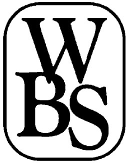

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Imaging of acute pulmonary thromboembolism: should spiral computed tomography replace the ventilation–perfusion scan?

Tom Powell, FFR (RCSI), Nestor L. Müller, MD, PhD*

Department of Radiology, University of British Columbia, Vancouver General Hospital, 899 West 12th Avenue, Vancouver, BC, V5Z 1M9, Canada

For several decades, ventilation–perfusion (V/Q) scintigraphy has been the main imaging modality used in the evaluation of patients with suspected acute pulmonary embolism (PE) [1,2]. A high-probability V/Q scan provides sufficient certainty to confirm the diagnosis of PE, whereas a normal or near-normal scan reliably excludes the diagnosis [2]. In the Prospective Investigation of Pulmonary Embolism Diagnosis (PIOPED) study, indeterminate scans present in 39% of patients (364 of 931) showed a 30% incidence of PE, and low-probability scans seen in 34% of patients (312 of 931) showed a 14% incidence. Based on these data, it was concluded that indeterminate and low-probability lung scans (ie, two-thirds of V/Q scans in the PIOPED study) were not useful in establishing or excluding a diagnosis of acute PE [2]. Furthermore, although there was good interobserver agreement for high-probability and normal V/Q scans, there was a 25% to 30% disagreement between observers in the interpretation of intermediate and low-probability scans [2].

Pulmonary angiography has traditionally been considered the gold standard for diagnosing PE [1]. Pulmonary angiography allows direct visualization of the pulmonary arterial tree and the detection of filling defects that are typically seen in acute PE. Nevertheless, it is an invasive test with associated morbidity (6%) and mortality (0%–0.5%) and is underused [3]. It has been estimated that, even in academic centers, only 12% to 14% of patients with a nondiagnostic V/Q scan undergo pulmonary angiography [3,4].

The introduction of spiral CT in the late 1980s made it possible to image the entire chest in a short period of time and to analyze the pulmonary arteries during the peak of contrast enhancement. Several studies have shown a high sensitivity and specificity of spiral CT in the diagnosis of PE [5–18]. The accuracy has been improved further with the recent introduction of multidetector CT [18,19]. In an increasing number of centers, spiral CT has become the imaging modality of choice in the evaluation of patients with a clinical suspicion of acute PE.

This article discusses the role of the various imaging modalities in the diagnosis of acute PE and suggests a diagnostic imaging algorithm based on current evidence in the literature.

Chest radiography

Chest radiography is of limited value in the diagnosis of PE (Box 1). Its major importance lies in excluding other disease processes that can mimic PE, such as pneumonia and pneumothorax [20–22].

The chest radiographs of 1063 patients who were suspected of having acute PE and who were part of the PIOPED study were interpreted independently by two radiologists [20]. Of these patients, 383 had angiographically proven PE and 680 a normal pulmonary angiogram. The prevalence of the most common findings, such as atelectasis and focal areas of increased opacity, was not significantly different

* Corresponding author.
E-mail address: nmuller@vanhosp.bc.ca (N.L. Müller).

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Box 1. Value of chest radiography in the diagnosis of acute pulmonary embolism

- Limited value in diagnosis
- Performed mainly to exclude other diseases that may mimic PE clinically
- Findings with low sensitivity and relatively high specificity
  - Peripheral oligemia (Westermark sign)
  - Enlargement of central pulmonary artery (Fleischner's sign)
  - Pleural-based opacity (Hampton's hump)
  - Elevated hemidiaphragm
- Nonspecific findings
  - Air–space consolidation
  - Linear atelectasis
  - Pleural effusion
- Radiograph normal in 10% to 15% of cases with proven diagnosis

from that in patients who did not have embolism. Overall, atelectasis had a sensitivity of 20% and a specificity of 85%, and pleural-based areas of increased opacity (Hampton's hump) had a sensitivity of 22% and a specificity of 82% in the diagnosis of acute PE. Similarly, oligemia (Westermark sign), a prominent central pulmonary artery (Fleischner's sign), vascular redistribution, and pleural effusion were poor predictors of PE. The chest radiograph was interpreted as normal in 12% of patients who had PE and in 18% of patients in whom PE was absent at angiography.

