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.

J Bras Pneumol 2004; 30(5) 474-9

Key words: Diagnostic imaging. Pulmonary embolism./diagnosis. Angiography. Lung diseases/radionuclide imaging. Tomography, emission-computed single-photon/methods.

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Submitted: 15 December, 2003. Accepted, after review: 16 January, 2004.

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 imging 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 is 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].

Abreviations used in this paper:
CT – Computed tomography
PE – Pulmonary embolism
V/Q – Ventilation-perfusion
US – Ultrasound
DVP – Deep vein thrombosis

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].

Figure 1- Acute pulmonary thromboembolism in 46-year old woman. Spiral CT image performed on multidetector CT reveals filling defects in the right middle, right and left lower lobe pulmonary arteries (arrows).

SPIRAL COMPUTED TOMOGRAPHY

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.

Figure 2A- Acute pulmonary thromboembolism in 15-year old female. The patient was paraplegic following a motor vehicle accident. Spiral CT image performed on multidetector CT shows complete obliteration of the lumen of the left lower lobe pulmonary arterial branches by emboli. Note increased diameter of the occluded vessels. B - Lung windows demonstrate decreased attenuation and vascularity of the left lower lobe (Westermark sign) secondary to the occlusive emboli.

Figure 3- Acute pulmonary thromboembolism in 37-year old man. Spiral CT image shows triangular pleural based opacity in the posterior segment of the right upper lobe, consistent with pulmonary hemorrhage distal to occlusive thromboembolism.

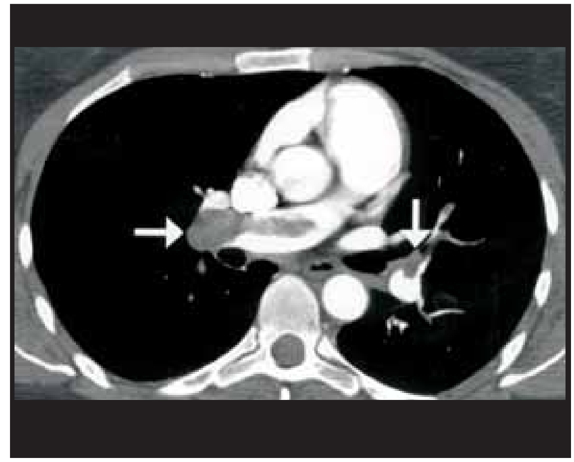


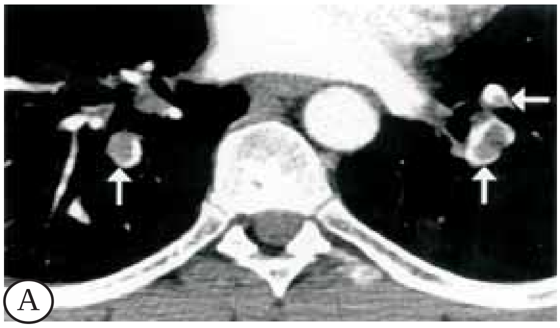
Figure 4- Acute pulmonary thromboembolism in 49-year old woman. Spiral CT image performed on multidetector CT reveals filling defects in the right main and interlobar pulmonary arteries and in the left lower lobe pulmonary artery with extension into the lingular artery (arrows).

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 (11).

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% (3). 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 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



B

C

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).

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 6A- Multiplanar reformations images from multidector 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:

1. Wells PS, Rodger M. Diagnosis of pulmonary embolism: when is imaging needed? Clin Chest Med. 2003;24:13-28.
2. The PIOPED Investigators. Value of ventilation-perfusion scan in acute pulmonary embolism. Results of the prospective investigation of pulmonary embolism diagnosis (PIOPED). JAMA 1990; 263: 2753-9.
3. Stein PD, Athanasoulis C, Alavi A. Complications and validity of pulmonary angiography in acute pulmonary embolism. Circulation 1992; 85: 462-8.
4. Schluger N, Henschke CI, King T. Diagnosis of pulmonary embolism at a large teaching hosptital. J. Thorac Imag 1994; 9: 180-4
5. Cooper TJ, Hayward MWJ, Hartog M. Survery on the use of pulmonary scintigraphy and angiography for supspected pulmonary thromboembolism in the UK. Clin Radiol 1991; 43: 243-5
6. Remy-Jardin M, Remy J, Deschildre F. Diagnosis of pulmonary embolism with spiral CT: Comparison with pulmonary angiography and scintigraphy. Radiology 1996; 200: 699-706.
7. Mayo JR, Remy-Jardin M, Müller NL. Pulmonary embolism: prospective comparison of spiral CT with ventilation-perfusion scintigraphy. Radiology 1997; 205: 447-52.
8. Qanadli SD, El Hajjam M, Mesurolle B. Pulmonary embolism detection: prospective evaluation of dual-section helical CT versus selective pulmonary arteriography in 157 patients. Radiology 2000; 217:447-55.
9. Coche EE, Müller NL, Kim W, Wiggs BR, Mayo JR. Acute pulmonary embolism: ancillary findings at spiral CT. Radiology 1998;207:753-8.
10. Shah AA, Davis SD, Gamsu G, Intriere L. Parenchymal and pleural findings in patients witth and patients without acute pulmonary embolism detected at spiral CT. Radiology 1999;211:147-53.
11. Maki DD, Gefter WB, Alavi A. Recent advances in pulmonary imaging. Chest 1999;116:1388-402.
12. Baile EM, Mayo JR, King GG, Müller NL, Coche EC, Paré PD. Contrast-enhanced spiral CT is comparable to pulmonary angiography for the diagnosis of pulmonary embolism. Am J Resp Crit Care Med 2000; 161:1010-5.
13. Remy-Jardin M, Mastora I, Remy J. Pulmonary embolus imaging with multislice CT. Radiol Clin North America 2003; 41:507-19
14. Patel S, Kazerooni EA, Cascade PN. Pulmonary embolism: optimization of small pulmonary artery visualization at multi-detector row CT. Radiology 2003; 227:455-60.
15. Goodman LR, Lipchik RJ, Kuzo RS, Liu Y, McAuliffe TL, O'Brien DJ. Subsequent pulmonary embolism: risk after a negative helical CT pulmonary angiogram - prospective comparison with scintigraphy. Radiology 2000; 215:535-42.
16. Swensen SJ, Sheedy PF, Ryu JH, Picket al. Outcomes after withholding anticoagulation from patients with suspected acute pulmonary embolism and negative computed tomographic findings: a cohort study. Mayo Clinic Proceedings 2002; 77:130-8.
17. Powell T, Müller NL. Imaging of Acute Pulmonary Thromboembolism: Should Spiral Computed Tomography Replace the V/Q Scan? Clin Chest Med. 2003; 24:29-38