

**American College of Radiology**  
**ACR Appropriateness Criteria®**  
**Suspected Pulmonary Embolism**

**Variant: 1 Suspected pulmonary embolism. Low or intermediate pretest probability with a negative D-dimer. Initial Imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
US duplex Doppler lower extremity	Usually Not Appropriate	O
US echocardiography transesophageal	Usually Not Appropriate	O
US echocardiography transthoracic resting	Usually Not Appropriate	O
Arteriography pulmonary with right heart catheterization	Usually Not Appropriate	⊕⊕⊕⊕⊕
MRA pulmonary arteries without and with IV contrast	Usually Not Appropriate	O
MRA pulmonary arteries without IV contrast	Usually Not Appropriate	O
CT chest with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT chest without and with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT chest without IV contrast	Usually Not Appropriate	⊕⊕⊕
CTA chest with IV contrast with CTV lower extremities	Usually Not Appropriate	⊕⊕⊕
CTA pulmonary arteries with IV contrast	Usually Not Appropriate	⊕⊕⊕
V/Q scan lung	Usually Not Appropriate	⊕⊕⊕

**Variant: 2 Suspected pulmonary embolism. Low or intermediate pretest probability with a positive D-dimer. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
CTA pulmonary arteries with IV contrast	Usually Appropriate	⊕⊕⊕
V/Q scan lung	Usually Appropriate	⊕⊕⊕
MRA pulmonary arteries without and with IV contrast	May Be Appropriate	O
CTA triple rule out	May Be Appropriate (Disagreement)	⊕⊕⊕
US duplex Doppler lower extremity	Usually Not Appropriate	O
US echocardiography transesophageal	Usually Not Appropriate	O
US echocardiography transthoracic resting	Usually Not Appropriate	O
Arteriography pulmonary with right heart catheterization	Usually Not Appropriate	⊕⊕⊕⊕⊕
MRA pulmonary arteries without IV contrast	Usually Not Appropriate	O
CT chest with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT chest without and with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT chest without IV contrast	Usually Not Appropriate	⊕⊕⊕
CTA chest with IV contrast with CTV lower extremities	Usually Not Appropriate	⊕⊕⊕

**Variant: 3 Suspected pulmonary embolism. High pretest probability. Initial Imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
CTA pulmonary arteries with IV contrast	Usually Appropriate	⊕⊕⊕
V/Q scan lung	Usually Appropriate	⊕⊕⊕
US duplex Doppler lower extremity	May Be Appropriate (Disagreement)	O
US echocardiography transthoracic resting	May Be Appropriate	O

MRA pulmonary arteries without and with IV contrast	May Be Appropriate	O
US echocardiography transesophageal	Usually Not Appropriate	O
Arteriography pulmonary with right heart catheterization	Usually Not Appropriate	⊕⊕⊕⊕
MRA pulmonary arteries without IV contrast	Usually Not Appropriate	O
CT chest with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT chest without and with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT chest without IV contrast	Usually Not Appropriate	⊕⊕⊕
CTA chest with IV contrast with CTV lower extremities	Usually Not Appropriate	⊕⊕⊕
CTA triple rule out	Usually Not Appropriate	⊕⊕⊕

#### **Variant: 4 Suspected pulmonary embolism. Pregnant patient. Initial Imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
US duplex Doppler lower extremity	Usually Appropriate	O
Radiography chest	Usually Appropriate	⊕
CTA pulmonary arteries with IV contrast	Usually Appropriate	⊕⊕⊕
V/Q scan lung	Usually Appropriate	⊕⊕⊕
US echocardiography transesophageal	Usually Not Appropriate	O
US echocardiography transthoracic resting	Usually Not Appropriate	O
Arteriography pulmonary with right heart catheterization	Usually Not Appropriate	⊕⊕⊕⊕
MRA pulmonary arteries without and with IV contrast	Usually Not Appropriate	O
MRA pulmonary arteries without IV contrast	Usually Not Appropriate	O
CT chest with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT chest without and with IV contrast	Usually Not Appropriate	⊕⊕⊕
CT chest without IV contrast	Usually Not Appropriate	⊕⊕⊕
CTA chest with IV contrast with CTV lower extremities	Usually Not Appropriate	⊕⊕⊕
CTA triple rule out	Usually Not Appropriate	⊕⊕⊕

#### **Panel Members**

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#### **Summary of Literature Review**

#### **Introduction/Background**

Venous thromboembolism, including deep vein thrombosis (DVT) and pulmonary embolism (PE), is the third most common cardiovascular disease after acute coronary syndrome and stroke [1]. More than 290,000 cases of fatal PE and 230,000 cases of nonfatal PE are estimated to occur in the United States each year [2]. PE is a leading cause of pregnancy-related mortality in the developed world, accounting for 20% of maternal deaths in the United States [3]. This document focuses on the initial evaluation for clinically suspected PE, recognizing that as many as 80% of PE cases are

associated with DVT [4]. PE also may occur without detectable DVT. For patients with suspected DVT, please refer to the ACR Appropriateness Criteria® topic on [Suspected Lower Extremity Deep Vein Thrombosis](#) for imaging guidelines [5].

