Suspected Pulmonary Embolism
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
1. Heit JA, Cohen AT, Anderson FA, Jr., on Behalf of the VTE Impact Assessment Group. Estimated Annual Number of Incident and Recurrent, Non-Fatal and Fatal Venous Thromboembolism (VTE) Events in the US. *ASH Annual Meeting Abstracts.* 2005;106(11):910-.	Review/Other-Dx	N/A	To estimate the total annual number of non-fatal and fatal DVT and PE events (incident and recurrent) in the US.	Estimated total annual number of symptomatic VTE events exceeded 600,000, (DVT, n=376,365; PE, n=237,058). Study confirms that VTE is a major US health problem.	4
2. Stein PD, Hull RD, Saltzman HA, Pineo G. Strategy for diagnosis of patients with suspected acute pulmonary embolism. *Chest.* 1993;103(5):1553-1559.	Review/Other-Dx	887 patients; 640 had either an intermediate probability (V/Q) scan or a V/Q scan probability that was discordant with the prior estimate of probability by clinical assessment	A position paper that describes how investigators from both groups (Prospective Investigation of Pulmonary Embolism Diagnosis [PIOPED] and Canadian study groups) have utilized the combined scientific database in order to rationalize seemingly polarized diagnostic recommendations into a single practical algorithm.	108/640 patients of whom the diagnosis of PE was uncertain would have shown proximal DVT. In 239/640 patients, tests for DVT would have been negative and the risks of PE in these patients are calculated to be less than 10%. Therefore, for 347/640 patients, confident recommendations for treatment or no treatment could have been given without pulmonary angiography. Accordingly, in the PIOPED study group of 887 patients, the need for pulmonary angiography would have been reduced from 640 (72%) to 293 patients (33%). A diagnostic strategy that includes the clinical evaluation, V/Q scan, and evaluation for DVT would decrease the number of patients who require pulmonary angiography from 72% to 33%.	4
3. Agnelli G, Becattini C. Acute pulmonary embolism. *N Engl J Med.* 2010;363(3):266-274.	Review/Other-Dx	N/A	To review the optimal diagnostic strategy and management of acute PE.	Diagnostic workup should be tailored to the severity of the clinical presentation on the basis of whether the patient's condition is hemodynamically stable or unstable. In patients with hemodynamic stability, the diagnosis of PE should follow a sequential diagnostic workup consisting of clinical probability assessment, D-dimer testing, and (if necessary) MDCT or V/Q scanning.	4
4. Gandara E, Wells PS. Diagnosis: use of clinical probability algorithms. *Clin Chest Med.* 2010;31(4):629-639.	Review/Other-Dx	N/A	To review role of clinical prediction rules in the diagnostic process and their clinical application into diagnostic algorithms.	Evidence suggests that patients with suspected PE are managed better with a diagnostic strategy that includes clinical pretest probability assessment, D-dimer test, and/or imaging.	4

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5. Gimber LH, Travis RI, Takahashi JM, Goodman TL, Yoon HC. Computed Tomography Angiography in Patients Evaluated for Acute Pulmonary Embolism with Low Serum D-dimer Levels: A Prospective Study. *Perm J.* 2009;13(4):4-10.	Observational-Dx	347 patients with D-dimer level ≤1.0 µg/mL	Prospective observational study to evaluate roles for clinical probability and CTA in emergency department patients suspected of acute PE but having a low serum D-dimer level.	In one participant, CTA showed a PE that was agreed on by both the initial and study radiologists. In six participants, the initial findings were reported as positive for PE but were not interpreted as positive by the study radiologist. In none of these participants was PE diagnosed on the basis of clinical probability, of findings on ancillary studies and three-month follow-up examination, or by another radiologist, unaware of findings, acting as a tiebreaker. Pulmonary CTA findings positive for acute embolism should be viewed with caution, especially if the suspected PE is in a distal segmental or subsegmental artery in a patient with a serum D-dimer level of ≤1.0 µg/mL. Furthermore, the Wells criteria may be of limited additional value in this group of patients with low D-dimer levels because most will have low or intermediate clinical probability of PE.	1
6. Gupta RT, Kakarla RK, Kirshenbaum KJ, Tapson VF. D-dimers and efficacy of clinical risk estimation algorithms: sensitivity in evaluation of acute pulmonary embolism. *AJR Am J Roentgenol.* 2009;193(2):425-430.	Observational-Dx	627 patients	Prospective study to test the efficacy of clinical risk algorithms and a quantitative immunoturbidimetric D-dimer assay in the evaluation of patients undergoing pulmonary CTA for suspected acute PE.	CTA showed that 28 patients had PE (6 in the low-probability group, 17 in the intermediate-probability group, and 5 in the high-probability group). The sensitivity, NPV, and specificity of the D-dimer assay were 100%, 100%, and 25% (low-clinical-probability group); 100%, 100%, and 33% (intermediate-probability group); and 80%, 80%, and 37% (high-probability group). Data support the use of a quantitative D-dimer assay as a first-line test in evaluation for PE when the clinical probability of the presence of PE is low or intermediate. The sensitivity and NPV were 100% for these cases. More than 26% of CTA examinations might have been avoided if the D-dimer assay had been used as a first-line test in the care of patients at low or intermediate risk. Because of the small sample size, the D-dimer assay is not recommended as a first-line test in the evaluation of patients at high risk.	3

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
7. Kabrhel C. Outcomes of high pretest probability patients undergoing d-dimer testing for pulmonary embolism: a pilot study. *J Emerg Med.* 2008;35(4):373-377.	Observational-Dx	541 patients enrolled; 130 patients had Wells Score >4 and 33 patients had Wells Score >6 (not mutually exclusive)	To prospectively assess the test characteristics of the ELISA (enzyme-linked immunosorbent assay) D-dimer in the diagnosis of clinically significant PE in emergency department patients with high pretest probability for the disease.	Of subjects with Wells Score >4, 23 (18%) were diagnosed with PE and 40 (31%) had a negative D-dimer. No patient with Wells Score >4 (sensitivity 100%, 95% CI, 82%-100%; specificity 37%, 95% CI, 28%-47%) or Wells Score >6 (sensitivity 100%, 95% CI, 63%-100%; specificity 56%, 95% CI, 35%-76%) who had a negative D-dimer was diagnosed with PE. The likelihood ratio for a negative D-dimer was 0 for both the Wells >4, and Wells >6 groups, however, the upper limits of the CI around the post-test probability for PE were 16% and 33%, respectively, for these high probability groups. In this pilot study, the rapid ELISA D-dimer had high sensitivity and NPV even when applied to patients with high pretest probability for PE. However, with the post-test probability of PE still as high as 16%-33% in the negative D-dimer groups, this precludes applying the results to patient care at present. Further testing is warranted to determine whether these findings can be safely incorporated into practice.	3
8. 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.	Observational-Dx	152 patients 9 interpreters	To determine the sensitivity and specificity of the chest radiograph for the diagnosis of PE.	The average true-positive ratio (sensitivity) was 0.33, with a range of 0.52-0.88. The average true-negative ratio (specificity) was 0.59, with a range of 0.31-0.80. The false-positive and false-negative ratios were respectively, 0.21 (range 0.05-0.39) and 0.41 (range 0.15-0.70). A predictive index, reflecting the overall accuracy of diagnosis, was calculated for the entire group and was 0.40, with a range of 0.17-0.57. There appeared to be no correlation between training or experience and accuracy of performance in this study.	4