In another study, chest radiographs of 152 patients who were suspected of having acute PE were randomized and presented for interpretation to nine readers (seven of whom were subspecialty chest radiologists) [21]. Only 108 of the 152 patients proved to have PE at pulmonary angiography. The readers were asked to answer the question, "Does this patient have PE?" The average true-positive ratio (sensitivity) was 0.33 (range, 0.08–0.52) and the average true-negative ratio (specificity), 0.59 (range, 0.31–0.80).

Most episodes of PE produce no symptoms or detectable changes at chest radiography. Even if the diagnosis is suspected clinically and confirmed angiographically, no abnormalities are seen on radiographs in approximately 10% to 15% of cases (see Box 1).

Ventilation–perfusion scintigraphy

In a random sample of 931 patients who underwent scintigraphy in the PIOPED study, 13% had high-probability scans, 39% had intermediate-probability scans, 34% had low-probability scans, and 14% had normal or near-normal scans [2]. There was good agreement for classifying V/Q scans as high probability (95%) or as normal (94%); however, there was a 25% to 75% disagreement in interpreting intermediate-probability and low-probability scans [2]. Of the 931 patients, 755 underwent pulmonary angiography. Of patients who had high-probability scans and a definitive diagnosis at angiography, 88% had emboli compared with 33% of patients who had intermediate-probability scans, 16% who had low-probability scans, and 9% who had near-normal or normal scans. The diagnostic value was not significantly different between men and women and among patients of different ages [23,24].

Diagnostic utility was similar among patients who had pre-existing cardiac or pulmonary disease when compared with patients who had no such disease. In a subset of patients who had chronic obstructive pulmonary disease (COPD), the sensitivity of a high-probability scan was significantly lower than in patients who had no pre-existing cardiopulmonary disease [25]; however, the positive predictive value of a high-probability scan was 100% and the negative predictive value of a low-probability or very low–probability scan, 94%.

Although clinical assessment of patients who have suspected acute PE does not lead to a definitive diagnosis in most instances, the results from the PIOPED study emphasize the importance of incorporating the pretest clinical likelihood of PE in the overall diagnostic evaluation. In patients who had low-probability or very low-probability V/Q scans and no history of immobilization, recent surgery, trauma to the lower extremities, or central venous instrumentation, the prevalence of PE was 4.5% [26]. In patients who had low-probability or very low-probability V/Q scan interpretations and one risk factor, the prevalence of PE was 12%; in patients who had two or more risk factors, the prevalence was 21%. Most patients had intermediate-probability or low-probability V/Q scans and an intermediate clinical likelihood of PE. For these patients, the combination of clinical assessment and V/Q scans did not provide adequate information to direct patient management accurately, and further investigation with peripheral venous studies, spiral CT, or pulmonary angiography was required.

The value of V/Q scans in patients who have COPD is controversial. In one combined V/Q-angiographic study of 83 patients who had COPD and suspected PE, the overall sensitivity and specificity of V/Q imaging were 0.83 and 0.92, respectively [27]. False-negative interpretations occurred in 3 of the 16 patients who showed ventilation abnormalities in more than 50% of the lungs, whereas in the 67 patients who had ventilation abnormalities affecting 50% or less of the lungs, the sensitivity (0.95) and specificity (0.94) for detecting PE were high. The researchers concluded that V/Q imaging was a reliable method for detecting PE in patients who had regions of V/Q-matched defects as long as ventilation abnormalities were limited in extent.

In a later study performed to assess the accuracy of chest radiographs in predicting the extent of airway disease in patients with suspected PE, investigators found that V/Q scans were indeterminate in all 21 patients who had radiographic evidence of widespread COPD, in 35% of patients who had focal obstructive disease, and in 18% of patients whose chest radiographs revealed no evidence of COPD [28]. The investigators concluded that ventilation imaging probably was not warranted in patients who had radiographic evidence of widespread COPD.