Diagnosis of PE is challenging because of the nonspecific nature of the clinical presentation, with associated symptoms such as chest pain, shortness of breath, and tachycardia that may mimic other pulmonary or cardiac conditions. The diagnostic challenge of PE is most commonly addressed with clinical scoring algorithms such as the Wells criteria and the Geneva score [6-8], D-dimer testing, and specialized CT angiography (CTA) [9], during which the images are acquired with a timing of the iodinated contrast bolus to best opacify the pulmonary arteries.

In hemodynamically stable patients with a low or intermediate clinical likelihood of PE, normal results on D-dimer testing obviates the need for PE imaging. When patients do not fall into these categories, CT pulmonary angiography (CTPA) is commonly performed. There are 3 additional variants covered in this document: patients with a positive D-dimer without a high-risk clinical score (Variant 2), patients with a high pretest probability for PE (Variant 3), and pregnant patients (Variant 4). This document draws on the findings of the joint American College of Cardiology/ACR guideline on chest pain in the emergency room [9] and the American Thoracic Society/Society of Thoracic Radiology Clinical Practice Guideline: Evaluation of Suspected Pulmonary Embolism In Pregnancy [3].

## **Special Imaging Considerations**

Chest radiography is very limited in the assessment for PE, but it may diagnose a pneumothorax, pneumonia, or other condition. A chest radiograph is typically used in the interpretation of a ventilation and perfusion (V/Q) lung scan [10]. Because chest radiography is typically performed before advanced imaging is considered, it is not included in the ratings for Variants 1 through 3.

For the purposes of distinguishing between CT and CTA, ACR Appropriateness Criteria topics use the definition in the [ACR–NASCI–SIR–SPR Practice Parameter for the Performance and Interpretation of Body Computed Tomography Angiography](#) (CTA) [11]:

*"CTA uses a thin-section CT acquisition that is timed to coincide with peak arterial or venous enhancement. The resultant volumetric dataset is interpreted using primary transverse reconstructions as well as multiplanar reformations and 3-D renderings."*

All elements are essential: 1) timing, 2) reconstructions/reformats, and 3) 3-D renderings. Standard CTs with contrast also include timing issues and reconstructions/reformats. Only in CTA, however, is 3-D rendering a **required** element. This corresponds to the definitions that the CMS has applied to the Current Procedural Terminology codes.

In addition, CTPA is a named CT angiogram with intravenous (IV) contrast. CTPA follows the definition of a CTA above, with the addition that the timing of the scan is tailored so that contrast enhances the pulmonary arterial system to identify potential filling defects.

## **Initial Imaging Definition**

Initial imaging is defined as imaging at the beginning of the care episode for the medical condition

defined by the variant. More than one procedure can be considered usually appropriate in the initial imaging evaluation when:

- There are procedures that are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care)

OR

- There are complementary procedures (ie, more than one procedure is ordered as a set or simultaneously where each procedure provides unique clinical information to effectively manage the patient's care).

## **Discussion of Procedures by Variant**

### **Variant 1: Suspected pulmonary embolism. Low or intermediate pretest probability with a negative D-dimer. Initial Imaging.**

Because this scenario is clinically important, it is presented in Variant 1 despite the fact that the literature does not support advanced imaging [12-16].

In hemodynamically stable patients with a low or intermediate clinical likelihood of PE, normal results on D-dimer testing excludes the need for imaging [12]. A meta-analysis of 52 studies, comprising 55,268 patients, comparing the test characteristics of gestalt (a physician's unstructured estimate) and clinical decision rules for evaluating adults with suspected PE showed that PE can be safely excluded by a low clinical probability assessment and a negative D-dimer result without the need for imaging [8].

Radiographs are typically performed because the differential diagnosis is broad in this patient population.

### **Variant 1: Suspected pulmonary embolism. Low or intermediate pretest probability with a negative D-dimer. Initial Imaging.**

#### **A. CTPA**

The literature does not support the use of CTPA for the evaluation of suspected PE. This is in keeping with the fact that no advanced imaging is supported for patients included in this clinical scenario [8,12-16].

### **Variant 1: Suspected pulmonary embolism. Low or intermediate pretest probability with a negative D-dimer. Initial Imaging.**

#### **B. CT Chest With IV Contrast**

The literature does not support the use of CT chest with IV contrast for the evaluation of suspected PE for patients with low to intermediate probability and negative D-dimer [8,12-16]. The use of CT for alternate diagnoses is beyond the scope of this document.

### **Variant 1: Suspected pulmonary embolism. Low or intermediate pretest probability with a negative D-dimer. Initial Imaging.**

#### **C. CT Chest Without and With IV Contrast**

The literature does not support the use of CT chest without and with IV contrast for the evaluation of suspected PE for patients with low to intermediate probability and negative D-dimer [8,12-16]. The use of CT for alternate diagnoses is beyond the scope of this document.

