

**American College of Radiology  
ACR Appropriateness Criteria®**

**Clinical Condition:**                      **Acute Chest Pain—Suspected Pulmonary Embolism.**

Radiologic Procedure	Rating	Comments	<u>RRL*</u>
X-ray chest	9	To exclude other causes of acute chest pain.	Min
CTA chest (noncoronary)	9	Current standard of care for detection of PE.	Med
CTA chest with CT venography	7	If suspicion for DVT is high and/or if US inconclusive.	Med
US lower extremity with Doppler	7	If chest x-ray is negative and index of suspicion is high.	None
NUC Tc-99m V/Q scan lung	6	If chest x-ray is negative and CTA is contraindicated or nondiagnostic.	Med
INV pulmonary angiography with right heart catheterization	5	If suspicion is high and CTA is inconclusive.	High
MRA pulmonary arteries	4	If patient is unable to receive iodinated contrast, may be alternative to V/Q scan.	None
US echocardiography transesophageal	2	Limited experience. Has been used for main pulmonary emboli.	None
US echocardiography transthoracic	2	To assess right ventricle function after the diagnosis of PE.	None
<b><u>Rating Scale:</u> 1=Least appropriate, 9=Most appropriate</b>			<b>*Relative Radiation Level</b>

An ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those exams generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.

# ACUTE CHEST PAIN—SUSPECTED PULMONARY EMBOLISM

Expert Panel on Cardiac Imaging: Michael A. Bettmann, MD<sup>1</sup>; Eric M. Lyders, MD<sup>2</sup>; E. Kent Yucel, MD<sup>3</sup>; Arfa Khan, MD<sup>4</sup>; Linda B. Haramati, MD<sup>5</sup>; Vincent B. Ho, MD<sup>6</sup>; Anna Rozenshtein, MD<sup>7</sup>; Frank J. Rybicki, MD, PhD<sup>8</sup>; U. Joseph Schoepf, MD<sup>9</sup>; William Stanford, MD<sup>10</sup>; Pamela K. Woodard, MD<sup>11</sup>; Michael Jaff, MD.<sup>12</sup>

## **Summary of Literature Review**

Over 200,000 cases of pulmonary thromboembolism (PE) are estimated to occur in the United States each year. Additional cases may not be diagnosed because the symptoms of chest pain, shortness of breath, tachycardia, etc, are nonspecific and may mimic other pulmonary or cardiac conditions. Unsuspected PE continues to be a frequent autopsy finding.

It has been further estimated that over 80% of PE cases are associated with deep vein thrombosis (DVT). It is, therefore, easy to see why pulmonary embolism, for purposes of both diagnosis and treatment, is often considered a complication or a consequence of DVT [1]. The only concern with this approach is that there is not invariably an association: some cases of PE are due to embolization from other sites, such as pelvic veins or the upper extremities, or even from the right heart or from in situ thrombosis.

Diagnostic efforts in radiology are aimed at: 1) reaching an acceptable level of diagnostic certainty of PE to warrant anticoagulant therapy, using the least invasive tests, and 2) eliminating other reasons for the patient's symptoms. Over the past decade, the probability of a patient having PE is typically arrived at using a Bayesian approach in which the pretest likelihood of the condition (PE), based on clinical and laboratory evidence, is modified by the results of the appropriate radiological procedure(s) in order to estimate a post-test probability of the condition. This approach has changed over the last five years, largely due to technological advances and clinical studies using multidetector computed tomography (CT), in combination with studies such as serum D-dimer.

## **Chest Radiograph**

The posterioranterior and lateral chest radiograph is an important initial study because it may eliminate the need for additional radiographic procedures by revealing an obvious reason for acute symptoms, such as pneumonia [2]. A recent chest radiograph is particularly useful, even required, if an abnormal pattern is identified on radionuclide perfusion lung scan [3]. The chest radiograph findings may help clarify confusing scan patterns.

## **Computed Tomography**

Computed tomography pulmonary angiography (CTPA) is indicated in the evaluation of patients suspected of having a pulmonary embolism. CTPA has been playing an increasingly significant role in the diagnosis of pulmonary embolism since the first major clinical study in 1992 by Remy-Jardin [4]. Technological advancements in CT, from helical CT to the use of multidetector CT, have led to better resolution of the pulmonary tree, and numerous studies have examined the accuracy of CTPA as compared to ventilation and perfusion (V/Q) imaging and conventional angiography [5-13]. There appears to be an evolving consensus that CTA is now the primary imaging modality to evaluate patients suspected of having acute PE.