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
9. 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.	Observational-Dx	1,063 patients: PE was confirmed angiographically in 383 patients and excluded in 680 patients	To determine the sensitivity, specificity, and PPV and NPV of chest radiographic findings in patients suspected of having acute PE.	The chest radiograph was interpreted as normal in only 12% of patients with PE. The most common chest radiographic finding in patients with PE was atelectasis and/or parenchymal areas of increased opacity; however, the prevalence was not significantly different from that in patients without PE. Oligemia (the Westermark sign), prominent central pulmonary artery (the Fleischner sign), pleural-based area of increased opacity (the Hampton hump), vascular redistribution, pleural effusion, elevated diaphragm, and enlarged hilum were also poor predictors of PE. The value is to exclude diagnoses that mimic PE and aid in V/Q scan interpretation.	3
10. Remy-Jardin M, Remy J, Wattinne 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.	Review/Other-Dx	42 patients	To prospectively determine the usefulness of spiral CT in the evaluation of suspected PE.	All 23 patients with normal findings of spiral volumetric CT had normal findings of pulmonary angiography. With spiral volumetric CT, the finding of 112 central emboli (eight main, 28 lobar, and 76 segmental) corresponded exactly to the angiographic findings, but nine intersegmental lymph nodes were erroneously interpreted as filling defects. Technique may identify thrombi in second to fourth division vessels but routine use not established.	4
11. Blachere H, Latrabe V, Montaudon M, et al. Pulmonary embolism revealed on helical CT angiography: comparison with ventilation-perfusion radionuclide lung scanning. *AJR Am J Roentgenol.* 2000;174(4):1041-1047.	Observational-Dx	216 consecutive patients	Comparison of helical CTA with V/Q scan as the initial diagnostic test for PE.	Helical CTA could replace V/Q scan as the initial imaging choice in patients with suspected PE.	3

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
12. 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.	Observational-Dx	94 non-consecutive patients	To compare MDCT to V/Q scan for diagnosis of PE.	Sensitivity of thin-collimation MDCT and V/Q scintigraphy for the detection of PE was 96% (27/28; CI, 82%, 99%) and 98% (65/66; CI, 92%, 99%), respectively. Specificity of CT and V/Q scintigraphy was 86% (24/28; CI, 67%, 96%) and 88% (58/66; CI, 77%, 94%), respectively. Examinations with spiral CT yielded conclusive results more often than examinations with planar V/Q scintigraphy (P<.05). Five V/Q scintigrams and spiral CT scans were discordant. Twelve pulmonary angiographic examinations were performed. Angiographic findings were concordant in 10 (91%) of 11 patients with conclusive CT scans in whom pulmonary angiography was attempted. CT was used to establish an alternative diagnosis in 19 (29%) of 66 patients in whom PE was excluded. Thin-collimation MDCT is more accurate than V/Q scintigraphy in the diagnosis of acute PE in outpatients. Furthermore, CT provides alternative diagnoses for patients without PE on high-quality transverse or near-isotropic reformatted images.	1
13. 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.	Experimental-Dx	78 patients	Prospective randomized trial to compare spiral CTA with V/Q as the initial investigation of patients with suspected PE.	Spiral CTA demonstrated pulmonary emboli in 6/39 patients (16%) in the spiral CTA first group and V/Q was high probability for PE in 5/39 patients (13%) in the V/Q first group.	1
14. 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.	Observational-Dx	164 consecutive patients	To assess prospectively the clinical effectiveness of helical CT in evaluation of unresolved suspicion for PE.	In 40 (24.4%) of 164 patients, the diagnosis of PE was based on results at helical CT (n=39) or pulmonary angiography (n=1).	2
15. 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.	Observational-Dx	54 patients	To compare the accuracy of spiral CT with that of V/Q scintigraphy in diagnosis of PE.	The prospective sensitivity and specificity for segmental or subsegmental PE were 67% and 100%, respectively, and the PPV and NPV were 100% and 90%, respectively. Spiral CT has greater accuracy and specificity than V/Q scanning.	2

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16. Gerard SK, Hsu TC. Pulmonary embolism: diagnosis with spiral CT versus ventilation-perfusion scintigraphy. *Radiology.* 1999;210(2):576-577.	Review/Other-Dx	N/A	Letter to editor about study by Dr. Garg and colleagues (reference 15).	Dr. Garg and colleagues agree that spiral CT scanning may have selective utility to help diagnose PE in the setting of equivocal or clinically inconsistent scintigraphic results. However, lung scanning is noninvasive, is inexpensive, is readily available in the acute care setting, and provides high sensitivity, which merits its ongoing use as the primary screening test for PE, in keeping with recent recommendations.	4
17. Hiorns MP, Mayo JR. Spiral computed tomography for acute pulmonary embolism. *Can Assoc Radiol J.* 2002;53(5):258-268.	Review/Other-Dx	N/A	Review data on the use of CTA for PE.	Spiral CT is a good confirmatory test, though will be recognized as the primary imaging modality in the future.	4
18. 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.	Observational-Dx	63 patients	To prospectively evaluate the diagnostic accuracy of V/Q scan vs CTA.	Spiral CT: sensitivity, 92.9%, specificity, 85.7% PPV, 92.9%, NPV, 85.7%. V/Q scans: sensitivity, 57.1%, specificity, 42.9%, PPV, 66.7%, NPV, 33.3%.	3
19. 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.	Observational-Dx	139 patients	To compare prospectively the accuracy of spiral CT with that of V/Q scintigraphy for diagnosing PE.	Sensitivities, specificities, and kappa values with spiral CT and scintigraphy were 87%, 95%, and 0.85 and 65%, 94%, and 0.61, respectively.	3
20. Schoepf UJ, Costello P. CT angiography for diagnosis of pulmonary embolism: state of the art. *Radiology.* 2004;230(2):329-337.	Review/Other-Dx	N/A	Review of MDCT for the evaluation of suspected PE.	MDCT should overcome most of the limitations of CT for the diagnosis of PE, most notably the detection of peripheral emboli.	4

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21. Ritchie G, McGurk S, McCreath C, Graham C, Murchison JT. Prospective evaluation of unsuspected pulmonary embolism on contrast enhanced multidetector CT (MDCT) scanning. *Thorax.* 2007;62(6):536-540.	Review/Other-Dx	487 patients	To quantify the incidence of unsuspected PE in an unselected inpatient population undergoing contrast enhanced MDCT scanning of the thorax and to assess etiological factors in their development.	547 inpatients who had undergone MDCT scanning were identified. Following exclusions 487 remained, 28 of whom (5.7%) had PE. Unsuspected PE was more common with increasing age, occurring in 9.2% (20/218) of all patients over 70 years and 16.7% (11/66) of those over 80 years (P<0.001). 18/28 positive scans (64.3%) were at the segmental or subsegmental level. No other etiological factor was identified which significantly increased the incidence of unsuspected PE. No significant difference was noted between 4-slice and 16-slice MDCT. 9 of the cases of incidental PE (32.1%) were not identified by the original reporting radiologists.	4
22. Anderson DR, Kahn SR, Rodger MA, et al. Computed tomographic pulmonary angiography vs ventilation-perfusion lung scanning in patients with suspected pulmonary embolism: a randomized controlled trial. *JAMA.* 2007;298(23):2743-2753.	Experimental-Dx	1,417 patients	To determine whether the widely adopted new technology of uncertain sensitivity (CTPA) was at least as safe as the standard technology V/Q scanning at not missing the detection of clinically important PE.	701 patients were randomized to CTPA and 716 to V/Q scanning. Of these, 133 patients (19.2%) in the CTPA group vs 101 (14.2%) in the V/Q scan group were diagnosed as having PE in the initial evaluation period (difference, 5.0%; 95% CI, 1.1% to 8.9%) and were treated with anticoagulant therapy. Of those in whom PE was considered excluded, 2 of 561 patients (0.4%) randomized to CTPA vs 6 of 611 patients (1.0%) undergoing V/Q scanning developed VTE in follow-up (difference, -0.6%; 95% CI, -1.6% to 0.3%) including 1 patient with fatal PE in the V/Q group. In this study, CTPA was not inferior to V/Q scanning in ruling out PE. However, significantly more patients were diagnosed with PE using the CTPA approach. Further research is required to determine whether all PE detected by CTPA should be managed with anticoagulant therapy.	1