**Variant 1: Suspected pulmonary embolism. Low or intermediate pretest probability with a negative D-dimer. Initial Imaging.**

**D. CT Chest Without IV Contrast**

The literature does not support the use of CT chest without IV contrast for the evaluation of suspected PE for patients with low to intermediate probability and negative D-dimer [8,12-16]. The use of CT for alternate diagnoses is beyond the scope of this document.

**Variant 1: Suspected pulmonary embolism. Low or intermediate pretest probability with a negative D-dimer. Initial Imaging.**

**E. CTA Chest With IV Contrast with CTV Lower Extremities**

The literature does not support the use of CTA chest with IV contrast with CT venography (CTV) lower extremities for the evaluation of suspected PE for patients with low to intermediate probability and negative D-dimer [8,12-16]. The use of CTA for alternate diagnoses is beyond the scope of this document.

**Variant 1: Suspected pulmonary embolism. Low or intermediate pretest probability with a negative D-dimer. Initial Imaging.**

**F. Arteriography Pulmonary with Right Heart Catheterization**

Pulmonary angiography, including right heart catheterization and measurement of pulmonary artery and right heart pressures, is almost never used as a first-line test for PE, although it had historic diagnostic use [17-19] before it was supplanted by CTPA. The overall accuracy of catheter pulmonary angiography is likely to be inferior to CTPA. The role of angiography, when therapy such as pulmonary embolectomy is performed, is not within the scope of this document. This is in keeping with evidence suggesting that advanced imaging is not supported for patients included in Variant 1 [8,12-16].

**Variant 1: Suspected pulmonary embolism. Low or intermediate pretest probability with a negative D-dimer. Initial Imaging.**

**G. MRA Pulmonary Arteries Without and With IV contrast**

The literature does not support the use of MR angiography (MRA) pulmonary arteries without and with IV contrast for the evaluation of suspected PE for patients with low to intermediate probability and negative D-dimer [8,12-16].

**Variant 1: Suspected pulmonary embolism. Low or intermediate pretest probability with a negative D-dimer. Initial Imaging.**

**H. MRA Pulmonary Arteries Without IV contrast**

The literature does not support the use of MRA pulmonary arteries without IV contrast for the evaluation of suspected PE for patients with low to intermediate probability and negative D-dimer [8,12-16].

**Variant 1: Suspected pulmonary embolism. Low or intermediate pretest probability with a negative D-dimer. Initial Imaging.**

**I. US Duplex Doppler Lower Extremity**

The literature does not support the use of ultrasound (US) duplex Doppler lower extremity for the evaluation of suspected PE for patients with low to intermediate probability and negative D-dimer [8,12-16].

**Variant 1: Suspected pulmonary embolism. Low or intermediate pretest probability with a negative D-dimer. Initial Imaging.**

## **J. US Echocardiography Transesophageal**

The literature does not support the use of US echocardiography transesophageal for the evaluation of suspected PE for patients with low to intermediate probability and negative D-dimer [8,12-16].

## **Variant 1: Suspected pulmonary embolism. Low or intermediate pretest probability with a negative D-dimer. Initial Imaging.**

### **K. US Echocardiography Transthoracic Resting**

The literature does not support the use of US echocardiography transthoracic resting for the evaluation of suspected PE for patients with low to intermediate probability and negative D-dimer [8,12-16].

## **Variant 1: Suspected pulmonary embolism. Low or intermediate pretest probability with a negative D-dimer. Initial Imaging.**

### **L. V/Q Scan Lung**

The literature does not support the use of V/Q scan lung for the evaluation of suspected PE for patients with low to intermediate probability and negative D-dimer [8,12-16].

## **Variant 2: Suspected pulmonary embolism. Low or intermediate pretest probability with a positive D-dimer. Initial imaging.**

## **Variant 2: Suspected pulmonary embolism. Low or intermediate pretest probability with a positive D-dimer. Initial imaging.**

### **A. CTPA**

CTPA is a first-line diagnostic imaging tool after the D-dimer examination and is routinely performed in this clinical scenario. CTPA is highly sensitive and specific [20-24]. CTPA may occasionally demonstrate pathology other than PE that may be responsible for the patient's symptoms [22].

## **Variant 2: Suspected pulmonary embolism. Low or intermediate pretest probability with a positive D-dimer. Initial imaging.**

### **B. CT Chest With IV Contrast**

There is no relevant literature to support the use of CT chest with IV contrast to assess PE in patients with low or intermediate probability with positive D-dimer. When IV contrast is given during the CT acquisition, the study should be performed as a CTPA.

## **Variant 2: Suspected pulmonary embolism. Low or intermediate pretest probability with a positive D-dimer. Initial imaging.**

### **C. CT Chest Without and With IV Contrast**

There is no relevant literature to support the use of CT chest without and with IV contrast to assess PE in patients with low or intermediate probability with positive D-dimer. When IV contrast is given during the CT acquisition, the study should be performed as a CTPA.

## **Variant 2: Suspected pulmonary embolism. Low or intermediate pretest probability with a positive D-dimer. Initial imaging.**

### **D. CT Chest Without IV Contrast**

There is no relevant literature to support the use of CT chest without IV contrast to assess PE in patients with low or intermediate probability with positive D-dimer.