When an attempt is made to distinguish V/Q matching that is compatible with PE from that caused by COPD, a computation of the actual V/Q ratio may be useful. In one study in which a V/Q ratio of 1.25 or higher was used to define an area of mismatch, the percentage of patients classified correctly as having PE or COPD increased from 56% to 88%, based simply on a consideration of the matched or mismatched character of perfusion [29].

In another study of 108 patients who had COPD and who were suspected of having PE (21 of whom had the diagnosis confirmed by angiography), it was not possible to distinguish between patients who had and did not have emboli by clinical assessment alone [25]. Among the 108 patients, high-probability, intermediate-probability, low-probability, and normal-probability scan results were present in 5%, 60%, 30%, and 5%, respectively. The frequency of PE in these categories was 100%, 22%, 2%, and 0%, respectively. Although high-probability and low-probability V/Q scan results have good predictive values, most patients who have COPD have intermediate-probability scans and require further investigation, which may include spiral CT and angiography.

Approximately 15% of patients who have PE have high-probability V/Q scan results, 40% have intermediate-probability scans, 30% have low-probability scans, and 15% have normal or near-normal scan results [2]. Approximately 90% of patients who have high-probability scan results have PE compared with 30% of patients who have intermediate-probability scans, 15% who have low-probability scan results, and 9% who have normal or near-normal scans [2,30].

The diagnostic accuracy can be improved by combining the results of V/Q scanning with the clinical impression. In the PIOPED study, a pretest clinical probability of PE was estimated before lung scanning [2]. Three probabilities were considered: low (0% to 19%), intermediate (20% to 79%), and high (80% to 100%). A low-probability scan result paired with a low clinical index of suspicion had a negative predictive value of 96%. Conversely, a concordant high-probability V/Q scan result paired with a high clinical index of suspicion had a positive predictive value of 96%. Only 25% of patients fit into these clinicoscintigraphic categories, with 75% of patients having an uncertain diagnosis [2]. Even under optimal circumstances of excellent clinical assessment and expert interpretation of V/Q scans, further investigation is often required to establish the presence or absence of emboli.

Spiral computed tomography

The introduction of spiral CT in the late 1980s made it possible to image large portions of the chest during a single breath hold and to image the pulmonary arteries during peak enhancement with intravenous contrast. Several studies have shown that spiral CT has a high sensitivity and specificity in the diagnosis of emboli in the central and segmental pulmonary arteries. These studies, performed in the 1990s, were based on the use of single-detector CT scanners. Recently, a new generation of CT scanners has been introduced. These scanners have multiple detector rows (4, 8, and, since 2002, 16 rows) (multidetector CT) and greater rotation speeds. Multidetector CT scanners allow imaging of the entire chest during a single breath hold with thinner sections. The improved spatial resolution allows assessment of subsegmental vessels while the greater rotation speeds of the CT gantry result in reduced artifacts from cardiac and respiratory motion. Multidetector CT with 1.25mm-thick sections allows accurate analysis of peripheral pulmonary arteries down to the fifth order [19].

The diagnosis of acute PE on contrast-enhanced CT scan is based on the presence of partial or complete filling defects within the pulmonary arteries (Box 2) [5,31]. A partial filling defect is defined as an

Box 2. Acute pulmonary embolism—spiral CT findings

- Vascular findings
  - Intravascular filling defect
  - Acute angles with vessel wall
  - Complete cutoff of vascular opacification
  - Increased diameter of occluded vessel
- Helpful parenchymal findings
  - Wedge-shaped nonenhancing, pleural-based opacities
  - Linear atelectasis
- Sensitivity of spiral CT, 90%; specificity, 90%
- False-negative interpretation mainly owing to subsegmental emboli
- False-positive interpretation owing to hilar nodes and technical pitfalls

intravascular central or marginal area of low attenuation surrounded by variable amounts of contrast material (Figs. 1, 2). A complete filling defect is defined as an intraluminal area of low attenuation that occupies the entire arterial section, as evidenced by the abrupt termination of the contrast column within a visible vessel (Fig. 2) [5,6]. The most reliable sign of an acute embolus is a filling defect forming an acute angle with the vessel wall and outlined by contrast material (Fig. 3). Although filling defects that form a smooth obtuse angle with the vessel wall or a complete cutoff of contrast opacification of a vessel may be caused by acute emboli, they also may be seen with chronic emboli.

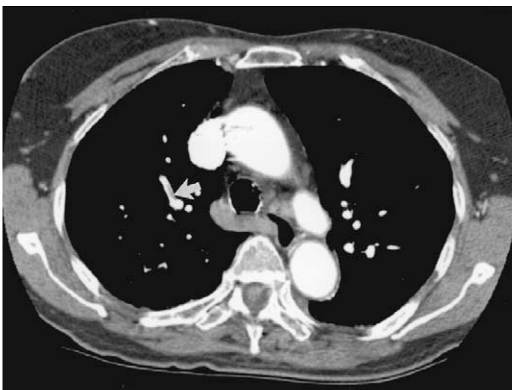

Fig. 1. Acute PE. Multidetector spiral CT image shows a partial filling defect in the anterior segmental artery of the right upper lobe (*arrow*).

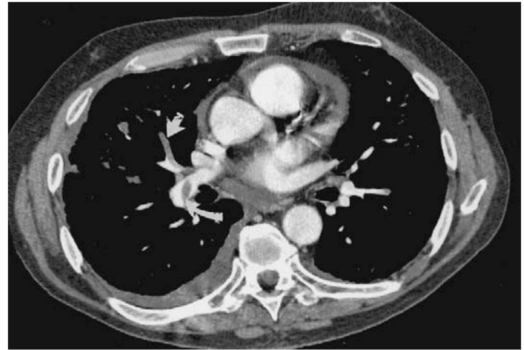

Fig. 2. Acute PE. Multidetector spiral CT image shows a complete filling defect in the medial segmental artery of the right middle lobe (*straight arrow*) and a partial filling defect in the right lower lobe artery (*curved arrow*).

The diagnosis of acute PE requires an assessment of vascular and parenchymal findings. An assessment of the lung windows will not only help to identify the segmental and subsegmental pulmonary arteries by their proximity to the bronchi but will also assess for the presence of ancillary signs that may be helpful in suggesting the presence of PE [32].

The most helpful ancillary sign is the presence of a nonenhancing pleural-based, wedge-shaped pul-

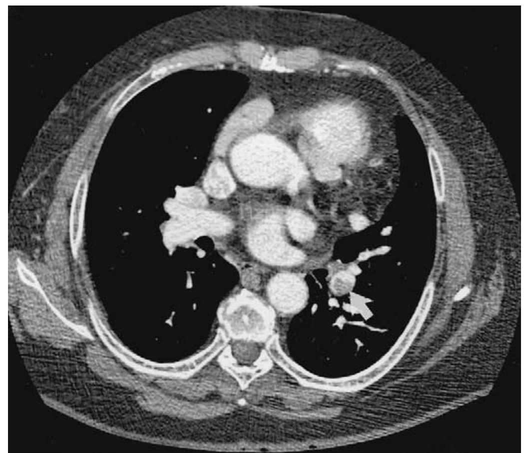

Fig. 3. Acute PE. Multidetector spiral CT image shows a partial filling defect in left lower lobe pulmonary artery (*arrow*), outlined by contrast and forming an acute angle with the vessel wall.

monary opacity [32]. Linear (platelike) atelectasis is also seen with increased frequency on CT in patients with acute PE [32]. Other findings, such as areas of decreased attenuation and pleural effusion, are not helpful in distinguishing patients with and without acute PE [32].

In a study of 88 patients who had suspected PE [32], the findings that were seen most commonly in patients who had PE included wedge-shaped, pleural-based opacities (present in 62% of patients who had emboli compared with 27% of patients who did not) and linear opacities (present in 46% with emboli and 21% without). Areas of oligemia were seen in 3 of 26 patients (11%) who had acute PE but also in 6 of 62 patients (10%) who did not have emboli.