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23. Wiener RS, Schwartz LM, Woloshin S. When a test is too good: how CT pulmonary angiograms find pulmonary emboli that do not need to be found. *BMJ.* 2013;347:f3368.	Review/Other-Dx	N/A	To determine how CT pulmonary angiograms find pulmonary emboli.	PE is unquestionably an important cause of death, and rapid diagnosis and treatment can be life saving. But the diagnostic zeal and technological advances meant to improve outcomes of patients with PE are double edged swords: some patients are helped, but many are harmed through overdiagnosis and overtreatment. The idea that PE can be overdiagnosed will be new and counterintuitive for some clinicians, but the harms are just as real as those of underdiagnosis.	4
24. American College of Radiology. ACR–NASCI–SIR–SPR Practice Parameter for the Performance and Interpretation of Body Computed Tomography Angiography (CTA). Available at: http://www.acr.org/~/media/ACR/Documents/PGTS/guidelines/Body_CTA.pdf.	Review/Other-Dx	N/A	Guidance document to promote the safe and effective use of diagnostic and therapeutic radiology by describing specific training, skills and techniques.	N/A	4
25. 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.	Observational-Dx	305 consecutive patients	Prospective study to determine the value of V/Q scanning in suspected PE.	Segmental mismatched defects are highly predictive of PE, but caution is needed in "low probability scan" category, where PE incidence may be 25%-40%.	3
26. 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.	Observational-Dx	383 with acute PE, 681 patients which PE was excluded	To test the hypothesis that V/Q in patients with suspected acute PE can be evaluated on the basis of the total number of mismatched vascular defects, irrespective of whether such defects are moderate or large size segmental defects.	Predictive value of the cumulative number of mismatched moderate size segmental defects was nearly the same as that of mismatched large segmental defects. This suggests that the diagnostic value of mismatched moderate size segmental defects is the same as mismatched large segmental defects. Lung scans evaluated on the basis of the number of mismatched vascular defects (moderate and/or large segmental defects) were compared with V/Q scans evaluated on the basis of the number of mismatched segmental equivalents. The number of mismatched vascular defects is as powerful for the assessment of V/Q scans as the number of mismatched segmental equivalents. The number of mismatched vascular defects, however, is easier to interpret, and permits a more objective evaluation.	3

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27. Value of the ventilation/perfusion scan in acute pulmonary embolism. Results of the prospective investigation of pulmonary embolism diagnosis (PIOPED). *JAMA.* 1990;263(20):2753-2759.	Experimental-Dx	933 patients 931 had scintigraphy and 755 had pulmonary angiography	Prospectively study a random sample of patients to determine the value of V/Q scans in evaluation of suspected PE.	Almost all PE patients had abnormal scans of high, intermediate, or low probability, but so did most without PE (sensitivity, 98%; specificity, 10%). Of 116 patients with high-probability scans and definitive angiograms, 102 (88%) had PE, but only a minority with PE had high-probability scans (sensitivity, 41%; specificity, 97%). Of 322 with intermediate-probability scans and definitive angiograms, 105 (33%) had PE. Clinical assessment and V/Q scan established the diagnosis or exclusion of PE only for patients with clear and concordant clinical and V/Q scan findings.	1
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.	Observational-Dx	243 patients; 248 pulmonary angiograms	To examine the role of pulmonary angiography vs noninvasive tests in suspected PE.	No mortality from angiography occurred, and serious complications occurred in 2% of patients. Anticoagulation in 83 patients was associated with bleeding in 25, two of whom died. Data show that V/Q scanning can be used to separate many of the patients suspected of having PE who need anticoagulant treatment from those who do not.	2
29. 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.	Review/Other-Dx	N/A	An evaluation of the criteria used for categorical interpretation of the V/Q scans performed in the PIOPED study.	A single moderate perfusion defect is appropriately categorized as intermediate, rather than as low probability. Extensive matched V/Q abnormalities are appropriate for low probability, provided that the chest radiograph is clear. Two segmental mismatches may not be the optimum threshold for high probability and in some cases should be considered for intermediate probability. However, due to the small number of cases with this finding, no definite, statistically founded recommendation can be made. We suggest that the revised criteria resulting from these adjustments should now be used for the interpretation of V/Q scans.	4

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30. Gottschalk A, Stein PD, Sostman HD, Matta F, Beemath A. Very low probability interpretation of V/Q lung scans in combination with low probability objective clinical assessment reliably excludes pulmonary embolism: data from PIOPED II. *J Nucl Med.* 2007;48(9):1411-1415.	Observational-Dx	Data from PIOPED II	To test the hypothesis that a very low probability interpretation of the V/Q scan has a PPV of <10%.	The PPV of a very low probability interpretation of the V/Q scans was 36/440 patients (8.2%). Among patients with suspected PE who had a low clinical probability objective clinical assessment and a very low probability V/Q scan, the PPV was 8/259 patients (3.1%). Among women ≤40 years of age, the PPV of the very low probability V/Q with a low objective clinical assessment was 1/50 (2%). The very low probability V/Q scan together with a low probability clinical assessment reliably excludes PE.	3
31. Grifoni S, Vanni S, Magazzini S, et al. Association of persistent right ventricular dysfunction at hospital discharge after acute pulmonary embolism with recurrent thromboembolic events. *Arch Intern Med.* 2006;166(19):2151-2156.	Observational-Dx	301 consecutive patients	To evaluate the prognostic value of RVD persistence at hospital discharge with regard to the likelihood of recurrent VTE.	Patients with RVD persistence showed an increased risk of recurrent VTE (14 patients, 9.2% patient-years) compared with those without RVD (15 patients, 3.1% patient-years) or RVD regression (3 patients, 1.1% patient-years) (P=.001). 6/8 deaths related to PE occurred in patients with RVD persistence. At multivariate analysis, adjusted by anticoagulant treatment duration, RVD persistence was an independent predictor of recurrent VTE (hazard ratio, 3.79; P<.001). Persistent RVD at hospital discharge after an acute PE is associated with recurrent VTE.	1
32. Hirohashi T, Yoshinaga K, Sakurai T, et al. [Study of the echocardiographic diagnosis of acute pulmonary thromboembolism and risk factors for venous thromboembolism]. *J Cardiol.* 2006;47(2):63-71.	Observational-Dx	75 patients known with VTE, 101 suspected for VTE, 50 control subjects	To identify the relationship of risk factors for atherosclerosis with VTE and the utility of TTE in acute pulmonary thromboembolism.	The incidence of hyperlipidemia in the VTE group was statistically higher than that in the control group (OR 2.16, 95% CI, 1.43-3.08). Additionally, the incidence of obesity was higher in the VTE and N groups than in the control group (OR was 2.76, 95% CI, 1.67-4.37). The incidence of tricuspid regurgitation, RV dilation, and pulmonary hypertension in acute pulmonary thromboembolism was statistically greater than that in NC group. Hyperlipidemia and obesity may be risk factors for VTE. However, obese patients can manifest similar findings to VTE. Although TTE is not recommended as a diagnostic or screening test in acute pulmonary thromboembolism, it should be used as an ancillary test.	3

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33. 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.	Review/Other-Dx	139 consecutive patients: (74 men, 65 women)	Prospective, multicenter study of V/Q scanning, pulmonary angiography, and venography in consecutive patients with clinically suspected PE and abnormal perfusion scans to determine the right approach to diagnosing PE.	Ventilation scanning increased the probability of PE in patients with large perfusion defects and ventilation mismatch, but a V/Q match was not helpful in ruling out PE. Small perfusion defects with mismatch had neither sufficiently high nor low probability to be of diagnostic value. The observed frequency of proximal vein thrombosis (19% to 51%) and its association with the range of V/Q defects have important implications for management of PE. Pulmonary angiography and venography is required in most patients with perfusion abnormalities because the probability of PE is neither sufficiently high nor low to confirm or exclude PE.	4
34. 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.	Observational-Dx	83 patients	Comparison of V/Q lung scintigraphy and CTA using advanced imaging techniques for both modalities.	SPECT improves sensitivity and specificity over planar V/Q scans. SPECT has better sensitivity than CTPA (97% vs 86%), though decreased specificity (91% vs 98%).	2
35. 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.	Review/Other-Dx	104 patients with suspected PE	To evaluate accuracy of revised PIOPED criteria over original.	Revised criteria are more accurate; even higher with experienced readers.	4
36. 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 Am J Roentgenol.* 1990;154(5):975-981.	Observational-Dx	96 patients	To determine which of the various "probability" schemes (for PE) is best.	The Biello and McNeil criteria showed the most favorable likelihood ratio for predicting an angiogram not showing pulmonary emboli. Analysis of ROC curves yielded the greatest area under the ROC curve for the Biello criteria, but there were no statistically significant differences among the three sets of criteria. The rating scheme proposed by Biello, et al is a good compromise.	3