Multiple studies have shown that CTPA is highly sensitive and specific [6,11,13-15]; discrepancies with conventional angiography are mainly at the subsegmental level where even angiographers tend to have poor interobserver agreement. Intra- and interobserver variability for CTPA have been shown to be very good to the segmental level, better than with V/Q imaging. Overall, CTPA has been shown to have a higher sensitivity and specificity than V/Q scans.

When combined with clinical assessment and serum D-dimer, the results of (CTA) can be highly predictive. A positive CTA result combined with high or intermediate suspicion on clinical assessment has a high positive predictive value. In patients with low clinical suspicion and a negative CTA, acute PE can safely be ruled out. In addition, the adjunctive use of CT venography with CTA improves the sensitivity the detecting DVT, with similar specificity [14-16].

CTPA also has fewer “nondiagnostic” studies than V/Q scans. Studies have shown it to be a useful adjunct to V/Q imaging in certain clinical situations and, more recently, as a primary screening exam. Initial outcome studies have shown no adverse outcomes in patients with a negative CTA who were not subsequently treated. Another study has shown CTPA to be cost-effective in conjunction with lower extremity duplex exams. More recently, as noted,

<sup>1</sup>Principal Author, Wake Forest University School of Medicine Radiology, Winston-Salem, NC; <sup>2</sup> Research Author, Wake Forest University Baptist Medical Center, Winston-Salem, NC; <sup>3</sup>Co-Chair, Boston VA Healthcare System, West Roxbury, Mass; <sup>4</sup>Co-Chair, Long Island Jewish Medical Center, New Hyde Park, NY; <sup>5</sup>Albert Einstein College of Medicine, Montefiore Medical Center, Bronx, NY; <sup>6</sup>Uniformed Services University, Bethesda, Md; <sup>7</sup>Columbia Presbyterian Medical Center, New York, NY; <sup>8</sup>Brigham and Women's Hospital, Boston, Mass; <sup>9</sup>Medical University of South Carolina, Charleston, SC; <sup>10</sup>University of Iowa Hospitals & Clinics, Iowa City, Iowa; <sup>11</sup>Mallinckrodt Institute of Radiology, Saint Louis, Mo; <sup>12</sup>Massachusetts General Hospital, Boston, Mass, American College of Cardiology.

Reprint requests to: Department of Quality & Safety, American College of Radiology, 1891 Preston White Drive, Reston, VA 20191-4397.

An ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those exams generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.

the combination of MDCTA and high-specificity D-dimer assay has been shown to have very high positive and negative predictive values [6,16]. In addition, CTPA may occasionally demonstrate pathology other than PE that may be responsible for the patient's symptoms.

Conventional CT with contrast material is generally not indicated in the routine work-up of acute chest pain thought to be secondary to acute PE [16,17]. Some clinical evidence, however, suggests that high contrast CT may be useful in assessing patients with pulmonary hypertension thought to be secondary to chronic, recurrent pulmonary embolism.

A few studies have suggested that electron beam CT may be useful to evaluate for PE, but it is not widely available and evidence supporting its role is limited [18]. In general, data support the use of MDCTA as more accurate than single slice CT or other studies, such as V/Q scans.

### **Ventilation and Perfusion Imaging**

Since its introduction in the mid-1960s by Wagner et al and others, lung perfusion imaging has been considered to be indicated in the workup of patients with suspected PE [2,3,19]. The role of lung perfusion imaging for evaluating suspected PE has, however, diminished with the widespread use of CTA. Still, a totally normal pattern of regional perfusion in multiple projections, accompanied by a normal ventilation scan, is widely accepted as indicating that pulmonary emboli are not present and no further workup (for PE) is necessary.

An abnormal pattern of regional perfusion (Q) may be suggestive, but is not specific, for diagnosing PE and thus requires correlation with other modalities such as ventilation (V) imaging and a recent chest radiograph [20-22]. These are performed to help differentiate between reduced pulmonary arterial blood flow due to vascular obstructions and secondary reductions in regional blood flow associated with a variety of airways diseases.