## **Variant 2: Suspected pulmonary embolism. Low or intermediate pretest probability with a**

## **positive D-dimer. Initial imaging.**

### **E. CTA Chest With IV Contrast With CTV Lower Extremities**

Older literature shows that the field of view for CTA can be extended to include the lower extremities so that both the pulmonary arteries and the deep veins of the leg can be imaged during the same imaging session [25,26]. However, this protocol is very rarely used at present, owing to the accuracy of performing US for DVT and the increased burden of contrast and radiation for the associated extended craniocaudal field of view [27].

## **Variant 2: Suspected pulmonary embolism. Low or intermediate pretest probability with a positive D-dimer. Initial imaging.**

### **F. CTA Triple Rule Out**

Technological advancements in temporal and spatial resolution in electrocardiogram-gated CT have allowed accurate evaluation of the pulmonary vasculature, thoracic aorta, and coronary arteries on a single CT study for patients with acute chest pain. This "triple rule out" CT protocol to evaluate for PE, acute aortic syndrome, and acute coronary syndrome has been shown to be technically feasible in some patient groups, although it has yet to be proven useful through large-scale clinical trials [28-30]. In one recent study [31], the prevalence of acute aortic syndrome and acute coronary syndrome among patients suspected clinically of having PE was 5.5% and 0.5%, respectively, leading the authors to conclude that patients suspected for PE could be evaluated with dedicated CTPA.

## **Variant 2: Suspected pulmonary embolism. Low or intermediate pretest probability with a positive D-dimer. Initial imaging.**

### **G. Arteriography Pulmonary with Right Heart Catheterization**

Pulmonary angiography, including right heart catheterization and measurement of pulmonary artery and right heart pressures, is almost never used as a first-line test for PE, although it had historic diagnostic use [17-19] before it was supplanted by CTPA. The overall accuracy of catheter pulmonary angiography is likely to be inferior to CTPA. The role of angiography, when therapy such as pulmonary embolectomy is performed, is not within the scope of this document. This invasive procedure has an estimated morbidity and mortality of 3.5% to 6% and 0.2% to 0.5%, respectively [32,33].

## **Variant 2: Suspected pulmonary embolism. Low or intermediate pretest probability with a positive D-dimer. Initial imaging.**

### **H. MRA Pulmonary Arteries Without and With IV Contrast**

MRA can identify emboli in the central and segmental pulmonary arteries [34-37] among patients with low or intermediate probability with positive D-dimer [38]. However, limitations were identified by the Prospective Investigation of Pulmonary Embolism Diagnosis III (PIOPED III) trial [39,40], although some data are more promising [41]. The PIOPED III trial compared gadolinium-enhanced MRA to a composite reference standard (D-dimer, V/Q scan, CTPA) for accuracy [21]. In that study, MRA was technically inadequate in a large proportion (25%) of patients. Among technically adequate tests, sensitivity was 78% and specificity was 99% [21]. Similar results were found in a prospective study including 300 patients referred for CTPA in whom MRA was also performed [24]. For patients with conclusive MRA results, sensitivity and specificity were approximately 85% and 97%, respectively, compared with the standard diagnostic workup including CTPA [24]. A recent systematic review and patient-based meta-analysis reported similar results with an overall sensitivity of 75% (95% confidence interval [CI], 70%-79%) and an overall specificity of 80% (95% CI, 77%-83%) [1,42]. MRA pulmonary arteries without and with IV contrast is used far less commonly than CTPA. In addition, the study duration is longer than CTPA, and there

can be limited access to the patient, raising concerns for those patients who may become hemodynamically unstable.

**Variant 2: Suspected pulmonary embolism. Low or intermediate pretest probability with a positive D-dimer. Initial imaging.**

**I. MRA Pulmonary Arteries Without IV Contrast**

Noncontrast MRA sequences alone for PE have been reported but remain investigational [41,43,44]. There is limited relevant literature to support the use of noncontrast MRA for suspected PE, low or intermediate pretest probability with a positive D-dimer.

**Variant 2: Suspected pulmonary embolism. Low or intermediate pretest probability with a positive D-dimer. Initial imaging.**

**J. US Duplex Doppler Lower Extremity**

Compression US with Doppler flow studies are used to evaluate for peripheral DVT [45,46] and may be useful for patients who do not have a high likelihood of PE, particularly if the patient has symptoms of extremity DVT. The presence of DVT does not indicate the presence of PE, but it increases the likelihood. A negative extremity US study does not exclude PE, although it significantly decreases its likelihood [47-49].

**Variant 2: Suspected pulmonary embolism. Low or intermediate pretest probability with a positive D-dimer. Initial imaging.**

**K. US Echocardiography Transesophageal**

Literature suggests that PE can be suspected during echocardiography when there is a hypo- or akinetic mid and basal right ventricular free wall associated with a seemingly normal or hyperkinetic right ventricular apical wall motion [50]. Although additional studies have focused on the accuracy of these findings on a practical basis, all patients for whom these findings are suggested—either for transesophageal or transthoracic echocardiography—will undergo CTPA to identify a filling defect in the diagnosis of PE [51]. Risk stratification for right ventricular failure when there is a positive CTPA [52-57] is commonly used, but this clinical situation (after a diagnosis of PE) is not within the scope of this document.