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37. Kjaergaard J, Schaadt BK, Lund JO, Hassager C. Quantitative measures of right ventricular dysfunction by echocardiography in the diagnosis of acute nonmassive pulmonary embolism. *J Am Soc Echocardiogr.* 2006;19(10):1264-1271.	Observational-Dx	300 consecutive patients	To evaluate the incremental diagnostic information from quantitative measures of RV size, pressure, and function by TTE.	Among measures of RV anatomy, RV pressure estimates, and estimates of global and regional RV function with significant diagnostic information in a logistic regression analysis, the acceleration time of RV outflow less than 89 milliseconds, the ratio of RV to LV diameter greater than 0.78, RV outflow tract fractional shortening less than 35%, and signs of RV strain on ECG had independent, incremental diagnostic information (area under the ROC curve = 0.81). If D-dimer greater than 4.1 mmol/L was included, the area under the curve increased to 0.88. The NPV and PPV if any 2 of 3 factors in the final model were present were 88% and 70%, respectively. TTE is able to identify differential diagnoses and enhance pretest probability of PE significantly. TTE could therefore be considered as an integral part of the initial diagnostic workup of patients suspected of PE, especially if definitive diagnostic imaging has limited availability.	1
38. 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.	Observational-Dx	55 patients with signs of PE: 41 women, 14 men	To compare the diagnostic value of chest US and V/Q scan, vs MRA.	Chest US may be used as a diagnostic adjunct, but cannot exclude PE.	2
39. 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.	Observational-Dx	117 patients with signs of PE: 68 women, 49 men	To evaluate the diagnostic value of chest US for the diagnosis of PE.	Chest US had sensitivity of 94%, specificity 87%, PPV 92%, NPV 91%, accuracy 91%. Spiral CT had sensitivity of 85%, specificity and PPV of 100%, NPV of 83% and an accuracy of 92%. Chest US can improve the diagnosis of PE.	2

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Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
40. 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.	Review/Other-Dx	14: (8 heart failure patients, 2 cardiogenic shock patients, 2 atrial septal defect patients, 1 aortic dissection patient, 1 pneumonia patient)	To determine whether TEE is useful in the evaluation of PE.	TTE showed right heart strain in 8 patients but did not visualize PE in any of the patients. The TEE diagnosis of occult central pulmonary artery thromboembolism changed treatment in all 14 patients. Presence of risk factors for PE and right heart strain on TTE should alert the physician to suspect PE. If and when TEE is performed in patients with acute cardiopulmonary disorders with risk factors for PE and right heart strain, the physician should evaluate the main pulmonary artery and its branches for central pulmonary artery thromboemboli.	4
41. Toosi MS, Merlino JD, Leeper KV. Prognostic value of the shock index along with transthoracic echocardiography in risk stratification of patients with acute pulmonary embolism. *Am J Cardiol.* 2008;101(5):700-705.	Observational-Dx	159 patients	Review echocardiographic features to assess value of the shock index along with TTE in risk stratification of patients with acute PE.	Sensitivity and NPV of diastolic LV impairment (E/A wave <1), RV hypokinesis, RV/LV >1, and end-diastolic RV diameter >3 cm for in-hospital mortality were 100%.	3
42. Kluge A, Luboldt W, Bachmann G. Acute pulmonary embolism to the subsegmental level: diagnostic accuracy of three MRI techniques compared with 16-MDCT. *AJR Am J Roentgenol.* 2006;187(1):W7-14.	Observational-Dx	62 patients	To assess the individual and combined usefulness of MRI techniques in cases of acute PE and to compare the usefulness of these techniques with that of 16-MDCT (reference standard).	Per-patient basis: sensitivities of real-time MRI, MRA, MR perfusion imaging, and the combined protocol were 85%, 77%, 100%, and 100%, respectively. Specificities were 98%, 100%, 91%, and 93%. The kappa values in a comparison of the MR techniques with CT were 0.89, 0.87, 0.86, and 0.9. Per-embolus basis: sensitivities of real-time MRI, MRA, and MR perfusion imaging for lobar PE were 79%, 62%, and 100%, respectively. Sensitivities for segmental PE were 86%, 83%, and 97%, respectively. MR perfusion imaging had a sensitivity of 93% for subsegmental PE. 8/9 incidental findings revealed on CT were also subsequently diagnosed with real-time MRI. The combined MR protocol is both reliable and sensitive in comparison with 16-MDCT in the diagnosis of PE. MR perfusion imaging is sensitive for the detection of PE, whereas real-time MR and MRA are specific.	2

Suspected Pulmonary Embolism
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
43. Kluge A, Mueller C, Strunk J, Lange U, Bachmann G. Experience in 207 combined MRI examinations for acute pulmonary embolism and deep vein thrombosis. *AJR Am J Roentgenol.* 2006;186(6):1686-1696.	Observational-Dx	221 consecutive patients: (119 men, 102 women; mean age 51 years; range, 31-86 years)	To prospectively assess the feasibility and quality of combined MRI exams consisting of thoracic MRI for suspected PE and MR venography for DVT, to assess the diagnostic yield of a combined examination for detecting thromboembolism compared with each component alone, and to retrospectively assess the concordance of duplex US and MR venography.	Among 207 combined examinations, PE was diagnosed in 76 and DVT in 78 examinations. Thirteen patients without PE showed DVT; thus, MR venography detected 17% additional cases of thromboembolism. Agreement with duplex US was good at the upper leg (kappa = 0.87-0.89) but moderate at the pelvis (kappa = 0.59-0.65).	2
44. 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.	Observational-Dx	141 patients 61 men, 80 women (median age of 53 years: range 16-87), 2 reviewers	Prospectively evaluate MRA compared to conventional pulmonary angiography (reference standard) for the diagnosis of PE.	MRA identified 27/35 patients with proven PE (sensitivity 77%, 95% CI, 61-90). Sensitivity of MRA for isolated subsegmental, segmental, and central or lobar PE was 40%, 84%, and 100%, respectively (P<0.01 for isolated subsegmental vs segmental or larger PE). MRA is sensitive and specific for central/lobar and segmental PE, similar to data for CTA, though diagnostic value diminishes more peripherally.	1
45. Pleszewski B, Chartrand-Lefebvre C, Qanadli SD, et al. Gadolinium-enhanced pulmonary magnetic resonance angiography in the diagnosis of acute pulmonary embolism: a prospective study on 48 patients. *Clin Imaging.* 2006;30(3):166-172.	Observational-Dx	48 consecutive patients: 28 women and 20 men, with a mean age 55 years (range, 22-84 years), Catheter angiography (n=15), CTA (n=34), V/Q (n=45)	To prospectively compare the diagnostic value of MRA with a diagnostic strategy, taking into account catheter angiography, CTA, and lung scintigraphy in patients with clinically suspected PE.	Pulmonary MRA had a sensitivity of 82% and a specificity of 100% with slightly less sensitivity than CTA. In the diagnostic algorithm of PE, pulmonary MRA should be considered as an alternative to CTA when iodine contrast injection or radiation is a significant matter.	3
46. Huisman MV, Klok FA. Magnetic resonance imaging for diagnosis of acute pulmonary embolism: not yet a suitable alternative to CT-PA. *J Thromb Haemost.* 2012;10(5):741-742.	Review/Other-Dx	N/A	A commentary on the study to evaluate the performance of current MRI technology in comparison to 64-row CT-PA in diagnosing a PE.	No results stated in abstract.	4