A "mismatched" V/Q pattern consisting of both abnormal perfusion and normal ventilation in the same region (eg, segments) may strongly point to the presence of vascular obstruction(s). However, this pattern is not specific to PE, because other conditions may also reduce pulmonary arterial blood flow while preserving ventilation in the same region (eg, malignancies, arthritis).

In most cases a "matched" V/Q pattern (defects) suggests the presence of airways disease, thus lowering the probability of PE. Even so, it is often difficult to evaluate scans in which widespread ventilatory abnormalities are known to exist, eg, chronic obstructive pulmonary disease (COPD), and/or when extensive abnormalities are observed in more than 50% of one or both lungs on the chest radiograph.

A number of schemes based on various V/Q scan patterns have been developed to assign different probabilities for

the presence (or absence) of PE [20,22-26]. Many of these use somewhat different (confusing to some) criteria. Generally, V/Q findings are categorized as: "high probability" (mismatched V/Q defects), "intermediate probability" (essentially not meeting the criterion of either "high" or "low"), "low probability" (matched V/Q defects), and "normal" (no perfusion defects). All of the probability schemes incorporate the results of a recent chest radiograph. At least one study suggests that using single pattern emission computed tomography (SPECT) imaging improves the sensitivity and specificity of V/Q scintigraphy [27].

Ventilation imaging may be performed either before or after macroaggregated albumin (MAA) perfusion imaging. Performing a (low dose) MAA scan before the Xe-133 V scan has the advantage of allowing the V scan to be obtained in the appropriate projection, rather than in the usual posterior projection. Results with Tc-99m labeled microaerosol agents (DTPA, pertechnetate, etc) are comparable to studies using inert gases such as xenon or krypton and have the advantage of providing multiple views for regional V/Q comparisons.

Lung scans sometimes may be indicated in pregnant women, in which case the administered dose of the radiopharmaceutical(s) should be reduced by a factor of three or more with correspondingly longer acquisition times to achieve adequate imaging statistics. In this way, radiation-absorbed dose may be minimized. If the MAA Q scan is performed first and is normal, the V scan can be avoided.

A follow-up MAA Q scan may be recommended 6-8 weeks after the discovery of a "mismatched" V/Q pattern (presumption of PE), because failure of observed resolution or at least significant improvement in regional perfusion may signal the ultimate development (less than 1%) of pulmonary hypertension secondary to chronic thromboembolic obstruction in the major pulmonary vessels. Caution should be exercised in interpreting perfusion imaging soon (days) after acute PE, because re-establishment of regional perfusion (resolution of defects) occurs at varying and unpredictable rates.

### **MAA Perfusion Imaging without Ventilation Imaging**

MAA perfusion (Q) imaging alone, without ventilation, may be indicated particularly when the condition of the patient suddenly deteriorates and acute PE is suspected as a significant contributory cause. The demonstration of regions of reduced perfusion, not explained by recent radiograph findings, warrants a consideration of PE and possibly the need for further workup such as pulmonary angiography. It may also be indicated in patients who are not candidates for MDCTA, such as those who are too large for available CT gantries or who are unable to remain still and breath-hold for even the few seconds necessary.

An ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those exams generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.

### Selective Pulmonary Angiography

Pulmonary angiography, including right heart catheterization and measurement of pulmonary artery and right heart pressures, is an acceptably safe, albeit invasive, procedure when performed in a facility that ensures adequate monitoring of patients. The results may establish the specific diagnosis of PE when an acceptable level of certainty cannot be reached by noninvasive imaging [23,28,29]. However, the experience of the radiologist who performs and interprets this invasive procedure is crucial. As noted, studies suggest that the overall accuracy of catheter pulmonary angiography may be inferior to that of MDCTA, due to technical factors such as patient movement and vessel overlap, as well as inter- and intra-observer variability in interpretation.

The amount of contrast material injected should be limited to that necessary to establish (or exclude) the presence of PE. The number of selective arterial injections may be reduced by evaluating suspicious pulmonary vascular territories indicated by the results of noninvasive V/Q lung scanning. Magnification techniques and imaging in special projection may overcome problems with overlapping vessels.