**Variant 2: Suspected pulmonary embolism. Low or intermediate pretest probability with a positive D-dimer. Initial imaging.**

**L. US Echocardiography Transthoracic Resting**

Literature suggests that PE can be suspected during echocardiography when there is a hypo- or akinetic mid and basal right ventricular free wall associated with a seemingly normal or hyperkinetic right ventricular apical wall motion [50]. Although additional studies have focused on the accuracy of these findings on a practical basis, all patients for whom these findings are suggested—either for transesophageal or transthoracic echocardiography—will undergo CTPA to identify a filling defect in the diagnosis of PE [51]. Risk stratification for right ventricular failure when there is a positive CTPA [52-57] is commonly used, but this clinical situation (after a diagnosis of PE) is not within the scope of this document.

**Variant 2: Suspected pulmonary embolism. Low or intermediate pretest probability with a positive D-dimer. Initial imaging.**

**M. V/Q Scan Lung**

The use of V/Q scans has considerably diminished with the widespread use of CTPA. Imaging protocols have evolved [10,58,59], and in some cases, perfusion imaging alone can be performed. The high negative predictive value of a normal V/Q scan has been confirmed by several studies,

including a large outcome study [60]. Among the weaknesses of V/Q scanning are the high proportion of nondiagnostic results and the inability to provide an alternative diagnosis [1,58]. Abnormal regional lung perfusion may suggest the diagnosis of PE, but it is not specific. Findings require correlation with ventilation studies or other imaging. Investigators have studied single-photon emission CT (SPECT) to improve the sensitivity and specificity of V/Q scintigraphy [61]. The addition of CT to SPECT enables V/Q detection of conditions other than PE (such as radiation therapy induced changes, emphysema, and extrinsic vascular compression from conditions such as neoplasm or mediastinal adenopathy). However, this use remains experimental, and it is not rated as a separate imaging study.

**Variant 3: Suspected pulmonary embolism. High pretest probability. Initial Imaging.**

**Variant 3: Suspected pulmonary embolism. High pretest probability. Initial Imaging.**

**A. CTPA**

CTPA is the first-line diagnostic imaging tool and is routinely performed in the United States for nearly all patients in this clinical scenario. CTPA is highly sensitive and specific [20-24]. CTPA may occasionally demonstrate pathology other than PE that may be responsible for the patient's symptoms [22].

**Variant 3: Suspected pulmonary embolism. High pretest probability. Initial Imaging.**

**B. CT Chest With IV Contrast**

There is no relevant literature to support the use of other imaging protocols when CTPA is performed for PE. When IV contrast is given during the CT acquisition, the study should be performed as a CTPA.

**Variant 3: Suspected pulmonary embolism. High pretest probability. Initial Imaging.**

**C. CT Chest Without and With IV Contrast**

There is no relevant literature to support CT chest without and with IV contrast for suspected PE, high pretest probability. When IV contrast is given during the CT acquisition, the study should be performed as a CTPA.

**Variant 3: Suspected pulmonary embolism. High pretest probability. Initial Imaging.**

**D. CT Chest Without IV Contrast**

There is no relevant literature to support CT chest without IV contrast for suspected PE, high pretest probability.

**Variant 3: Suspected pulmonary embolism. High pretest probability. Initial Imaging.**

**E. CTA Chest With IV Contrast With CTV Lower Extremities**

Older literature shows that the field of view for CTA can be extended to include the lower extremities so that both the pulmonary arteries and the deep veins of the leg can be imaged during the same imaging session [25,26]. However, this protocol is very rarely used at present, owing to the accuracy of performing US for DVT and the increased burden of contrast and radiation for the associated extended craniocaudal field of view [27].

**Variant 3: Suspected pulmonary embolism. High pretest probability. Initial Imaging.**

**F. CTA Triple Rule Out**

Technological advancements such as electrocardiogram-gated CT and dual-source CT have allowed accurate evaluation of the pulmonary vasculature, thoracic aorta, and coronary arteries on a single CT study for patients with acute chest pain. This "triple rule out" CT protocol to evaluate

for PE, acute aortic syndrome, and acute coronary syndrome has been shown to be technically feasible in some patient groups, although it has yet to be proven useful through large-scale clinical trials [28-30]. In one recent study [31], the prevalence of acute aortic syndrome and acute coronary syndrome among patients suspected clinically of having PE was 5.5% and 0.5%, respectively, leading the authors to conclude that patients suspected for PE could be evaluated with dedicated CTPA.

**Variant 3: Suspected pulmonary embolism. High pretest probability. Initial Imaging.**

**G. Arteriography Pulmonary with Right Heart Catheterization**

Pulmonary angiography, including right heart catheterization and measurement of pulmonary artery and right heart pressures, is almost never used as a first-line test for PE, although it had historic diagnostic use [17-19] before it was supplanted by CTPA. The overall accuracy of catheter pulmonary angiography is likely to be inferior to CTPA. The role of angiography, when therapy such as pulmonary embolectomy is performed, is not within the scope of this document. This invasive procedure has an estimated morbidity and mortality of 3.5% to 6% and 0.2% to 0.5%, respectively [32,33].

**Variant 3: Suspected pulmonary embolism. High pretest probability. Initial Imaging.**

**H. MRA Pulmonary Arteries Without and With IV Contrast**

MRA can identify emboli in the central and segmental pulmonary arteries [34-37] among patients with low or intermediate probability with positive D-dimer [38]. However, limitations were identified by the PIOPED III trial [39,40], although some data are more promising [41]. The PIOPED III trial compared gadolinium-enhanced MRA to a composite reference standard (D-dimer, V/Q scan, CTPA) for accuracy [21]. In that study, MRA was technically inadequate in a large proportion (25%) of patients. Among technically adequate tests, sensitivity was 78% and specificity was 99% [21]. Similar results were found in a prospective study including 300 patients referred for CTPA in whom MRA was also performed [24]. For patients with conclusive MRA results, sensitivity and specificity were approximately 85% and 97%, respectively, compared with the standard diagnostic workup including CTPA [24]. A recent systematic review and patient-based meta-analysis reported similar results with an overall sensitivity of 75% (95% CI, 70%-79%) and an overall specificity of 80% (95% CI, 77%-83%) [1,42]. MRA pulmonary arteries without and with IV contrast is used far less commonly than CTPA. In addition, the study duration is longer than CTPA, and there can be limited access to the patient, raising concerns for those patients who may become hemodynamically unstable.

**Variant 3: Suspected pulmonary embolism. High pretest probability. Initial Imaging.**

**I. MRA Pulmonary Arteries Without IV Contrast**

Noncontrast MRA sequences alone for PE have been reported but remain investigational [43]. There is limited literature to support the use of noncontrast MRA of the pulmonary arteries for the evaluation of PE [24,34].

**Variant 3: Suspected pulmonary embolism. High pretest probability. Initial Imaging.**

**J. US Duplex Doppler Lower Extremity**

Compression US may be useful for patients who do not have a high likelihood of PE, particularly if the patient has symptoms of extremity DVT. Compression US with Doppler flow studies are used to evaluate for peripheral DVT. US studies include duplex Doppler with leg compression and continuous-wave Doppler [45,46]. The presence of DVT does not indicate the presence of PE, but it increases the likelihood. A negative extremity US study does not exclude PE, although it

significantly decreases its likelihood [47-49].

**Variant 3: Suspected pulmonary embolism. High pretest probability. Initial Imaging.**

**K. US Echocardiography Transesophageal**

Literature suggests that PE can be suspected during echocardiography when there is a hypo- or akinetic mid and basal right ventricular free wall associated with a seemingly normal or hyperkinetic right ventricular apical wall motion [50]. Although additional studies have focused on the accuracy of these findings on a practical basis, all patients for whom these findings are suggested—either for transesophageal or transthoracic echocardiography—will undergo CTPA to identify a filling defect in the diagnosis of PE [51]. Risk stratification for right ventricular failure when there is a positive CTPA [52-57] is commonly used, but this clinical situation (after a diagnosis of PE) is not within the scope of this document.

**Variant 3: Suspected pulmonary embolism. High pretest probability. Initial Imaging.**

**L. US Echocardiography Transthoracic Resting**

Literature suggests that PE can be suspected during echocardiography when there is a hypo- or akinetic mid and basal right ventricular free wall associated with a seemingly normal or hyperkinetic right ventricular apical wall motion [50]. Although additional studies have focused on the accuracy of these findings on a practical basis, all patients for whom these findings are suggested—either for transesophageal or transthoracic echocardiography—will undergo CTPA to identify a filling defect in the diagnosis of PE [51]. Risk stratification for right ventricular failure when there is a positive CTPA [52-57] is commonly used, but this clinical situation (after a diagnosis of PE) is not within the scope of this document.

**Variant 3: Suspected pulmonary embolism. High pretest probability. Initial Imaging.**

**M. V/Q Scan Lung**

The use of V/Q scans has considerably diminished with the widespread use of CTPA. Imaging protocols have evolved [10,58,59], and in some cases, perfusion imaging alone can be performed. The high negative predictive value of a normal V/Q scan has been confirmed by several studies, including a large outcome study [60]. Among the weaknesses of V/Q scanning are the high proportion of nondiagnostic results and the inability to provide alternative diagnosis [1,58]. Abnormal regional lung perfusion may suggest the diagnosis of PE, but it is not specific. Findings require correlation with ventilation studies or other imaging. Investigators have studied SPECT to improve the sensitivity and specificity of V/Q scintigraphy [61]. The addition of CT to SPECT enables V/Q detection of conditions other than PE (such as radiation therapy induced changes, emphysema, and extrinsic vascular compression from conditions such as neoplasm or mediastinal adenopathy). However, this use remains experimental, and it is not rated as a separate imaging study.

**Variant 4: Suspected pulmonary embolism. Pregnant patient. Initial Imaging.**

Pregnancy frequently alters the diagnostic strategy for patients with clinically suspected PE, and thus it is considered as a separate variant. For guidance on pregnant patients, please refer to the Safety Considerations in Pregnant Patients section below.

**Variant 4: Suspected pulmonary embolism. Pregnant patient. Initial Imaging.**

**A. Radiography Chest**

Although radiographs are neither sensitive nor specific, the role in pregnancy becomes more relevant when compared to the other variants. The rationale is that an alternative diagnosis may be found, and for patients without clinical evidence of lower extremity DVT, radiography can inform

the choice between CTPA and V/Q scanning as a second imaging test.

**Variant 4: Suspected pulmonary embolism. Pregnant patient. Initial Imaging.**

**B. CTPA**

Although the CTPA acquisition may be modified [62-64] for the physiology of pregnancy, CTPA is commonly performed. In a study involving pregnant women with high pretest probability and those with intermediate probability and positive D-dimer followed by negative bilateral lower extremity US who were evaluated with CTPA, the positive rate was 5.7% (19 of 332), and the indeterminate rate was 6.9% (23 of 332) [65].

**Variant 4: Suspected pulmonary embolism. Pregnant patient. Initial Imaging.**

**C. CT Chest With IV Contrast**

When IV contrast is given during the CT acquisition, the study should be performed as a CTPA. There is no relevant literature to support the use of CT chest with IV contrast for suspected PE in a pregnant patient.

**Variant 4: Suspected pulmonary embolism. Pregnant patient. Initial Imaging.**

**D. CT Chest Without and With IV Contrast**

When IV contrast is given during the CT acquisition, the preferred protocol is CTPA. There is no relevant literature to support the use of CT chest without and with IV contrast for suspected PE in a pregnant patient.

**Variant 4: Suspected pulmonary embolism. Pregnant patient. Initial Imaging.**

**E. CT Chest Without IV Contrast**

There is no relevant literature to support the use of CT chest without IV contrast for suspected PE in a pregnant patient.

**Variant 4: Suspected pulmonary embolism. Pregnant patient. Initial Imaging.**

**F. CTA Chest With IV Contrast with CTV Lower Extremities**

Older literature shows that the field of view for CTA can be extended to include the lower extremities so that both the pulmonary arteries and the deep veins of the leg can be imaged during the same imaging session [25,26]. However, this protocol is very rarely used at present, owing to the accuracy of performing US for DVT and the increased burden of contrast and radiation for the associated extended craniocaudal field of view [27].

**Variant 4: Suspected pulmonary embolism. Pregnant patient. Initial Imaging.**

**G. CTA Triple Rule Out**

There is no relevant literature to support the use of CTA triple rule out for suspected PE in a pregnant patient.

**Variant 4: Suspected pulmonary embolism. Pregnant patient. Initial Imaging.**

**H. Arteriography Pulmonary with Right Heart Catheterization**

There is no relevant literature to support diagnostic catheterization for PE in pregnant patients. This invasive procedure has an estimated morbidity and mortality of 3.5% to 6% and 0.2% to 0.5%, respectively [32,33]. If IV contrast is used, CTPA should be performed for diagnosis. The role of catheterization in intervention is not considered in this document.

**Variant 4: Suspected pulmonary embolism. Pregnant patient. Initial Imaging.**

**I. MRA Pulmonary Arteries Without and With IV Contrast**

In general, gadolinium-based contrast agents should be administered with caution to pregnant or

potentially pregnant patients [66]. Because there are alternative methods to evaluate for PE in pregnancy that have greater benefit to the patient or fetus when compared with possible but unknown risk of fetal exposure to free gadolinium ions, MRA without and with IV contrast is rarely, if ever, performed.

**Variant 4: Suspected pulmonary embolism. Pregnant patient. Initial Imaging.**

**J. MRA Pulmonary Arteries Without IV Contrast**

Noncontrast MRA sequences alone for PE have been reported but remain investigational [43]. There is limited literature to support the use of noncontrast MRA of the pulmonary arteries for the evaluation of PE, including among pregnant patients [24,34].

**Variant 4: Suspected pulmonary embolism. Pregnant patient. Initial Imaging.**

**K. US Duplex Doppler Lower Extremity**

Compression US has an expanded role in pregnancy when compared with Variants 2 and 3 [45-49]. Pregnant patients with a positive compression US can be initiated on anticoagulation without further imaging. This strategy is particularly appealing for patients with symptoms of lower extremity DVT. Although there is a low false-negative rate of US [67], additional testing may be useful if an initial US does not show DVT.