Suspected Pulmonary Embolism
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
47. Sostman HD, Jablonski KA, Woodard PK, et al. Factors in the technical quality of gadolinium enhanced magnetic resonance angiography for pulmonary embolism in PIOPED III. *Int J Cardiovasc Imaging.* 2012;28(2):303-312.	Review/Other-Dx	N/A	To perform a retrospective analysis of the data collected in the PIOPED III study by assessing the relationship to the proportion of examinations deemed "uninterpretable" by central readers to the clinical centers, MR equipment platform and vendors, degree of vascular opacification in different orders of pulmonary arteries; type, frequency and severity of image artifacts; patient co-morbidities, symptoms and signs; and reader characteristics.	Centers, MR equipment vendor and platform, degree of vascular opacification, and motion artifacts influenced the likelihood of central reader determinations that images were "uninterpretable". Neither the reader nor patient characteristics (age, body mass index, respiratory rate, heart rate) correlated with the likelihood of determining examinations "uninterpretable". Vascular opacification and motion artifact are the principal factors influencing MRA interpretability. Some centers obtain better images more consistently, but the reasons for differences between centers are unclear.	4
48. Stein PD, Chenevert TL, Fowler SE, et al. Gadolinium-enhanced magnetic resonance angiography for pulmonary embolism: a multicenter prospective study (PIOPED III). *Ann Intern Med.* 2010;152(7):434-443, W142-433.	Experimental-Dx	371 adults	To investigate performance characteristics of MRA, with or without MR venography, for diagnosing PE.	MRA, averaged across centers, was technically inadequate in 25% of patients (92 of 371). The proportion of technically inadequate images ranged from 11% to 52% at various centers. Including patients with technically inadequate images, MRA identified 57% (59 of 104) with PE. Technically adequate MRA had a sensitivity of 78% and a specificity of 99%. Technically adequate MRA and venography had a sensitivity of 92% and a specificity of 96%, but 52% of patients (194 of 370) had technically inadequate results. LIMITATION: A high proportion of patients with suspected embolism was not eligible or declined to participate.	2

Suspected Pulmonary Embolism
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
49. Schiebler ML, Nagle SK, Francois CJ, et al. Effectiveness of MR angiography for the primary diagnosis of acute pulmonary embolism: clinical outcomes at 3 months and 1 year. *J Magn Reson Imaging.* 2013;38(4):914-925.	Observational-Dx	190 patients	To determine the effectiveness of MRA for PE in symptomatic patients.	There were 190 MRA for PE exams performed with 97.4% (185/190) of diagnostic quality. There were 148 patients (120 F: 28 M) that had both a diagnostic MRA for PE exam and 1 complete year of EMR follow-up. There were 167 patients (137 F: 30 M) with ≥3 months follow-up. We found 83% (139/167) and 81% (120/148) MRA for PE exams negative for PE at 3 months and 1 year, respectively. Positive exams for PE were seen in 14% (23/167). During the 1-year follow-up period, 5 patients (false negative) were diagnosed with DVT (5/148 = 3.4%), and 1 of these patients also experienced a non-life-threatening PE. The NPV for MRA for PE was 97% (92–99; 95% CI) at 3 months and 96% (90–98; 95% CI) with 1 year of follow-up.	3
50. 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.	Observational-Dx	86 patients: x-ray angiography (n=34), V/Q scans and concurrent clinical impression (n=30)	To assess the accuracy and potential of MR in the evaluation of suspected PE. Blinded, prospective interpretations of multiphasic, cardiac-gated spin-echo MRI were compared with retrospective chart review.	Subgroup with angiographic proof - MRI had sensitivity of 90%, specificity of 77%, PPV of 86%, and NPV of 83%. In 21 patients with intermediate probability of PE on V/Q scans and angiograms, MRI enabled diagnosis of PE in 12/12 patients (sensitivity 100%) and absence of PE in 7/9 patients (specificity 78%). MRI reliably depicts large and medium-size pulmonary emboli, regardless of infiltrates or effusion.	2
51. 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.	Observational-Dx	39 consecutive patients	Prospective study to evaluate the feasibility and diagnostic value of real-time MRI (True fast imaging with steady-state precession) vs MRA for PE.	Compared with MRA, the sensitivities and specificities of real time sequences for PE were 93% and 100% (per examination), 96% and 100% (lobar artery PE), and 97% and 100% (segmental artery PE), respectively. Compared with scintigraphy, the sensitivity and specificity of real time-MRI were 83% and 100%, respectively. The MRA reached 100% sensitivity and specificity in this subgroup. Diagnosis of PE by real-time MRI is feasible and offers the advantage of rapid imaging times, decreasing artifact from respiratory motion common in MRA.	3

Suspected Pulmonary Embolism
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
52. Venkatesh AK, Kline JA, Courtney DM, et al. Evaluation of pulmonary embolism in the emergency department and consistency with a national quality measure: quantifying the opportunity for improvement. *Arch Intern Med.* 2012;172(13):1028-1032.	Observational-Dx	5940 patients	To perform a prospective, multicenter observational study of ED patients evaluated for PE to quantify the prevalence of avoidable imaging in ED patients with suspected PE.	Imaging was performed in 2238 low-risk patients (38%), of whom 811 had no D-dimer testing, and 394 had negative D-dimer test results. Imaging was avoidable, according to the NQF measure, in 1205 patients (32%; 95% CI, 31%-34%). Avoidable imaging owing to not ordering a D-dimer test was associated with age (OR, 1.15 per decade; 95% CI, 1.10-1.21). Avoidable imaging owing to imaging after a negative D-dimer test result was associated with inactive malignant disease (OR, 1.66; 95% CI, 1.11-2.49).	3
53. Lucassen W, Geersing GJ, Erkens PM, et al. Clinical decision rules for excluding pulmonary embolism: a meta-analysis. *Ann Intern Med.* 2011;155(7):448-460.	Meta-analysis	52 studies, 55,268 patients	To compare the test characteristics of gestalt (a physician's unstructured estimate) and clinical decision rules for evaluating adults with suspected PE and assess the failure rate of gestalt and rules when used in combination with d-dimer testing.	Clinical decision rules and gestalt can safely exclude PE when combined with sensitive d-dimer testing. The authors recommend standardized rules because gestalt has lower specificity, but the choice of a particular rule and d-dimer test depend on both prevalence and setting.	M
54. Kelley MA, Carson JL, Palevsky HI, Schwartz JS. Diagnosing pulmonary embolism: new facts and strategies. *Ann Intern Med.* 1991;114(4):300-306.	Review/Other-Dx	N/A	To provide a clinical approach to the diagnosis of PE.	A normal lung scan or pulmonary angiogram rules out the diagnosis of clinically important PE with at least 95% certainty. Lung scan interpretations indicating high or low probability have approximately a 15% error in diagnosing or ruling out PE. The accuracy of either scan result improves when the clinical suspicion of PE matches the lung scan result. Serial impedance plethysmography of the lower extremities may exclude thromboembolism with 95% certainty in patients without high-probability lung scan results or cardiopulmonary disease.	4

Suspected Pulmonary Embolism
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
55. Raja AS, Greenberg JO, Qaseem A, Denberg TD, Fitterman N, Schuur JD. Evaluation of Patients With Suspected Acute Pulmonary Embolism: Best Practice Advice From the Clinical Guidelines Committee of the American College of Physicians. *Ann Intern Med.* 2015;163(9):701-711.	Review/Other-Dx	N/A	To present an evidence-based and high-value diagnostic strategy for the diagnosis of PE. Its goal is to help clinicians understand the potential hurdles to such an approach and outline performance improvement strategies to overcome them.	Clinicians should use validated clinical prediction rules to estimate pretest probability in patients in whom acute PE is being considered. Clinicians should not obtain d-dimer measurements or imaging studies in patients with a low pretest probability of PE and who meet all Pulmonary Embolism Rule-Out Criteria. Clinicians should obtain a high-sensitivity d-dimer measurement as the initial diagnostic test in patients who have an intermediate pretest probability of PE or in patients with low pretest probability of PE who do not meet all Pulmonary Embolism Rule-Out Criteria. Clinicians should not use imaging studies as the initial test in patients who have a low or intermediate pretest probability of PE. Clinicians should use age-adjusted d-dimer thresholds (age x 10 ng/mL rather than a generic 500 ng/mL) in patients older than 50 years to determine whether imaging is warranted. Clinicians should not obtain any imaging studies in patients with a d-dimer level below the age-adjusted cutoff. Clinicians should obtain imaging with CTPA in patients with high pretest probability of PE. Clinicians should reserve ventilation-perfusion scans for patients who have a contraindication to CTPA or if CTPA is not available. Clinicians should not obtain a d-dimer measurement in patients with a high pretest probability of PE.	4

Suspected Pulmonary Embolism
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
56. Perrier A, Roy PM, Sanchez O, et al. Multidetector-row computed tomography in suspected pulmonary embolism. *N Engl J Med.* 2005;352(17):1760-1768.	Observational-Dx	756 consecutive patients	To evaluate whether the use of D-dimer measurement and MDCT, without lower-limb US, might safely rule out PE.	PE was detected in 194 of the 756 patients (26%). Among the 82 patients with a high clinical probability of PE, MDCT showed PE in 78, and 1 patient had proximal DVT and a CT scan that was negative for PE. Of the 674 patients without a high probability of PE, 232 (34%) had a negative D-dimer assay and an uneventful follow-up; CT showed PE in 109 patients. CT and US were negative in 318 patients, of whom 3 had a definite thromboembolic event and 2 died of possible PE during follow-up (3-month risk of thromboembolism, 1.7%; 95% CI, 0.7 to 3.9). 2 patients had proximal DVT and a negative CT scan (risk, 0.6%; 95% CI, 0.2 to 2.2). The overall 3-month risk of thromboembolism in patients without PE would have been 1.5% (95% CI, 0.8 to 3.0) if the D-dimer assay and MDCT had been the only tests used to rule out PE and US had not been performed.	3
57. Warren DJ, Matthews S. Pulmonary embolism: investigation of the clinically assessed intermediate risk subgroup. *Br J Radiol.* 2012;85(1009):37-43.	Observational-Dx	2531 patients	To identify whether use of a dichotomized scoring system altered the overall NPV in patients referred for CTPA assessment of suspected PE.	2531 patients were investigated for suspected acute PE; acute thromboemboli were confirmed in 22.7%. The overall NPV for negative d-Dimer and intermediate pre-test probability was 98.9% [95% CI, 96.3%–99.7%]; with retrospective dichotomization, the NPV for the PE unlikely group was 99.0% (95% CI, 94.8%–99.8%). Implementation of dichotomized scoring, excluding PE unlikely with negative d-Dimer cases from further imaging, would have yielded a 4% reduction in CTPA referral pathway imaging at our institution.	3
58. Stein PD, Fowler SE, Goodman LR, et al. Multidetector computed tomography for acute pulmonary embolism. *N Engl J Med.* 2006;354(22):2317-2327.	Observational-Dx	824 patients	A multicenter investigation to determine the accuracy of CTA alone vs CTA + CT with venous-phase.	In patients with suspected PE, CTA + CT with venous-phase has increased sensitivity for thrombo-embolic disease compared with CTA alone, with similar specificity.	2

Suspected Pulmonary Embolism
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
59. 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 retrolective-prolective cohort study focusing on total diagnostic yield. *Eur Radiol.* 1998;8(1):90-96.	Observational-Dx	123 patients	To compare the diagnostic value of helical CT vs that of V/Q scintigraphy.	Sensitivity and specificity were 49% and 74% for the V/Q strategy and 75% and 90% for the CT strategy, respectively (P=0.01).	3
60. Hirai LK, Takahashi JM, Yoon HC. A prospective evaluation of a quantitative D-dimer assay in the evaluation of acute pulmonary embolism. *J Vasc Interv Radiol.* 2007;18(8):970-974.	Observational-Dx	361 consecutive patients	A prospective study designed to determine if a screening quantitative serum D-dimer measurement of 1.0 microg/mL or less precludes pulmonary CTA in patients with possible acute PE.	There were 310 patients who had negative pulmonary CTA results and 50 patients who had indeterminate CTA results. Only one patient had positive pulmonary CTA findings. Minimum 3-month follow-up information was available for 349 patients, none of whom reported subsequent PE, including those with indeterminate pulmonary CTA results. The use of a screening D-dimer measurement of 1.0 microg/mL or less precludes pulmonary CTA in patients with possible acute PE. The use of this quantitative D-dimer assay would decrease radiation exposure, contrast medium toxicity, cost, and time for patients seen in the emergency medicine department.	1
61. Ghuysen A, Ghaye B, Willems V, et al. Computed tomographic pulmonary angiography and prognostic significance in patients with acute pulmonary embolism. *Thorax.* 2005;60(11):956-961.	Observational-Dx	82 patients divided into: 21 pulmonary infarction, 29 prominent dyspnea, 32 circulatory failure	To determine the estimation of short-term prognosis by CTPA as a first line test in the acute PE diagnostic algorithm.	The mortality rate was 0%, 13.8% and 25% in the three groups, respectively. Neither the pulmonary obstruction index nor the pulmonary artery pressure could predict patient outcome. Analysis from logistic regression aimed at testing for mortality prediction revealed true reclassification of 89% using radiological variables. The results suggest that CTPA quantification of RV strain is an accurate predictor of in-hospital death related to PE.	2
62. He H, Stein MW, Zalta B, Haramati LB. Computed tomography evaluation of right heart dysfunction in patients with acute pulmonary embolism. *J Comput Assist Tomogr.* 2006;30(2):262-266.	Observational-Dx	74 consecutive patients: 47 women, 27 men	To evaluate the role of qualitative assessment of right heart dysfunction on MDCT in patients with acute PE.	The sensitivity and specificity of CT in demonstrating right heart dysfunction were 81% and 47%, respectively. Echocardiography had a sensitivity of 56% and a specificity of 42% in demonstrating right heart dysfunction.	3

Suspected Pulmonary Embolism
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
63. Lu MT, Cai T, Ersoy H, et al. Interval increase in right-left ventricular diameter ratios at CT as a predictor of 30-day mortality after acute pulmonary embolism: initial experience. *Radiology.* 2008;246(1):281-287.	Observational-Dx	50 patients; 19 men, 31 women	To retrospectively determine if the interval increase of RV/LV diameter ratio from negative prior to positive current CT examination findings for PE is more accurate for predicting 30-day mortality than positive CT ratio alone, by using patient 30-day mortality as reference standard.	For PE-related mortality : Sensitivity 0.78., Specificity 0.93., PPV 0.70., NPV 0.95. For all-cause mortality: 0.75, 0.89, 0.69, and 0.92. At target sensitivity (0.75), specificity of interval increase was significantly higher than from positive scans alone for both PE-related (0.93 vs 0.59, P=.001) and all-cause (0.89 vs 0.58, P=.05) mortality. The interval increase in four-chamber RV/LV diameter ratio is more accurate than the diameter ratio of the CT examination with positive findings for PE alone for mortality prediction after acute PE.	3
64. Nural MS, Elmali M, Findik S, et al. Computed tomographic pulmonary angiography in the assessment of severity of acute pulmonary embolism and right ventricular dysfunction. *Acta Radiol.* 2009;50(6):629-637.	Observational-Dx	85 patients: 20 hemo dynamically unstable PE, 33 stable PE, 32 no PE	To identify the role of CTPA in the assessment of the severity of acute PE and RVD.	With ROC analysis, the CTPA obstruction score and RV/LV short-axis ratio threshold values for the hemodynamically unstable PE patients were calculated to be 48% (95% sensitivity, 76% specificity) and 1.1 (85% sensitivity, 76% specificity), respectively. Three patients in the hemodynamically unstable PE group died within the first 24 hours. Logistic regression methods revealed only the RV diameter as a significant predictor of death (OR 1.24; 95% CI, 1.04-1.48; P=0.01). This study found that the parameters useful for distinguishing hemodynamically unstable PE and hemodynamically stable PE included CTPA obstruction score, RV and superior vena cava diameters, RV/LV short-axis ratio, interventricular septum shape, and reflux into the IVC. RV dilatation may be a significant predictor for mortality.	3

