Imaging of acute pulmonary thromboembolism*

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The diagnosis of acute pulmonary thromboembolism is based on clinical probability, use of D-dimer (when available) and imaging. The main imaging modalities used in the diagnosis are ventilation-perfusion (V/Q), pulmonary angiography, and computed tomography (CT). In the last decade several studies have demonstrated that spiral CT has a high sensitivity and specificity in the diagnosis of acute pulmonary thromboembolism. The evaluation of the pulmonary arteries has further improved with the recent introduction of multidetector spiral CT scanners. Several groups of investigators have suggested that contrast enhanced spiral should replace scintigraphy in the assessment of patients whose symptoms are suggestive of acute PE. This article discusses the role of the various imaging modalities in the diagnosis of acute pulmonary thromboembolism with emphasis on spiral CT.

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INTRODUCTION

Pulmonary thromboembolism (PTE) is a common clinical entity that results in considerable morbidity and mortality. Prompt and correct diagnosis is important because of the complications of PTE and the complications from treatment with anticoagulants. The diagnosis of acute PTE is based on clinical probability and use of D-dimer (when available) but confirmation of diagnosis requires specific imaging methods (1).

For many years, ventilation-perfusion (V/Q) scintigraphy was the main imaging modality used in the evaluation of patients with suspected PTE (2). A high probability V/Q scan provides sufficient certainty to confirm the diagnosis of PTE while a normal or near normal scan reliably excludes the diagnosis. However, only one third of the patients with clinically suspected PTE fall into one of these categories; two thirds of the patients have inconclusive V/Q scan results (2). It should also be noted there is limited availability of scintigraphy in Brazil thus further reducing its use.

Pulmonary angiography has traditionally been considered to be the gold standard for diagnosing PTE (2,3). Pulmonary angiography however is an invasive method available in a small number of centers that is performed less and less in the evaluation of these patients (4,5).

The introduction of spiral computed tomography (CT) in the early 1990s has made it possible to image the entire chest in a short period of time and analysis of the pulmonary arteries during the peak of contrast enhancement. Several studies have shown a high sensitivity and specificity for spiral CT in the diagnosis of PTE (6,7,8). The accuracy has been further improved with the recent introduction of multidetector CT. In an increasing number of centers, spiral CT has become the imaging modality of choice in the diagnosis of PTE.

The aim of this manuscript is to review the indications and limitations of the various imaging techniques used in the diagnosis of acute pulmonary embolism, with emphasis on spiral CT.

PULMONARY SCINTIGRAPHY

The diagnosis of PTE on scintigraphy is based on the presence of ventilation in the absence of perfusion, i.e., ventilation-perfusion mismatch, distal to obstructing emboli. The findings on the ventilation and perfusion scintigrams are classified in terms of the probability of emboli being present into high probability, intermediate probability, low probability, very low probability, and normal. A high probability V/Q scan provides sufficient certainty to confirm the diagnosis of PTE while a normal or near normal scan reliably excludes the diagnosis. However, in the PIOPED (Prospective Investigation of Pulmonary Embolism Diagnosis) study, indeterminate scans, present in 39% (364 of 931) of patients, showed a 30% incidence of PTE and low-probability scans, seen in 34% (312 of 931) of patients, a 14% incidence (2). Based on these data the authors concluded that indeterminate and low probability lung scans (i.e., two-thirds of V/Q scans in the PIOPED study) were not useful in establishing or excluding a diagnosis of acute PTE. Furthermore, although there was good interobserver agreement for high-probability and normal V/Q scans, there was a 25%-30% disagreement between observers in the interpretation of intermediate and low-probability scans (2).

PULMONARY ANGIOGRAPHY

At pulmonary angiography a catheter is introduced transvenously into the proximal pulmonary artery and contrast media is rapidly injected. The technique provides high spatial resolution and allows direct visualization of the arterial lumen and detection of emboli as intraluminal filling defects. However, pulmonary angiography is an invasive method associated with a 5% risk of cardiac and pulmonary complications and 0.3% mortality (3). Because of these potential risks there is considerable reluctance by clinicians and radiologists in the performance of pulmonary angiography for PTE. Even in large academic centres in the United States and United Kingdom it has been estimated that only 5 to 15% of patients with indeterminate ventilation-perfusion scintigrams undergo pulmonary angiography (4,5).

Abreviations used in this paper:

CT – Computed tomography  
PE – Pulmonary embolism  
V/Q – Ventilation-perfusion  
US – Ultrasound  
DVP – Deep vein thrombosis
Interpretation of Images:

Characteristic findings of acute PTE are: 1) partial central or marginal filling defect surrounded by a thin rim of contrast material (Fig. 1); or 2) complete filling defect with obstruction of an entire vessel section [6,7,8]. Pulmonary arteries completely obstructed by an acute embolus usually have an increased diameter (Fig. 2). Diagnosis of acute PTE requires assessment of both the vascular and parenchymal findings. Assessment of the lung windows is important not only to identify the pulmonary arteries by their proximity to the bronchi, but also to assess for the presence of ancillary signs that may be helpful in suggesting the presence of pulmonary embolism [9,10]. The most helpful ancillary sign is the presence of a non-enhancing pleural-based wedge-shaped pulmonary opacity (Fig. 3). Linear (plate-like) atelectasis is also seen with increased frequency on CT in patients with acute PTE. Other findings, such as areas of decreased attenuation and pleural effusion, are not helpful in distinguishing patients with and without acute PTE [9,10].

