Pulmonary Thromboembolic Disease: A New Role for Computed Tomography

Adam D. Olsan, MD; Charles C. Matthews, MD; Michael A. Sullivan, MD

Department of Radiology, Ochsner Clinic Foundation, New Orleans, LA

Over the past few years, computed tomography (CT) has emerged as a common noninvasive, definitive, alternative to ventilation-perfusion scintigraphy scan and pulmonary angiography in the evaluation of patients suspected of having pulmonary emboli. Additionally, recent articles have investigated the possibility of using CT to identify deep venous thrombi following a spiral CT pulmonary angiogram. Using the same bolus of contrast as that administered for a CT pulmonary angiogram, the ultimate goal is to design a single test that defines both aspects of pulmonary thromboembolic disease. More studies are needed and controversy exists, but CT's role in the evaluation of pulmonary thromboembolic disease appears promising.

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Deep venous thrombosis and pulmonary embolism (PE) are significant health problems in the United States (1). Pulmonary emboli often go undiagnosed and, if left untreated, are associated with a mortality rate of as high as 30% (2). Given this high mortality, a quick and accurate diagnostic test is needed.

Current examinations for the diagnosis of thromboembolic disease include laboratory tests, venous ultrasound, ventilation-perfusion scintigraphy (V/Q), and if necessary pulmonary angiography. D-dimer levels have proven effective in excluding pulmonary embolism in the outpatient setting but fail as an exclusionary test for hospitalized patients (3). Ultrasound is accurate in the detection of deep venous thrombi in the legs but does not exclude PE. Traditional pulmonary angiography is the gold standard for the diagnosis of PE, but the high cost, the invasive nature of the examination, and the requirement of a trained angiography team make it impractical in many cases of suspected PE. As illuminated by the Prospective Investigation of Pulmonary Embolism Diagnosis (PIOPED) study (4), scintigraphy is useful in the case of a normal or high-probability examination but creates a dilemma for the clinician in the case of an intermediate scan. This is of special concern since three-fourths of V/Q scans were neither high-probability nor normal in that study.

CT Pulmonary Angiography

The diagnosis of PE by CT pulmonary angiography (CTPA) is made when a thrombus in a pulmonary artery is identified as a central soft tissue opacification surrounded by contrast (Figure 1), as a complete cutoff of contrast material (Figure 2), or as an eccentric defect that projects into a vessel (Figure 3). In the case of acute PE, the thrombus is more likely to be central and surrounded by contrast or eccentric and creating an acute angle within the vessel. Chronic emboli will more likely be eccentric and smooth or consist of an occluding defect with areas of recanalization. Both acute and chronic emboli may be completely occluding, although acutely occluded vessels are often larger than expected and chronically occluded vessels are often smaller than expected (Figure 4) (5).

A successful study requires flooding the pulmonary arteries with intravenous contrast material. At Ochsner, this is achieved with 120-130 ccs of nonionic contrast material (Omnipaque 300; Nycomed Amersham Imaging, Princeton, NJ) injected through an 18 or 20 gauge peripheral IV at a flow rate of 3-4 cc/sec. Transverse images are then acquired from the diaphragm to the bottom of the aortic arch using 2.5 mm slice thickness and 2.5 mm spacing during an 8-10 second breath hold if possible. Timing is critical during this examination due to the finite amount of time that the pulmonary arteries are optimally enhanced.

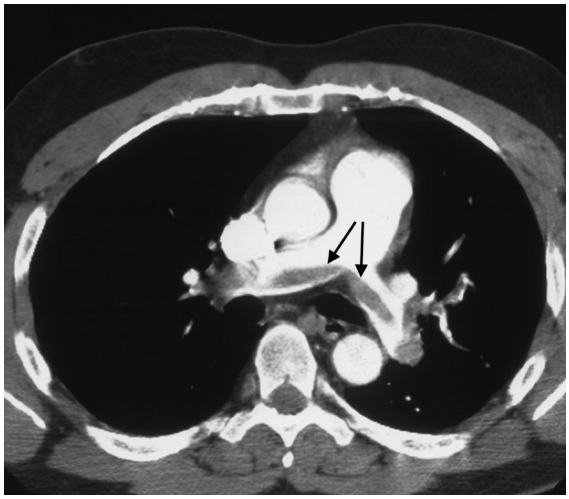


Figure 1. Saddle embolus extending into the right and left pulmonary arteries (arrows).