Suspected Pulmonary Embolism
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
65. van der Meer RW, Pattynama PM, van Strijen MJ, et al. Right ventricular dysfunction and pulmonary obstruction index at helical CT: prediction of clinical outcome during 3-month follow-up in patients with acute pulmonary embolism. *Radiology.* 2005;235(3):798-803.	Observational-Dx	120 consecutive patients	To retrospectively quantify RVD and the pulmonary artery obstruction index at helical CT on the basis of various criteria proposed in the literature and to assess the predictive value of these CT parameters for mortality within 3 months after the initial diagnosis of PE.	CT signs of RVD (RV/LV ratio, >1.0) were seen in 69 patients (57.5%). During follow-up, 7 patients died of PE. Both the RV/LV ratio and the obstruction index were shown to be significant risk factors for mortality within 3 months (P=.04 and .01, respectively). No such relationship was found for the ratio of the pulmonary artery to ascending aorta diameters (P=.66) or for the shape of the interventricular septum (P=.20). The PPV for PE-related mortality with an RV/LV ratio greater than 1.0 was 10.1% (95% CI, 2.9%, 17.4%). NPV for an uneventful outcome with an RV/LV ratio of 1.0 or less was 100% (95% CI, 94.3%, 100%). There was a 11.2-fold increased risk of dying of PE for patients with an obstruction index of 40% or higher (95% CI, 1.3, 93.6). Markers of RVD and pulmonary vascular obstruction, assessed with helical CT at baseline, help predict mortality during follow-up.	3
66. Haidary A, Bis K, Vrachliotis T, Kosuri R, Balasubramaniam M. Enhancement performance of a 64-slice triple rule-out protocol vs 16-slice and 10-slice multidetector CT-angiography protocols for evaluation of aortic and pulmonary vasculature. *J Comput Assist Tomogr.* 2007;31(6):917-923.	Observational-Dx	50 patients	To compare the enhancement of the pulmonary and aortic vasculature between a biphasic injection 64-slice, a single-phase injection 16-slice, and a single-phase injection 10-slice MDCTA protocols.	Individual mean pulmonary arterial and aortic attenuation values were statistically significantly less than 250 HU for the 16- and 10-slice protocols and statistically significantly more than 250 HU for the 64-slice protocols (P<0.05). Mean pooled pulmonary attenuation values were more than 250 HU in 18% (9/50) of the 16-slice and in 93% (39/42) of the 64-slice protocols. Mean pooled aortic attenuation values were more than 250 HU in 18.4% (9/49) of the 10- and 16-slice and in 100%. The triple rule-out 64-slice biphasic injection breath hold CTA protocol provides significantly higher attenuation of aortic and pulmonary vasculature compared with our current 10- and 16-slice protocols.	3

Suspected Pulmonary Embolism
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
67. Johnson TR, Nikolaou K, Wintersperger BJ, et al. ECG-gated 64-MDCT angiography in the differential diagnosis of acute chest pain. *AJR Am J Roentgenol.* 2007;188(1):76-82.	Observational-Dx	55 patients	To assess the diagnostic value of an ECG-gated 64-MDCTA protocol for simultaneous assessment of the pulmonary arteries, coronary arteries, and aorta within a single breath-hold. Findings on CTA were compared with those on X-ray coronary angiography in 20 patients.	Cause of chest pain correctly diagnosed in 37/55 patients. The protocol proved helpful in the differential diagnosis of acute chest pain.	1
68. Schertler T, Frauenfelder T, Stolzmann P, et al. Triple rule-out CT in patients with suspicion of acute pulmonary embolism: findings and accuracy. *Acad Radiol.* 2009;16(6):708-717.	Observational-Dx	125 patients	To prospectively investigate the diagnostic value of triple rule-out CT in patients suspected of having acute PE.	Sensitivity, specificity, and PPV and NPV of triple rule-out CT for cardiovascular disease were 100% (95% CI, 90%-100%), 98% (95% CI, 94%-100%), 95% (95% CI, 82%-99%), and 100% (95% CI, 97%-100%, respectively). Triple rule-out CT is feasible in patients with suspicion of PE, reveals a wide range of vascular and nonvascular chest disease, and offers an excellent overall diagnostic performance.	1
69. Ghaye B. Peripheral pulmonary embolism on multidetector CT pulmonary angiography. *JBR-BTR.* 2007;90(2):100-108.	Review/Other-Dx	N/A	To review the indications for treatment of isolated subsegmental PE.	Since its introduction in 1992, the sensitivity and specificity of CTPA increased due to reduced collimation and faster rotation time. The main limitation of single-detector row CTPA was diagnosis of PE at the subsegmental level, similar to other diagnostic techniques, such as pulmonary angiography, V/Q lung scan and MR. The advent of multi-detector row CT technology has increased the analysability of pulmonary vessels distal to the segmental level. Multi-detector row CTPA detects more subsegmental PE than single-detector row CTPA. The incidence of isolated subsegmental PE is between 5-15%, depending of the population investigated. Currently there is no straightforward admitted guidelines for treatment of subsegmental PE	4

Suspected Pulmonary Embolism
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
70. Stein PD, Henry JW. Prevalence of acute pulmonary embolism in central and subsegmental pulmonary arteries and relation to probability interpretation of ventilation/perfusion lung scans. *Chest.* 1997;111(5):1246-1248.	Review/Other-Dx	375 patients	To determine the prevalence of acute PE limited to subsegmental pulmonary arteries.	Among all patients with PE, 6% (95% CI, 4 to 9%) had PE limited to subsegmental branches of the pulmonary artery. Patients with high-probability V/Q scans had PE limited to subsegmental branches in only 1% (95% CI, 0 to 4%). Among patients with low-probability V/Q lung scans, 17% (95% CI, 8 to 29%) had PE limited to the subsegmental branches. Patients with low-probability V/Q scans and no prior cardiopulmonary disease had PE limited to the subsegmental pulmonary arteries in 30% (95% CI, 13 to 53%), whereas patients with low-probability V/Q scans who had prior cardiopulmonary disease had PE limited to subsegmental pulmonary arteries in 8% (95% CI, 2 to 22%) ($p < 0.05$).	4
71. Carrier M, Righini M, Wells PS, et al. Subsegmental pulmonary embolism diagnosed by computed tomography: incidence and clinical implications. A systematic review and meta-analysis of the management outcome studies. *J Thromb Haemost.* 2010;8(8):1716-1722.	Meta-analysis	22 articles	To summarize the proportion of subsegmental PE diagnosed with single- and multiple-detectors CTPA and assess the safety of diagnostic strategies based on single- or multiple-detectors CTPA to exclude PE.	The rate of subsegmental PE diagnosis was 4.7% [95% CI: 2.5-7.6] and 9.4 (95% CI: 5.5-14.2) in patients that underwent a single- and multiple-detectors CTPA, respectively. The 3-month thromboembolic risks in patients with suspected PE and who were left untreated based on a diagnostic algorithm including a negative CTPA was 0.9% (95% CI: 0.4-1.4) and 1.1% (95% CI: 0.7-1.4) for single- and multiple-detectors CTPA, respectively.	M
72. 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 Am J Roentgenol.* 1993;161(6):1289-1292.	Review/Other-Dx	223 consecutive patients	To examine the usefulness and cost-effectiveness of compression US in evaluation of PE.	In 75 cases, the results of V/Q lung scanning indicated an indeterminate probability of PE. Evidence of thrombosis was seen on sonograms in 11 of these 75. In the remaining 64, 17 underwent pulmonary arteriography and four (24%) had PE. Findings on lung scans indicated a low probability of PE in 70/223 patients. Evidence of thrombosis was seen on sonograms in 11 of these 70. Five of the remaining 59 underwent pulmonary arteriography and one (20%) had PE.	4
73. 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.	Observational-Dx	51 patients	To determine whether compression US is useful to detect DVT.	US had sensitivity of 89%, specificity of 100%; routine use for PE not established.	3