A number of technical, anatomical, and patient related pitfalls may lead to misinterpretation of the CT images. Technical failures occur in 1% to 5% of scans, and are usually due to motion artifacts in dyspneic patients or insufficient vascular enhancement. In patients with severe dyspnea, motion artifacts can produce respiratory misregistration and inadequate sampling of the pulmonary vessels resulting in focal areas of decreased attenuation that can mimic a clot.

The lymphatic and connective tissue located adjacent to the pulmonary arteries may mimic the appearance of pulmonary emboli. This pitfall can be minimized by careful review of the images and the use of additional imaging rendering tools such as cine-viewing (which we use routinely) and multiplanar reconstructions.
Diagnostic Accuracy of Spiral CT

The reported diagnostic accuracy of spiral CT has varied depending on the technique used, the patient population, and whether the authors have limited the analysis to the central pulmonary arteries down the level of the segmental vessels or have included subsegmental arteries. Overall, these studies have shown a sensitivity of spiral CT of 90%, a specificity of 90%, positive predictive value of 93%, and negative predictive value of 94% for emboli down to and including the level of the segmental pulmonary arteries.

The results of the various studies in the literature indicate that although spiral CT has a high sensitivity in the detection of central emboli (Fig. 4), it is of limited value in the diagnosis of subsegmental emboli. It should be noted, however, that the clinical significance of isolated subsegmental emboli, especially in patients with no underlying disease, is controversial. Furthermore, it has been shown that even though pulmonary angiography is considered the gold standard for the diagnosis of pulmonary embolism, the interobserver agreement for the diagnosis of subsegmental emboli on angiography is only 66% (1). Experimental work in a porcine model has shown that spiral CT is comparable to pulmonary angiography in the diagnosis of subsegmental pulmonary embolism (12). Preliminary results indicate that the accuracy of spiral CT in the diagnosis of subsegmental emboli is be improved with the use of thinner sections such as 1 or 2 mm collimation and multidetector CT scanners (13, 14). Multidetector CT scanners allow evaluation of the entire chest within a few seconds using 1mm thick sections, thus providing better depiction of the segmental and subsegmental pulmonary arteries during peak of contrast opacification (Fig. 5). These scanners also allow high quality multiplanar reconstructions that further facilitate diagnosis or exclusion of PTE (Fig. 6) (13, 14).

Because of the limitations of angiography as a gold standard, a better way to determine the sensitivity of spiral CT in the detection of acute pulmonary thromboembolism is to look at the outcome of patients in whom anticoagulation was withheld after a negative spiral CT. The results of the various studies performed so far have shown that the outcome of patients after a negative CT is similar to that reported after a negative angiogram or negative V/Q scan (15, 16). Goodman et al compared 198 patients with negative spiral CT findings to 350 patients with a negative V/Q scan (normal or low probability) (15). During 3-month follow-up, subsequent PTE was observed in 1% of patients in the spiral CT group compared to 1.5% of patients in the V/Q group (not statistically significant). Swensen et al. reviewed 1512 consecutive patients who were referred for CT with clinically suspected acute pulmonary thromboembolism (16). Nine
hundred and ninety three of these patients received no anticoagulation and had CT scans interpreted as negative for acute pulmonary embolism. A 3-month probability of venous thromboembolism of 0.5% was identified in these patients. The authors concluded that it is safe to withhold anticoagulation in patients with a negative spiral CT and no clinical evidence of deep vein thrombosis (16).

**Diagnostic Algorithm**

Given the data in the literature, the following algorithm is recommended for the

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**Figure 5** Acute segmental and subsegmental pulmonary thromboembolism. A, Multidetector CT image at the level of the lower lobes demonstrates filling defects in the proximal segmental pulmonary arteries (arrows). B, Multidetector CT image at a more caudal level shows filling defects in distal segmental pulmonary arteries (arrows). C, Multidetector CT image at a lower level than B reveals filling defects in subsegmental pulmonary arteries (arrows).

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**Figure 6A** Multiplanar reformations images from multidetector CT. A, Sagittal reformation demonstrates filling defects in the right interlobar and lower lobe pulmonary arteries. B, Curved axial reformation demonstrates filling defects in the right superior segmental and in the lingular pulmonary arteries (arrows). Also note small right pleural effusion and subcarinal lymphadenopathy.
imaging evaluation of patients suspected of having acute pulmonary embolism (17):

1. All patients should have a chest radiograph, the main role of which is to exclude abnormalities such as pneumonia that may mimic pulmonary embolism clinically.

2. Patients with symptoms or signs of deep vein thrombosis should undergo evaluation of the leg veins, the most commonly recommended technique being Doppler ultrasound. If Doppler is positive, the patient can be considered to have acute pulmonary embolism and usually does not require further investigation.

3. Patients with clinically suspected acute PTE and no signs or symptoms of DVT should undergo spiral CT pulmonary angiography. It should be noted that spiral CT angiography requires the use of iodinated contrast material. Patients with a contraindication to the use of iodinated contrast material should undergo ventilation-perfusion scintigraphy. It should be noted that scintigraphy remains the imaging method of choice in centers in which spiral CT is not available.

4. Patients in whom the CT scans are suboptimal and in whom the CT scan results are negative but who have a high clinical index of suspicion for acute pulmonary embolism, should undergo pulmonary angiography.

REFERENCES: