td>
<td>IIa</td>
<td>B</td>
</tr>
<tr>
<td>CT angiography showing a segmental or more proximal thrombus confirms PE.</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Further testing to confirm PE may be considered in case of isolated sub-segmental clots.</td>
<td>IIb</td>
<td>C</td>
</tr>
</tbody>
</table>

Scintigraphy

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal perfusion lung scintigram excludes PE.</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>High probability V/Q scan confirms PE.</td>
<td>IIa</td>
<td>B</td>
</tr>
<tr>
<td>A non-diagnostic V/Q scan may exclude PE when combined with a negative proximal CUS in patients with low clinical probability or PE-unlikely.</td>
<td>IIa</td>
<td>B</td>
</tr>
</tbody>
</table>
Diagnostic algorithm: high-risk PE

- Suspected PE with shock or hypotension
  - CT angiography immediately available
    - No
      - Echocardiography
        - RV overload
          - No
            - Search for other causes of haemodynamic instability
          - Yes
            - CT angiography available and patient stabilized
              - No
                - PE-specific treatment: primary reperfusion
              - Yes
                - CT angiography

- CT angiography
  - Positive
    - No other test available or patient unstable: PE-specific treatment: primary reperfusion
  - Negative
    - Search for other causes of haemodynamic instability

---

Diagnosis

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspected PE with shock or hypotension</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>In suspected high-risk PE, as indicated by the presence of shock or hypotension, emergency CT angiography or bedside transthoracic echocardiography (depending on availability and clinical circumstances) is recommended for diagnostic purposes.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In patients with suspected high-risk PE and signs of RV dysfunction who are too unstable to undergo confirmatory CT angiography, bedside search for venous and/or pulmonary artery thrombi with CUS and/or TOE may be considered to further support the diagnosis of PE, if immediately available.</td>
<td>IIb</td>
<td>C</td>
</tr>
<tr>
<td>Pulmonary angiography may be considered in unstable patients admitted directly to the catheterization laboratory, in case coronary angiography has excluded an acute coronary syndrome and PE emerges as a probable diagnostic alternative.</td>
<td>IIb</td>
<td>C</td>
</tr>
</tbody>
</table>

D-dimer

• D-dimer is commonly used as a screening test in patients with a low and moderate probability clinical assessment.
• normal D-dimer has almost 100% negative predictive value (virtually excludes PE): no further testing is required.
• raised D-dimer is seen with PE but has many other causes and is, therefore, non-specific: it indicates the need for further testing if pulmonary embolism is suspected.

D-dimer

• On patients with a high probability clinical assessment, a D-dimer test is not helpful.
• because a negative D-dimer result does not exclude pulmonary embolism in more than 15%.
• Patients are treated with anticoagulants while awaiting the outcome of diagnostic tests.
Take home message:

- PE is common and under-recognized serious medical problem
- Early diagnosis and treatment is essential for good outcome
- High index of suspicion is needed in high risk patients
- In high risk patients and high clinical probability, spiral CT is the first line if available
- D-dimer is the first line in low and intermediate clinical probability