**Variant 4: Suspected pulmonary embolism. Pregnant patient. Initial Imaging.**

**L. US Echocardiography Transesophageal**

Literature suggests that PE can be suspected during echocardiography when there is a hypo- or akinetic mid and basal right ventricular free wall associated with a seemingly normal or hyperkinetic right ventricular apical wall motion [50]. Although additional studies have focused on the accuracy of these findings on a practical basis, all patients for whom these findings are suggested—either for transesophageal or transthoracic echocardiography—will undergo CTPA to identify a filling defect in the diagnosis of PE [51]. Risk stratification for right ventricular failure when there is a positive CTPA [52-57] is commonly used, but this clinical situation (after a diagnosis of PE) is not within the scope of this document.

**Variant 4: Suspected pulmonary embolism. Pregnant patient. Initial Imaging.**

**M. US Echocardiography Transthoracic Resting**

Literature suggests that PE can be suspected during echocardiography when there is a hypo- or akinetic mid and basal right ventricular free wall associated with a seemingly normal or hyperkinetic right ventricular apical wall motion [50]. Although additional studies have focused on the accuracy of these findings on a practical basis, all patients for whom these findings are suggested—either for transesophageal or transthoracic echocardiography—will undergo CTPA to identify a filling defect in the diagnosis of PE [51]. Risk stratification for right ventricular failure when there is a positive CTPA [52-57] is commonly used, but this clinical situation (after a diagnosis of PE) is not within the scope of this document.

**Variant 4: Suspected pulmonary embolism. Pregnant patient. Initial Imaging.**

**N. V/Q Scan Lung**

Unlike for patients who fall into Variants 2 and 3, V/Q scans are more frequently performed in pregnant patients [3,68,69]. Adjustments in the administered dose of the radiopharmaceutical(s) have been recommended [70,71], and if the perfusion scan is performed first and is normal, the ventilation scan may be avoided [72-74].

Among the weaknesses of V/Q scanning are the high proportion of nondiagnostic results and the

inability to provide alternative diagnosis [1,58]. However, given the radiation considerations in pregnancy, abnormal regional lung perfusion may suggest the diagnosis of PE, but it is not specific. Investigators have studied SPECT to improve the sensitivity and specificity of V/Q scintigraphy [61]. The addition of CT to SPECT enables V/Q detection of conditions other than PE (such as radiation therapy-induced changes, emphysema, and extrinsic vascular compression from conditions such as neoplasm or mediastinal adenopathy). However, this use remains experimental, and it is not rated as a separate imaging study.

## Summary of Recommendations

- **Variant 1:** Imaging is usually not appropriate for the initial imaging of patients with suspected PE with low or intermediate pretest probability with a negative D-dimer.
- **Variant 2:** CTA pulmonary arteries with IV contrast or V/Q scan lung is usually appropriate for the initial imaging of patients with suspected PE with low or intermediate pretest probability with a positive D-dimer. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care). The panel did not agree on recommending CTA triple rule out for the initial imaging of patients with suspected PE with low or intermediate pretest probability with a positive D-dimer. There is insufficient medical literature to conclude whether or not these patients would benefit from CTA triple rule out for this clinical scenario. CTA triple rule out in this patient population is controversial but may be appropriate.
- **Variant 3:** CTA pulmonary arteries with IV contrast or V/Q scan lung is usually appropriate for the initial imaging of patients with suspected PE with high pretest probability. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care). The panel did not agree on recommending US duplex Doppler lower extremity for the initial imaging of patients with suspected PE with high pretest probability. There is insufficient medical literature to conclude whether or not these patients would benefit from US duplex Doppler lower extremity for this clinical scenario. US duplex Doppler lower extremity out in this patient population is controversial but may be appropriate.
- **Variant 4:** US duplex Doppler lower extremity or radiography chest or CTA pulmonary arteries with IV contrast or V/Q scan lung is usually appropriate for the initial imaging of pregnant patients with suspected PE. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).

## Supporting Documents

The evidence table, literature search, and appendix for this topic are available at <https://acsearch.acr.org/list>. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents, please go to the ACR website at <https://www.acr.org/Clinical-Resources/Clinical-Tools-and-Reference/Appropriateness-Criteria>.

## Safety Considerations in Pregnant Patients

Imaging of the pregnant patient can be challenging, particularly with respect to minimizing radiation exposure and risk. For further information and guidance, see the following ACR documents:

- [ACR-SPR Practice Parameter for the Safe and Optimal Performance of Fetal Magnetic Resonance Imaging \(MRI\)](#) [75]
- [ACR-SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radiation](#) [76]
- [ACR-ACOG-AIUM-SMFM-SRU Practice Parameter for the Performance of Standard Diagnostic Obstetrical Ultrasound](#) [77]
- [ACR Manual on Contrast Media](#) [66]
- [ACR Manual on MR Safety](#) [78]

### Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

### 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. Patients in the pediatric age group are at inherently higher risk from exposure, because of both organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared with those specified for adults (see Table below). 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*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
0	0 mSv	0 mSv
	<0.1 mSv	<0.03 mSv
	0.1-1 mSv	0.03-0.3 mSv
	1-10 mSv	0.3-3 mSv
	10-30 mSv	3-10 mSv
	30-100 mSv	10-30 mSv

\*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (e.g., region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies."

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The 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 examinations 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.

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