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Diagnosis of Pulmonary Embolus

- In patients with suspected pulmonary embolism, posterior/anterior and lateral chest X-rays are recommended as an initial imaging examination because they may reveal an alternate diagnosis and obviate the need for further imaging.
- If the chest X-ray is negative and the patient has a D-dimer level over an age-adjusted threshold, CT pulmonary angiography (CTPA) is the examination of choice.
- Ventilation/perfusion scintigraphy is recommended only for patients who are allergic to iodinated contrast media or have poor kidney function. It should also be considered in young women because the breast radiation dose is lower than CTPA.
- In pregnant patients with symptoms of deep vein thrombosis, compression ultrasound may yield sufficient information to initiate treatment and avoid radiation exposure. If pulmonary embolism imaging is required in pregnancy, CTPA delivers lower radiation exposure to the fetus and is the imaging modality of choice.

Each year in the United States, pulmonary embolism (PE) leads to an estimated 290,000 fatalities and 230,000 non-fatal events. PE is a leading cause of pregnancy-related mortality and accounts for 20% of maternal deaths in the United States. Diagnosis is challenging because the symptoms of PE (chest pain, shortness of breath and tachycardia) are non-specific and mimic other pulmonary and cardiac conditions. Unsuspected PE continues to be a frequent autopsy finding.

Validated clinical decision tools, such as the Wells criteria and the Pulmonary Embolism Rule-Out Criteria (PERC), help categorize patients into three groups: 1) those who are very unlikely to have PE and do not require further evaluation for this condition; 2) those at intermediate risk who would benefit from plasma D-dimer testing; and 3) those at high risk for whom imaging is indicated. A normal age-adjusted D-dimer level is an accurate indication that a patient does not have PE. If anticoagulant treatment is not given to such patients, their estimated 3-month risk of thromboembolism is 0.14% (95% confidence interval, 0.05–0.41).

Chest Radiography

Posterior/anterior and lateral chest radiographs are valuable as initial imaging studies for patients with suspected PE because they may reveal an alternate diagnosis and eliminate the need for further imaging. A normal chest radiograph does not exclude PE.

CT Pulmonary Angiography (CTPA)

CT pulmonary angiography (CTPA) is a thin-section CT examination in which image acquisition is timed to coincide with peak pulmonary arterial enhancement. From this data set, axial images, multiplanar reformations, and 3D renderings are used to detect emboli. CTPA is highly accurate and can reveal emboli in sub-segmental blood vessels as small as 2–3 mm in diameter (Figure 1). Since the advent of widespread use of CTPA, the apparent incident of PE has increased substantially, with no increase in PE-related mortality. The high sensitivity of CTPA has raised concerns about overdiagnosis of PE, which may be associated with complications from anti-coagulation treatment in patients who would have recovered without treatment. Outcome studies have shown that if CTPA is negative, no adverse events are observed if the patient remains untreated for PE.