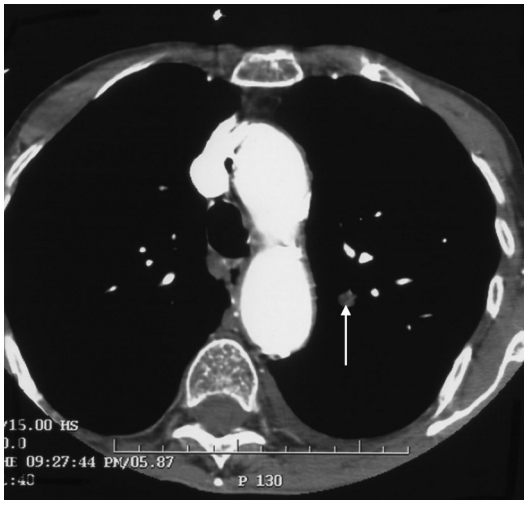


Figure 2. Arrow indicates complete occlusion of a pulmonary artery. Compare with other vessels that are filled with contrast and appear white.

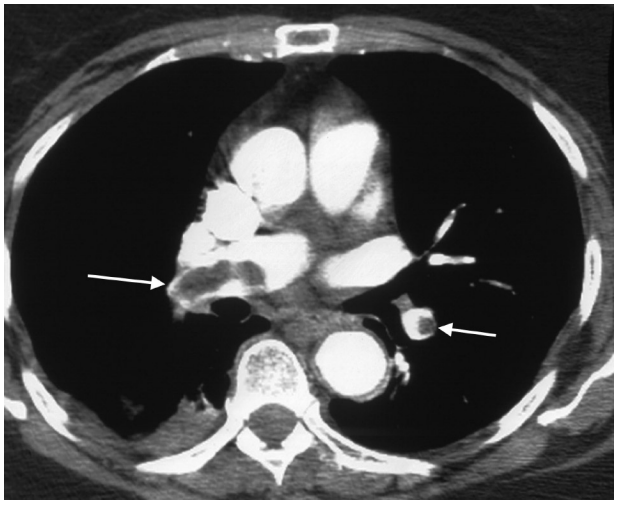


Figure 3. Bilateral emboli (arrows). The embolus in the left lower lobe artery is eccentric.

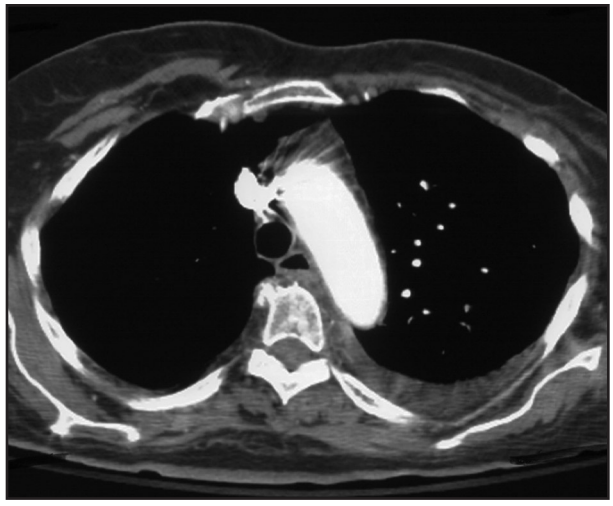


Figure 4. Decreased vascularity in the right upper lobe peripheral to a central embolus.

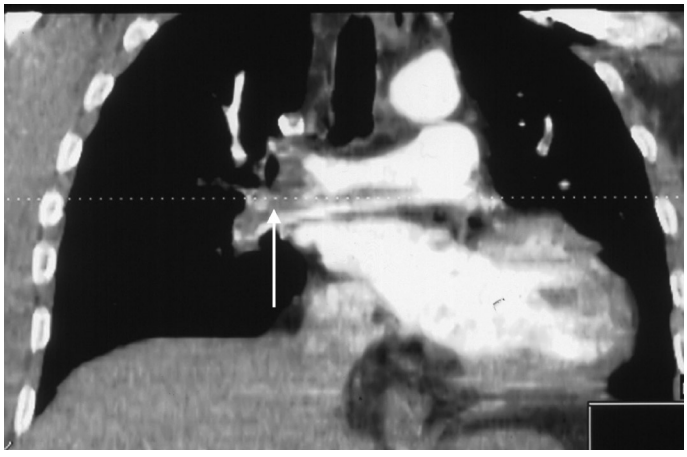


Figure 5. Coronal plane image shows a large embolus (arrow) in the right pulmonary artery extending into lobar branches.