In a second investigation of 92 patients, the only parenchymal abnormality significantly associated with acute PE was the presence of a peripheral wedge-shaped opacity [33]. This abnormality was seen in 7 of 28 patients (25%) who had PE compared with 3 of 64 patients (5%) who did not. As a manifestation of PE, a wedge-shaped pulmonary opacity abutting the pleural surface is seen more commonly on CT scan than on the chest radiograph [34]. The opacities may have the configuration of a full triangle or a truncated cone with a concave or convex apex (Fig. 4). It has been postulated that the latter appearance may be related to sparing of the apex of the cone from infarction as a result of collateral circulation from bronchial arteries [34].

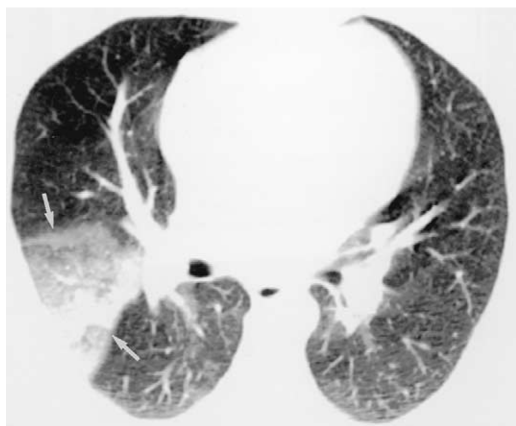

Fig. 4. Multidetector spiral CT image shows a wedge-shaped pulmonary opacity abutting the pleural surface in the posterior segment of the right upper lung lobe (*arrows*). Occlusive thrombus was present in the posterior segmental artery to the right upper lobe.

On CT, most infarcts appear to be reabsorbed partially or completely after 1 month, sometimes being manifested only as a scar [34].

Pitfalls and artifacts of computed tomography

Several technical, anatomic, and patient-related pitfalls may lead to misinterpretation of the CT images. Technical failures occur in 1% to 5% of scans and are usually caused by motion artifacts in dyspneic patients or insufficient vascular enhancement [9]. 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 PE. This pitfall is minimized by careful review of the images and the use of additional imaging-rendering tools, such as cineviewing and multiplanar reconstruction.

Diagnostic accuracy of spiral computed tomography

The reported diagnostic accuracy of spiral CT has varied depending on the technique used, the patient population, and whether investigators have limited the analysis to the central pulmonary arteries down the level of the segmental vessels or have included subsegmental arteries (Table 1) [6,8,9,11,14,15,18]. Overall, these studies have shown a sensitivity of spiral CT of approximately 90%, a specificity of 90%, a positive predictive value of 93%, and a negative predictive value of 94% for emboli down to and including the level of the segmental pulmonary arteries [35]. The results of the various studies in the literature indicate that, although single-detector spiral CT has a high sensitivity in the detection of central emboli, it is of limited value in the diagnosis of subsegmental emboli. 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 PE, the interobserver agreement for the diagnosis of subsegmental emboli on angiography is only 66% [3]. Experimental work in a porcine model has shown that single-detector spiral CT using thin collimation (3 mm or less) is comparable with pul-

Table 1
Accuracy of spiral computed tomography in the diagnosis of acute pulmonary embolism

Study	Year	Number of patients in study	CT protocols: Collimation (mm)	CT protocols: Lower anatomic level of interpretation	Sensitivity (%)	Specificity (%)	κ value
Remy-Jardin, et al [5]	1992	42	5	Segmental	100	96	NC
Goodman, et al [6]	1995	20	5	Segmental	86	92	NC
Senac, et al [7]	1995	45	5	Segmental	86	100	NC
van Rossum, et al [8]	1996	149	5	Segmental	82–90	93–96	0.774
Remy-Jardin, et al [9]	1996	75	5, 3	Segmental	91	78	NC
Ferretti, et al [10]	1997	164	5	Segmental	NC	NC	NC
Mayo, et al [11]	1997	142	3	Segmental	87	95	0.85
van Rossum, et al [12]	1998	123	5	Segmental	75	90	NC
Drucker, et al [13]	1998	47	5	Segmental	53–60	81–97	NC
Herold, et al [14]	1998	401	3	Subsegmental	88	94	0.72
Garg, et al [15]	1998	54	3	Subsegmental	67	100	NC
Baghaie, et al [16]	1998	370	3, 2	Subsegmental	96	100	0.87
Kim, et al [17]	1999	110	3	Segmental	92	96	NC
Qanadli, et al [18]	2000	157	2.5 (dual section)	Subsegmental	90	94	0.86

Abbreviations: k, kappa statistic; NC, not calculated.

monary angiography in the diagnosis of segmental and subsegmental PE [36].

Technique for spiral computed tomography

Optimal assessment of the pulmonary vessels on spiral CT requires careful attention to several parameters, including scan collimation, imaging volume, and contrast enhancement.

The imaging protocol depends on whether single-detector or multidetector CT is used. On single-detector CT, the following protocol is recommended: spiral CT during a 20- to 30-second breath hold using 3-mm collimation, a table speed of 5 to 6 mm/second, a pitch of 1.7 to 2.0, 120 kVp, and 180 to 320 mA. Images are reconstructed at 1.5-mm intervals and a field of view appropriate for the size of the patient.

Multiple detector row spiral CT scanners allow the acquisition of contiguous 0.7- to 2.5-mm thick slices through the entire chest during a single breath hold. The authors recommend use of the narrowest possible detector aperture within the constraints imposed by the duration of the contrast material bolus and the breath-holding capability of the patient. In patients who cannot hold their breath for the duration of the scan, good quality images can usually be obtained during quiet breathing.

The lung volume that is scanned should be large enough to include all segmental and subsegmental pulmonary arteries. This goal can be achieved by scanning from the top of the aortic arch to the dome of the diaphragm. Although the scans can be performed in the craniocaudal direction, scanning caudocranially helps to minimize motion artifacts, particularly in patients unable to hold their breath for the duration of the scan [37,38].

Nonionic iodinated contrast material is administered through an antecubital venous access or a central line using a power injector [37,38]. Injection rates ranging from 2 to 7 mL/second have been reported. The authors use 120 to 150 mL of 30% nonionic iodinated contrast material injected at a rate of 4 mL/second. In hemodynamically stable patients, a 10- to 15-second scan delay usually provides optimal contrast enhancement of the pulmonary arteries.

This delay may need to be increased in patients with severe pulmonary hypertension or right-sided heart failure. To determine the optimal time delay, a test injection can be performed to assess the circulation time. A total of 20 mL of contrast material is injected at a rate of 4 mL/second and serial scans performed at 3- to 5-second intervals for 20 seconds at the level of the main pulmonary artery. To ensure opacification of the peripheral arteries during the diagnostic study, 5 seconds are added to the time to peak enhancement of the main pulmonary artery [37,38].

Images are viewed at the workstation at settings appropriate for visualization of pulmonary vasculature (window width, 400 Hu; window level, 35 Hu) and lung parenchyma (window width, 1500 Hu; window level, −700 Hu). In selected cases, multiplanar reformatting may be helpful in demonstrating the extent of the PE [37] (Figs. 5, 6).

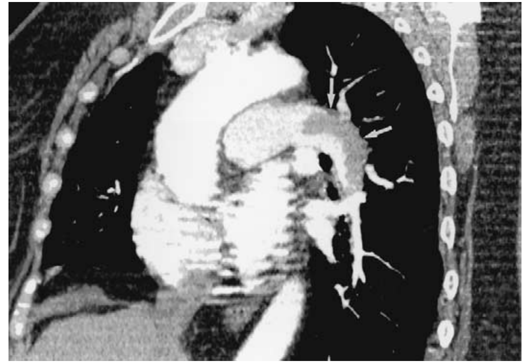

Fig. 6. Sagittal-oblique reformatted multislice CT image shows extent of thrombus narrowing the left lower lobe pulmonary artery as it curves posterolaterally and inferiorly (*arrow*).

Outcome studies

Traditionally, pulmonary angiography has been considered the gold standard in the diagnosis of acute PE. Nevertheless, it has two main limitations: (1) it is seldom performed, even when indicated [3,4]; and (2) it is associated with considerable interobserver disagreement, particularly for the diagnosis of subsegmental emboli [39]. In the PIOPED study [2], interobserver agreement was 92% for pulmonary angiography showing the presence of PE and 83% for studies showing the absence of PE.

Interobserver agreement is even lower when confined to angiography showing the presence of PE limited to the subsegmental pulmonary arteries [40]. Stein et al [40] reviewed data from patients participating in PIOPED. The copositivity of readings of PE in subsegmental branches (66%) was significantly lower than the copositivity of 98% for readings of PE in the main or lobar pulmonary arteries ($P < 0.001$) and the copositivity of 90% for readings of PE in the segmental arteries ($P < 0.05$) [40]. It has been proposed that the gold standard in the diagnosis of PE should be patient outcome and not pulmonary angiography [39].

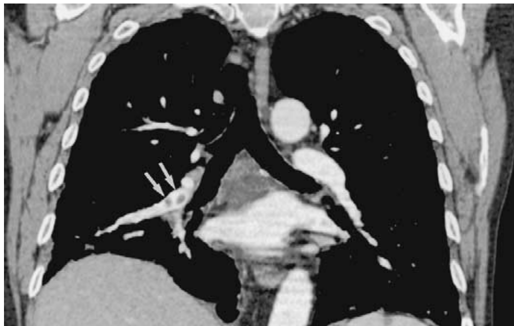

Fig. 5. Multislice spiral CT angiogram, reformatted in the coronal plane, shows nonocclusive emboli in the right lower lobe artery (*arrows*).

Patients with suspected acute PE and negative CT results have an excellent outcome without anticoagulation [41]. The outcomes are similar to those reported after withholding anticoagulation after a normal or low-probability V/Q scan or a negative angiogram [41–43]. Swensen et al reviewed the records of 1512 consecutive patients who were referred for CT with clinically suspected acute PE [41]. A total of 993 of these patients received no anticoagulation and had CT scans interpreted as negative for acute PE. A 3-month probability of venous thromboembolism of 0.5% was identified in these patients. This finding compares well with the reported incidence of venous thromboembolism in untreated patients with negative angiograms [44] and negative V/Q scintigraphy results [45]. Hull et al [45] found a 3-month cumulative incidence of 0.2% for nonfatal PE in 515 untreated patients with negative perfusion lung scan results.

Another clinical outcome study compared 198 patients with negative spiral CT findings with 350 patients with a negative V/Q scan (normal or low probability) [42]. During 3-month follow-up, subsequent PE was observed in 1% of the spiral CT group compared with 1.5% of the V/Q group (not statistically significant).

In a third investigation, the risk for PE was assessed in a group of 185 patients who had negative CT pulmonary angiograms, who had not received anticoagulation, and who were followed up clinically at 3 months, 6 months, and 1 year. A total of 135 of these patients had underlying lung disease, and 50 patients had no history of respiratory disorder [46]. No significant difference was seen between the 98% (132 of 135) negative predictive value of spiral CT angiography in patients with underlying lung disease and the 100% (50 of 50) negative predictive value in patients who had no history of respiratory disorder.

Based on the results of outcome studies, it seems safe to withhold anticoagulation in patients who have a negative spiral CT and no clinical evidence of deep vein thrombosis.

Should spiral computed tomography replace the ventilation–perfusion scan?