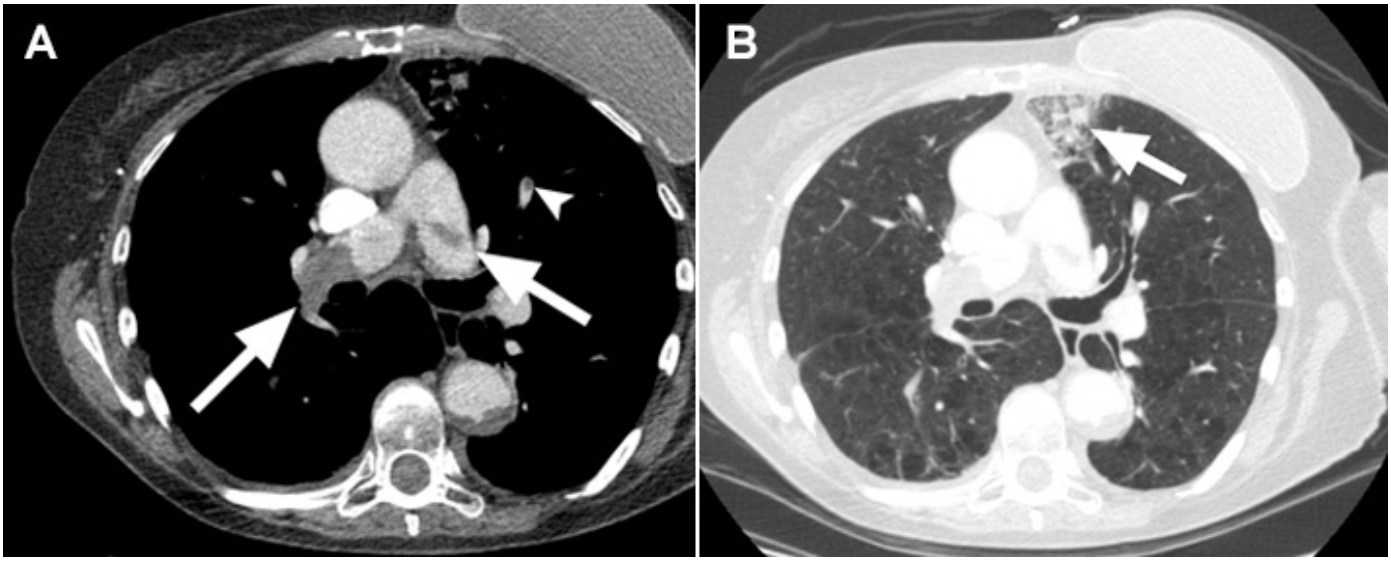

Figure 1. CTPA images for an 80-year-old woman with a history of breast cancer and shortness of breath. **(A)** Axial image demonstrates filling defects in the right and left pulmonary arteries (arrows). Another filling defect is seen in a left upper lobe segmental artery (arrow head). These are consistent with pulmonary emboli. **(B)** Axial image at the same location on lung window demonstrates ground glass opacity in the periphery of the left upper lobe consistent with an infarct.

CTPA can also identify signs of right ventricular dysfunction that may have prognostic implications that may guide the choice of therapy. It may also detect an alternate pathology that could be responsible for the patient's symptoms.

It is possible to follow CTPA with a scan of the lower extremities as the contrast media passes through the venous system to assess for deep vein thrombosis (DVT). However, this approach entails unnecessary radiation exposure.

CTPA can also be performed with a dual-energy CT (DECT) scanner, in which case a lower dose of contrast media can be administered. DECT should be considered for patients at higher risk of contrast-induced nephropathy, which is associated with pre-existing renal impairment, (eGFR < 45 mL/min/1.73 m2), diabetes mellitus, renal transplant, age > 70 years, anemia, congestive heart failure, hypotension, hypovolemia, taking nephrotoxic drugs, and/or multiple myeloma.

Ventilation/Perfusion Scintigraphy

The role of ventilation/perfusion (V/Q) scintigraphy has diminished with the advent of CTPA but remains an important diagnostic tool for patients with allergies to contrast media or poor kidney function (eGFR < 30 mL/min/1.73 m2) at risk for contrast nephropathy. No major adverse consequences are associated with radiopharmaceuticals used in this examniation; however, patients must be able to sit up or lie flat for about 45 minutes to complete the examination. The ventilation portion of the examination generally cannot be performed in patients with oxygen requirements > 10L. Because the radiation exposure from V/Q scintigraphy (3 mSv) is lower than that for CTPA, which directly irradiates the chest, V/Q scintigraphy may in some cases be considered in young women, whose breast tissue is especially vulnerable to radiation exposure.

An abnormal pattern of perfusion is not specific for the diagnosis of PE. It requires an evaluation of the anatomic basis of the perfusion deficit and correlation with ventilation imaging. It also requires a recent chest radiograph to differentiate between reduced arterial blood flow due to vascular obstruction and secondary reductions in perfusion associated with a variety of airway diseases. V/Q scanning is thus more frequently non-diagnostic in older patients and those with underlying lung disease.

Results of V/Q scans (Figure 2) are classified as high probability (> 80% chance of PE), intermediate probability (20-80% chance of PE), low probability (< 20% chance of PE), and normal. Only 1% of V/Q scans rated as "high probability" corresponds to an isolated sub-segmental occlusion, compared to 15% of CTPA scans. Nevertheless, a normal pattern of regional perfusion in multiple directions together with a normal ventilation scan is sufficient to rule out emboli.