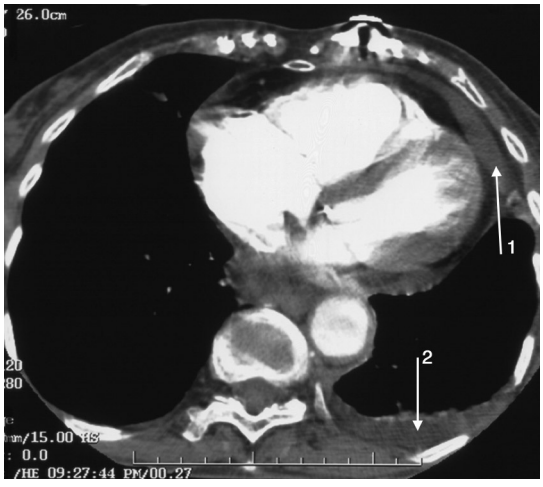


Figure 6. CTPA study reveals a pericardial effusion (arrow 1) and a plueral effusion (arrow 2).

In order to capture optimal enhancement of the central and peripheral pulmonary arteries, CT images of the main pulmonary artery are acquired during the injection of contrast, and scanning is begun several seconds after peak enhancement is identified. The several second delay allows time for contrast material to reach peripheral vessels.

Following primary acquisition, the images may be reformatted in other planes to allow visualization of the study in coronal, sagittal, or oblique sections (Figure 5). Often, this is helpful in determining whether a subtle hypoattenuating finding seen on axial sections is within or just outside a vessel. In most cases, the study is technically adequate and the diagnosis is obvious. In approximately 5%-10% of scans, however, the study is technically inadequate and nondiagnostic for PE (6). In 70%-75% of patients, an alternative explanation of the patient's symptoms is provided (Figure 6) (7). A scan may be nondiagnostic for PE due to decreased cardiac output (and therefore poor contrast enhancement), respiratory motion artifact, lung disease, size or position of the intravenous catheter, large habitus, or poor coordination of contrast bolus with image acquisition. Altering the image at a computer workstation may occasionally salvage a poorly contrasted examination.

CT Venography

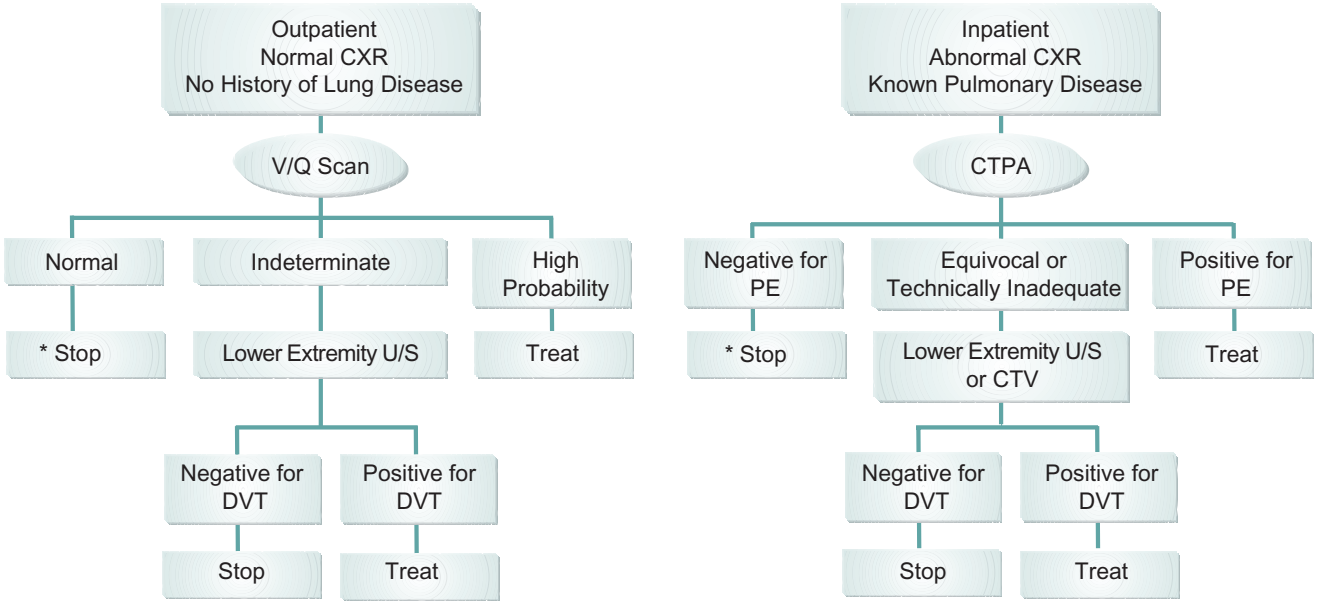
CT venography (CTV) of the inferior vena cava and lower extremity venous system has recently been investigated as a study that, when combined with CTPA, offers the possibility of a single study that defines both aspects of pulmonary thromboembolic disease (8,9). Using the same bolus of contrast administered for a CTPA, venous phase images of the inferior vena cava, pelvic, and femoral vessels are obtained; individual protocols differ. Following a 2 to 3.5 minute delay after CTPA, images from the diaphragm or iliac crest to the upper calves are acquired using 5-10 mm collimation at 1-5 cm intervals. Similar to PE, venous thrombi are identified as a filling defect within a vessel that may or may not be surrounded by contrast material. Current investigations of this technique are promising, and sensitivity and specificity are similar to those reported for ultrasound. In a study by Loud et al in which nearly half of the 650 patients who underwent CTV and CTPA also underwent bilateral lower-extremity sonography, sensitivity and specificity of CTV was reported as 97% and 100%, respectively (8). Other authors have reported similar results (9,10).