Several groups of investigators have shown that CT angiography is superior to V/Q scintigraphy in the diagnosis of acute PE [9,11,47]. In one prospective comparison of spiral CT and V/Q scintigraphy in 142 patients, two experienced observers assessed the results of both procedures independently [11]. The combination of a high-probability V/Q scan result and a spiral CT finding of PE was considered diagnostic, and no further imaging studies were performed. The combination of a normal, very low–probability, or low-probability V/Q scan and a negative spiral CT in a patient with a low clinical suspicion of PE was considered sufficient to exclude the disease. All other patients underwent pulmonary angiography. Twelve patients had discordant spiral CT and V/Q scans. Using angiographic results as the gold standard, the spiral CT interpretation was correct in 11 patients and the V/Q scan in 1 patient. Overall, CT angiography had a sensitivity of 87% and a specificity of 98% in the diagnosis of acute PE compared with a sensitivity of 65% and a specificity of 94% for a high-probability V/Q scan. There was better interobserver agreement in the interpretation of the spiral CT scans than the V/Q scans.

In a second investigation, spiral CT angiography was compared with V/Q scintigraphy in 179 patients [48]. CT angiography had a sensitivity of 94% and a specificity of 94%, whereas scintigraphy had a sensitivity of 81% and a specificity of 74% in the diagnosis of acute PE. Interobserver agreement was much better for interpretation of CT angiography (κ statistic = 0.72) than for scintigraphy (κ = 0.22) [48].

In a prospective randomized trial of 78 patients who had suspected PE, spiral CT or V/Q scans were performed as part of the initial investigation [47]. A confident diagnosis of PE was made in 35 of 39 patients (90%) who underwent spiral CT compared with 21 of 39 patients (54%) who underwent scintigraphy first. The main reason for this difference was the ability of CT to show lesions other than PE that were considered to be responsible for the symptoms of 13 of 39 patients (33%).

In another prospective study of 110 patients, spiral CT helped identify correctly 23 of 25 patients who had PE (sensitivity, 92%). In 57 of the 85 patients (67%) who did not have PE, spiral CT provided additional information that suggested or confirmed the alternate clinical diagnosis [17]. In this series, the most common diagnoses in patients with an abnormal CT scan who did not have PE were pneumonia, cardiovascular disease, interstitial lung disease, trauma-related chest abnormalities, and pulmonary or pleural malignancy.

Analysis of a decision model based on the published data has shown that the use of spiral CT is likely to improve cost-effectiveness in the work-up of PTE and to be associated with decreased mortality [49]. Various diagnostic algorithms have been assessed, including various combinations of V/Q scintigraphy, ultrasound, D-dimer assay, spiral CT, and conventional angiography for all realistic values of the pretest probability of PTE and coexisting DVT and of the diagnostic accuracy of spiral CT. All of the best diagnostic strategies include CT angiography [49].

Initially, spiral CT was only recommended in patients who had indeterminate or low-probability V/Q scans and a high clinical index of suspicion for PE [5,8,11]. Subsequently, it was suggested that spiral CT should be used instead of scintigraphy in the assessment of patients with underlying cardiopulmonary disease and an abnormal chest radiograph [47]. More recently, various investigators have suggested that spiral CT should replace scintigraphy in the assessment of patients whose symptoms are suggestive of acute PE [12,15,39,41].

Based on the data in the literature demonstrating a higher diagnostic accuracy of spiral CT when compared with scintigraphy in the diagnosis of acute PE, a better interobserver agreement, and the ability to suggest an alternate diagnosis in patients without PE, the authors believe that spiral CT should replace scintigraphy in the assessment of patients with clinically suspected acute PE.

Recommended imaging algorithm in patients with suspected acute pulmonary embolism

Given the data in the literature, the following imaging algorithm is recommended for the evaluation of patients suspected of having acute PE:

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

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 the Doppler study is positive, the patient can be considered to have acute PE and usually does not require further investigation.

Patients with clinically suspected acute PE and no signs or symptoms of deep vein thrombosis should undergo spiral CT pulmonary angiography. Spiral CT angiography requires the use of iodinated contrast material. Patients with a contraindication to the use of iodinated contrast material should undergo V/Q scintigraphy.

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

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