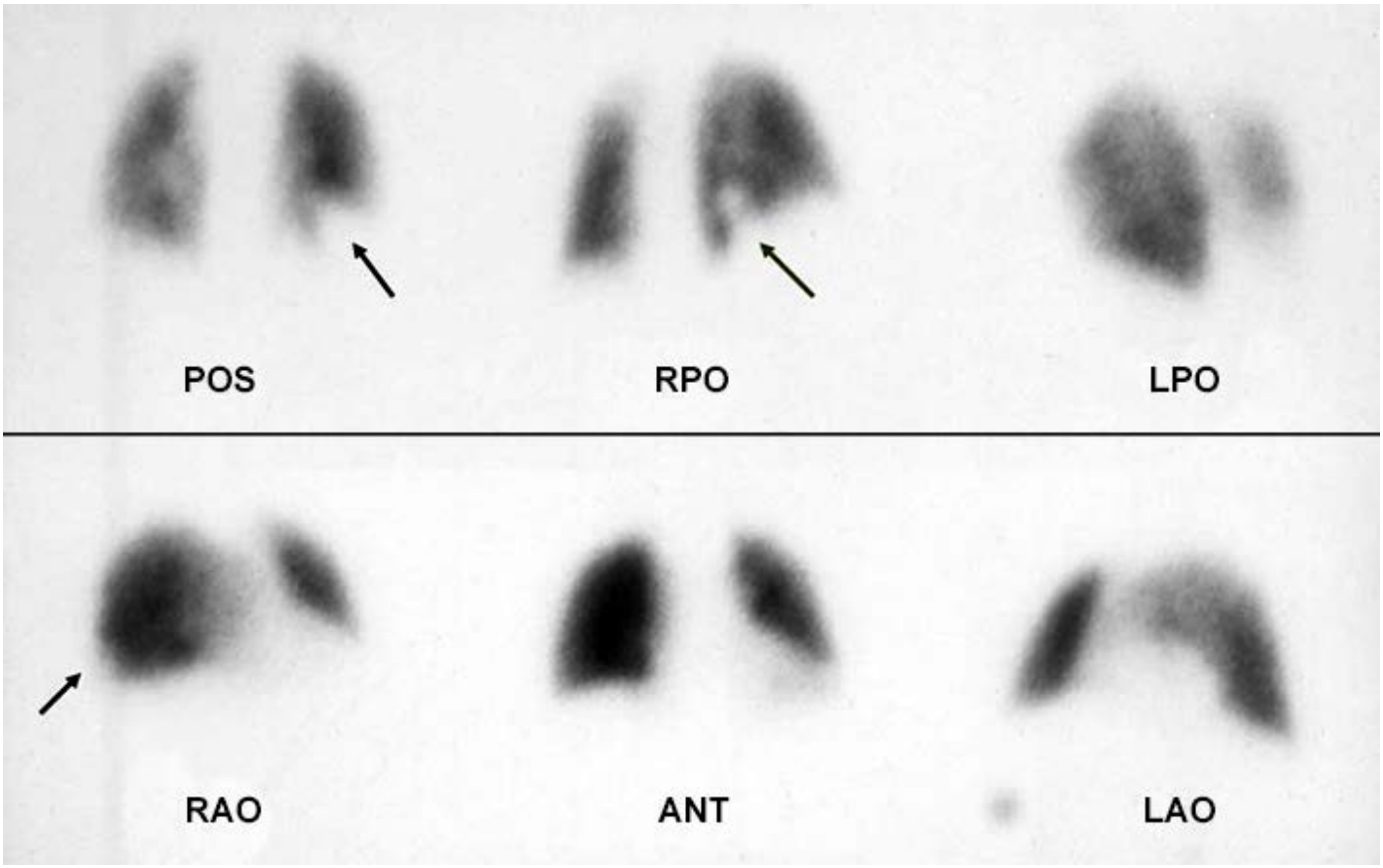

Figure 2. Perfusion images showing a perfusion deficit (arrows) corresponding to a single pulmonary embolus. ANT, anterior; POST, posterior; RPO, right posterior oblique; LPO, left posterior oblique; RAO right anterior oblique; LAO, left anterior oblique.

Compression Ultrasound

Compression ultrasound (CUS) is the examination of choice to detect DVT. In patients with suspected acute PE, a positive CUS provides indirect evidence that PE is present and justifies anti-coagulation therapy. Lower extremity venous ultrasound has a sensitivity of 95–97% and 72%, respectively, for proximal and distal evaluation of symptomatic patients. It has a sensitivity of 62% and 48%, respectively, for proximal and distal evaluation of asymptomatic, high-risk patients. Specificity of CUS is 93%–97%.

CUS is especially useful in pregnant patients because it can avoid radiation exposure if DVT is found. If DVT is not identified and further imaging is required to diagnose PE in pregnant patients, radiation exposure to the fetus is lower from CTPA than from V/Q scanning. If V/Q scanning must be performed because of CT contraindications, it is sometimes possible to reduce the radiopharmaceutical dose and increase the image acquisition time increased to minimize fetal radiation exposure.

Further Information

For further information on the diagnosis of PE, please contact Shaunagh McDermott, MD, Thoracic Imaging, Massachusetts General Hospital, at 617-724-3254.

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