Current Issues and Algorithms

Several studies have shown the accuracy of CTPA in the diagnosis of PE in the main, lobar, and segmental pulmonary arteries. In a prospective study of 249 patients clinically suspected of having PE in which all patients with abnormal V/Q scans underwent CTPA, van Rossum and colleagues reported a sensitivity and specificity of 95% and 97%, respectively (11). In a smaller study by Blum et al in which all patients suspected of PE underwent CTPA and traditional pulmonary angiography, sensitivity and specificity were both 100% (12). Other studies also report sensitivities and specificities of greater than 90%, which approach that of traditional angiography (13-15). Critics cite studies that report ranges of sensitivity from 53% to 100% and specificity from 81% to 100%. Mullins and colleagues state, "at least one multicenter trial is needed to provide answers to [CTPA] that the PIOPED study provided for the V/Q scan." Others are of the opinion that CTPA should not be the only test used to evaluate patients suspected of having PE (16,17).

Another controversy mentioned frequently in the literature is the significance of subsegmental PE. It is fairly well established that subsegmental PE may be missed using CTPA (18-20). Goodman and Lipchik (13) and Gurney (21) argue that traditional pulmonary angiography is, like CTPA, not infallible with regard to the diagnosis of subsegmental PE, and that the consequences of undiagnosed subsegmental emboli are exaggerated. Others suggest that in patients with poor cardiopulmonary reserve a peripheral embolus may be catastrophic (22,23). When patient outcomes were examined in a prospective study of 285 patients with negative CTPAs, the prevalence of subsequent PE after a negative CTPA was 1%. This finding is similar to studies of subsequent venous thromboembolism after negative scintigraphy, lower extremity ultrasound, pulmonary angiography, CTPA, or a combination of these examinations (24).

A large multicenter trial will undoubtedly be required to settle these issues, but until such a task is undertaken the debate continues. However, two experts have suggested similar algorithms for the diagnosis of PE based on the strengths and weaknesses of scintigraphy and CT. In outpatients with normal chest radiography and no history of lung disease (i.e. those who are likely to have a definitive V/Q scan), scintigraphy is performed first. If the study is low-probability or indeterminate, further investigation is suggested beginning with lower extremity ultrasound. For inpatients, those with abnormal chest radiographs, or known pulmonary disease, CT is performed first. While Woodard (25) recommends only CTPA initially, Goodman (24) recommends combined CTPA and CTV, which require no further investigation if positive. In the case of a technically inadequate or equivocal CT, or if clinical suspicion remains high, Goodman et al state that additional imaging is required. As of February 2000, Woodard (25) expressed confidence in the future role of CTV, stating that "we believe that the clinician can safely withhold anticoagulation therapy if the helical CT scan is negative for PE



Suggested algorithm for patients suspected of having pulmonary embolism.
* If clinical suspicion remains high, lower extremity imaging may be performed.
† If clinical suspicion remains high, traditional pulmonary angiography may be performed.

and a lower extremity examination—either Doppler ultrasound or CT—reveals no deep venous thrombus." Woodard stopped short of including CTV as a first line study and suggested that, in the case of a negative CTPA, ultrasound should be performed (7,24). A suggested algorithm for patients suspected of having PE is presented above.

Conclusion

Although large-scale, multicenter trials are still needed, CT for the detection of PE and lower extremity venous thrombosis appears to offer a promising alternative answer to the question of what to do with the patient who will most likely have an indeterminate V/Q scan.

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Dr. Adam Olsan is a Radiology resident at Ochsner Clinic Foundation.