The general indications for pulmonary angiography in the past have included a) cases with “low” or “intermediate” probability V/Q scan findings, particularly when there is a high clinical suspicion for PE, but anticoagulation is considered risky or contraindicated; b) circumstances where a specific diagnosis (ie, PE) is considered necessary for the proper management of the patient; c) when pulmonary thromboendarterectomy is considered (eg, chronic pulmonary hypertension secondary to major vessel thromboembolic occlusion); and d) before placement of a inferior vena cava (IVC) filter. With the recent technical advances with MDCTA and studies demonstrating its accuracy, there are now far fewer cases in which catheter pulmonary angiography is indicated or necessary.

### Ultrasound

Because of the high association of DVT with pulmonary embolism, ultrasound (US) evaluation of the venous drainage of the lower extremities is probably indicated. Abnormal US studies are not specific for acute DVT, as they may not indicate whether this is a relative new occurrence or a chronic condition. Obstruction of venous flow does not indicate the presence (or absence) of PE, but may increase (or decrease) its likelihood. Positive studies may identify patients at higher risk for subsequent PE. A negative study does not exclude PE [30-32].

US studies include duplex Doppler with leg compression and continuous wave (CW) Doppler [33,34]. For a more detailed discussion, refer to the Appropriateness Criteria® topic on deep vein thrombosis.

Transesophageal echo (TEE) and transthoracic echo (TTE) studies are generally not indicated in the workup of acute chest pain in the setting of suspected acute PE. These US procedures, however, may be helpful in evaluating right ventricular function in suspected chronic, major-vessel thromboembolic pulmonary hypertension, or in evaluating risk of right heart failure in patients with massive or submassive acute PE [35-37]. While sonography may be a useful adjunct, it cannot exclude PE.

### Magnetic Resonance Imaging/Angiography

Magnetic resonance imaging (MRI) is probably not indicated in the routine evaluation of patients with suspected PE. It may rarely be useful in patients who have large central emboli, particularly if used in conjunction with MRI for other indications, such as cardiac morphologic evaluation [38,39]. Magnetic resonance angiography (MRA), while not as widely utilized, has many of the advantages MDCTA: it provides rapid, noninvasive evaluation of the central and segmental pulmonary arteries [40-42]. Technologic innovations and increased experience may increase the role of MRA. Currently, it is mainly used in certain centers with particular interest and expertise, and in patients in whom contrast administration for MDCTA, or even for pulmonary angiography, is thought to be contraindicated because of renal failure, prior reaction to iodinated contrast, pulmonary hypertension or for other reasons.

### Anticipated Exceptions

If MDCTA is not available, then V/Q scans, pulmonary MRA or lower extremity ultrasound may need to be used for evaluation.

### Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® [Radiation Dose Assessment Introduction](#) document.

Relative Radiation Level Designations	
Relative Radiation Level	Effective Dose Estimate Range
None	0
Minimal	< 0.1 mSv
Low	0.1-1 mSv
Medium	1-10 mSv
High	10-100 mSv

An ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those exams generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.

## References

1. Stein PD, Hull RD, Saltzman HA, Pineo G. Strategy for diagnosis of patients with suspected acute pulmonary embolism. *Chest* 1993; 103(5):1553-1559.
2. Greenspan RH, Ravin CE, Polansky SM, McLoud TC. Accuracy of the chest radiograph in diagnosis of pulmonary embolism. *Invest Radiol* 1982; 17(6):539-543.
3. Worsley DF, Alavi A, Aronchick JM, Chen JT, Greenspan RH, Ravin CE. Chest radiographic findings in patients with acute pulmonary embolism: observations from the PIOPED Study. *Radiology* 1993; 189(1):133-136.
4. Remy-Jardin M, Remy J, Watinne L, Giraud F. Central pulmonary thromboembolism: diagnosis with spiral volumetric CT with the single-breath-hold technique--comparison with pulmonary angiography. *Radiology* 1992; 185(2):381-387.
5. Blachere H, Latrabe V, Montaudon M, et al. Pulmonary embolism revealed on helical CT angiography: comparison with ventilation-perfusion radionuclide lung scanning. *AJR* 2000; 174(4):1041-1047.
6. Coche E, Verschuren F, Keyeux A, et al. Diagnosis of acute pulmonary embolism in outpatients: comparison of thin-collimation multi-detector row spiral CT and planar ventilation-perfusion scintigraphy. *Radiology* 2003; 229(3):757-765.
7. Cross JJ, Kemp PM, Walsh CG, Flower CD, Dixon AK. A randomized trial of spiral CT and ventilation perfusion scintigraphy for the diagnosis of pulmonary embolism. *Clin Radiol* 1998; 53(3):177-182.
8. Ferretti GR, Bosson JL, Buffaz PD, et al. Acute pulmonary embolism: role of helical CT in 164 patients with intermediate probability at ventilation-perfusion scintigraphy and normal results at duplex US of the legs. *Radiology* 1997; 205(2):453-458.
9. Garg K, Welsh CH, Feyerabend AJ, et al. Pulmonary embolism: diagnosis with spiral CT and ventilation-perfusion scanning--correlation with pulmonary angiographic results or clinical outcome. *Radiology* 1998; 208(1):201-208.
10. Gerard SK, Hsu TC. Pulmonary embolism: diagnosis with spiral CT versus ventilation-perfusion scintigraphy. *Radiology* 1999; 210(2):576-577.
11. Katsouda E, Mystakidou K, Rapti A, et al. Evaluation of spiral computed tomography versus ventilation/perfusion scanning in patients clinically suspected of pulmonary embolism. *In Vivo* 2005; 19(5):873-878.
12. Mayo JR, Remy-Jardin M, Muller NL, et al. Pulmonary embolism: prospective comparison of spiral CT with ventilation-perfusion scintigraphy. *Radiology* 1997; 205(2):447-452.
13. Hiorns MP, Mayo JR. Spiral computed tomography for acute pulmonary embolism. *Can Assoc Radiol J* 2002; 53(5):258-268.
14. Stein PD, Fowler SE, Goodman LR, et al. Multidetector computed tomography for acute pulmonary embolism. *N Engl J Med* 2006; 354(22):2317-2327.
15. van Rossum AB, Pattynama PM, Mallens WM, Hermans J, Heijerman HG. Can helical CT replace scintigraphy in the diagnostic process in suspected pulmonary embolism? A retrospective-prospective cohort study focusing on total diagnostic yield. *Eur Radiol* 1998; 8(1):90-96.
16. Schoepf UJ, Costello P. CT angiography for diagnosis of pulmonary embolism: state of the art. *Radiology* 2004; 230(2):329-337.
17. Chintapalli K, Thorsen MK, Olson DL, Goodman LR, Gurney J. Computed tomography of pulmonary thromboembolism and infarction. *J Comput Assist Tomogr* 1988; 12(4):553-559.
18. Teigen CL, Maus TP, Sheedy PF, 2nd, Johnson CM, Stanson AW, Welch TJ. Pulmonary embolism: diagnosis with electron-beam CT. *Radiology* 1993; 188(3):839-845.
19. Wagner HN, Jr., Sabiston DC, Jr., Iio M, McAfee JG, Meyer JK, Langan JK. Regional Pulmonary Blood Flow In Man By Radioisotope Scanning. *JAMA* 1964; 187:601-603.
20. Biello DR, Mattar AG, McKnight RC, Siegel BA. Ventilation-perfusion studies in suspected pulmonary embolism. *AJR* 1979; 133(6):1033-1037.
21. Hull RD, Hirsh J, Carter CJ, et al. Diagnostic value of ventilation-perfusion lung scanning in patients with suspected pulmonary embolism. *Chest* 1985; 88(6):819-828.
22. Stein PD, Henry JW, Gottschalk A. Mismatched vascular defects. An easy alternative to mismatched segmental equivalent defects for the interpretation of ventilation/perfusion lung scans in pulmonary embolism. *Chest* 1993; 104(5):1468-1471.
23. Value of the ventilation/perfusion scan in acute pulmonary embolism. Results of the prospective investigation of pulmonary embolism diagnosis (PIOPED). The PIOPED Investigators. *JAMA* 1990; 263(20):2753-2759.
24. Gottschalk A, Sostman HD, Coleman RE, et al. Ventilation-perfusion scintigraphy in the PIOPED study. Part II. Evaluation of the scintigraphic criteria and interpretations. *J Nucl Med* 1993; 34(7):1119-1126.
25. Sostman HD, Coleman RE, DeLong DM, Newman GE, Paine S. Evaluation of revised criteria for ventilation-perfusion scintigraphy in patients with suspected pulmonary embolism. *Radiology* 1994; 193(1):103-107.
26. Webber MM, Gomes AS, Roe D, La Fontaine RL, Hawkins RA. Comparison of Biello, McNeil, and PIOPED criteria for the diagnosis of pulmonary emboli on lung scans. *AJR* 1990; 154(5):975-981.
27. Reinartz P, Wildberger JE, Schaefer W, Nowak B, Mahnken AH, Buell U. Tomographic imaging in the diagnosis of pulmonary embolism: a comparison between V/Q lung scintigraphy in SPECT technique and multislice spiral CT. *J Nucl Med* 2004; 45(9):1501-1508.
28. Cheely R, McCartney WH, Perry JR, et al. The role of noninvasive tests versus pulmonary angiography in the diagnosis of pulmonary embolism. *Am J Med* 1981; 70(1):17-22.
29. Hull RD, Hirsh J, Carter CJ, et al. Pulmonary angiography, ventilation lung scanning, and venography for clinically suspected pulmonary embolism with abnormal perfusion lung scan. *Ann Intern Med* 1983; 98(6):891-899.
30. Quinn RJ, Nour R, Butler SP, et al. Pulmonary embolism in patients with intermediate probability lung scans: diagnosis with Doppler venous US and D-dimer measurement. *Radiology* 1994; 190(2):509-511.
31. Smith LL, Iber C, Sirt S. Pulmonary embolism: confirmation with venous duplex US as adjunct to lung scanning. *Radiology* 1994; 191(1):143-147.
32. Sumner DS, Lambeth A. Reliability of Doppler ultrasound in the diagnosis of acute venous thrombosis both above and below the knee. *Am J Surg* 1979; 138(2):205-210.
33. Beecham RP, Dorfman GS, Cronan JJ, Spearman MP, Murphy TP, Scola FH. Is bilateral lower extremity compression sonography useful and cost-effective in the evaluation of suspected pulmonary embolism? *AJR* 1993; 161(6):1289-1292.
34. Cronan JJ, Dorfman GS, Scola FH, Schepps B, Alexander J. Deep venous thrombosis: US assessment using vein compression. *Radiology* 1987; 162(1 Pt 1):191-194.
35. Lechleitner P, Riedl B, Raneburger W, Gamper G, Theurl A, Lederer A. Chest sonography in the diagnosis of pulmonary embolism: a comparison with MRI angiography and ventilation perfusion scintigraphy. *Ultraschall Med* 2002; 23(6):373-378.
36. Mathis G, Bitschnau R, Gehmacher O, et al. Chest ultrasound in diagnosis of pulmonary embolism in comparison to helical CT. *Ultraschall Med* 1999; 20(2):54-59.
37. Patel JJ, Chandrasekaran K, Maniet AR, Ross JJ, Jr., Weiss RL, Guidotti JA. Impact of the incidental diagnosis of clinically unsuspected central pulmonary artery thromboembolism in treatment of critically ill patients. *Chest* 1994; 105(4):986-990.
38. Erdman WA, Peshock RM, Redman HC, et al. Pulmonary embolism: comparison of MR images with radionuclide and angiographic studies. *Radiology* 1994; 190(2):499-508.
39. Kluge A, Muller C, Hansel J, Gerriets T, Bachmann G. Real-time MR with TrueFISP for the detection of acute pulmonary embolism: initial clinical experience. *Eur Radiol* 2004; 14(4):709-718.

An ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those exams generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.

40. Loubeyre P, Revel D, Douek P, et al. Dynamic contrast-enhanced MR angiography of pulmonary embolism: comparison with pulmonary angiography. *AJR* 1994; 162(5):1035-1039.
41. Obernosterer A, Aschauer M, Portugaller H, Koppel H, Lipp RW. Three-dimensional gadolinium-enhanced magnetic resonance angiography used as a "one-stop shop" imaging procedure for venous thromboembolism: a pilot study. *Angiology* 2005; 56(4):423-430.
42. Oudkerk M, van Beek EJ, Wielopolski P, et al. Comparison of contrast-enhanced magnetic resonance angiography and conventional pulmonary angiography for the diagnosis of pulmonary embolism: a prospective study. *Lancet* 2002; 359(9318):1643-1647.

An ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those exams generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.