Suspected Pulmonary Embolism
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
74. 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.	Observational-Dx	36 patients	To examine the usefulness of lower limb Doppler venous compression US and serum D-dimer measurements in diagnosis of PE in patients with intermediate probability lung scans.	Pulmonary angiography demonstrated PE in 15 (41%) of 36 patients. US had sensitivity of 13%, specificity 100%. Five (14%) of the 36 patients had normal (<220 micrograms/L) D-dimer levels; none of the five had PE. Sensitivity and specificity of D-dimer values were 100% and 16%, respectively, with NPV of 100%.	2
75. Smith LL, Iber C, Sirr S. Pulmonary embolism: confirmation with venous duplex US as adjunct to lung scanning. *Radiology.* 1994;191(1):143-147.	Review/Other-Dx	285 lung scan and duplex US exams in 267 consecutive patients: (151 men and 134 women aged 17-98 years)	Retrospective review to assess the prevalence of DVT with venous duplex US in patients who underwent radionuclide lung scanning for evaluation of clinically suspected PE and to assess the clinical usefulness of this type of US in the selection of patients for anticoagulant therapy.	Thrombotic disease was confirmed with US in 7 (21%) of 33 patients with normal lung scans and in 64 (25%) of 252 patients with abnormal lung scans. Duplex US is a useful adjunct to lung scanning.	4
76. 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.	Observational-Dx	776 patients	To assess the usefulness of Doppler US to detect acute VTE both above and below the knee.	Above the knee, the sensitivity was 94% and the specificity, 90%. Below the knee, the sensitivity was 91% and the specificity was 84%.	3
77. American College of Radiology. ACR Appropriateness Criteria®: Suspected Lower Extremity Deep Vein Thrombosis. Available at: https://acsearch.acr.org/docs/69416/Narrative/. Accessed March 19, 2015.	Review/Other-Dx	N/A	Evidence-based guidelines to assist referring physicians and other providers in making the most appropriate imaging or treatment decision for a specific clinical condition.	N/A	4
78. Leung AN, Bull TM, Jaeschke R, et al. American Thoracic Society documents: an official American Thoracic Society/Society of Thoracic Radiology Clinical Practice Guideline--Evaluation of Suspected Pulmonary Embolism in Pregnancy. *Radiology.* 2012;262(2):635-646.	Review/Other-Dx	N/A	To provide guidance on suspected PE in pregnancy, a multidisciplinary panel of major medical stakeholders was convened to develop evidence-based guidelines for evaluation of suspected PE in pregnancy using the Grades of Recommendation, Assessment, Development, and Evaluation (GRADE) system. In formulation of the recommended diagnostic algorithm, the important outcomes were defined to be diagnostic accuracy and diagnostic yield; the panel placed a high value on minimizing cumulative radiation dose when determining the recommended sequence of tests.	Overall, the quality of the underlying evidence for all recommendations was rated as very low or low with some of the evidence considered for recommendations extrapolated from studies of the general population. Despite the low quality evidence, strong recommendations were made for 3 specific scenarios: performance of chest radiography as the first radiation-associated procedure; use of lung scintigraphy as the preferred test in the setting of a normal chest radiograph; and performance of CTPA rather than digital subtraction angiography in a pregnant woman with a nondiagnostic V/Q result.	4

Suspected Pulmonary Embolism
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
79. Revel MP, Cohen S, Sanchez O, et al. Pulmonary embolism during pregnancy: diagnosis with lung scintigraphy or CT angiography? *Radiology.* 2011;258(2):590-598.	Observational-Dx	94 lung scintigraphic exams and 46 CTA exams performed in 128 women	To retrospectively evaluate the rate of positive, negative and indeterminate results and the agreement between initial and expert readings for lung scintigraphy and CTA performed in patients suspected of having PE during pregnancy.	The rates of positive findings (7/43 patients [16%] with CTA and 10/91 patients [11%] with scintigraphy, P=.36), negative findings (28/43 patients [65%] with CTA and 64/91 patients [70%] with scintigraphy, P=.54), and indeterminate findings (8/43 patients [19%] with CTA and 17/91 patients [19%] with scintigraphy, P=.99) were similar for CTA and lung scintigraphy. There were four discrepancies between initial and expert readings for CTA ($\kappa = 0.84$; CI, 0.68, 0.99) and 14 for lung scintigraphy ($\kappa = 0.75$; 95% CI, 0.63, 0.87). Opacification was classified as good for only 23/46 CTA examinations (50%). Attenuation values were significantly different among the groups with good, suboptimal, or poor opacification. Alternative diagnoses unsuspected at chest radiography were demonstrated at CTA in 5/43 patients (12%). The mean maternal radiation dose was 0.9 mSv for lung scintigraphy and 7.3 mSv for CTA. Lung scintigraphy and CTA have comparable performances for PE diagnosis during pregnancy. Interobserver agreement is better for CTA, which also enables alternative diagnosis of unsuspected disease but delivers higher maternal radiation dose.	3
80. Shahir K, Goodman LR, Tali A, Thorsen KM, Hellman RS. Pulmonary embolism in pregnancy: CT pulmonary angiography versus perfusion scanning. *AJR Am J Roentgenol.* 2010;195(3):W214-220.	Observational-Dx	199 pregnant patients had 106 CTPA examinations and 99 perfusion scans	To retrospectively evaluate the equivalence of CTPA and perfusion scanning in terms of diagnostic quality and NPV in the imaging of PE in pregnancy.	CTPA and perfusion scanning have equivalent clinical NPV (99% for CTPA; 100% for perfusion scanning) and image quality in the care of pregnant patients. The choice of study should therefore be based on other considerations, such as radiation concern, radiographic results, alternative diagnosis, and equipment availability. Reducing the amount of radiation to the maternal breast favors use of perfusion scanning when the radiographic findings are normal and there is no clinical suspicion of an alternative diagnosis.	2

Suspected Pulmonary Embolism
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
81. Chen MM, Coakley FV, Kaimal A, Laros RK, Jr. Guidelines for computed tomography and magnetic resonance imaging use during pregnancy and lactation. *Obstet Gynecol.* 2008;112(2 Pt 1):333-340.	Review/Other-Dx	N/A	Evidence-based guidelines for the use of CT, MRI, and contrast media during pregnancy and lactation.	CT and MRI can be useful tools in pregnant and lactating women when used appropriately. Patients should know the risks and benefits involved.	4
82. American College of Radiology. ACR-SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radiation. Available at: http://www.acr.org/~/media/ACR/Documents/PGTS/guidelines/Pregnant_Patients.pdf.	Review/Other-Dx	N/A	Guidance document to promote the safe and effective use of diagnostic and therapeutic radiology by describing specific training, skills and techniques.	N/A	4
83. American College of Radiology. ACR-ACOG-AIUM-SRU Practice Paramater for the Performance of Obstetrical Ultrasound. Available at: http://www.acr.org/~/media/ACR/Documents/PGTS/guidelines/US_Obstetrical.pdf.	Review/Other-Dx	N/A	Guidance document to promote the safe and effective use of diagnostic and therapeutic radiology by describing specific training, skills and techniques.	N/A	4
84. Kanal E, Barkovich AJ, Bell C, et al. ACR guidance document on MR safe practices: 2013. *J Magn Reson Imaging.* 2013;37(3):501-530.	Review/Other-Dx	N/A	Guidance document on MR safety practices to help guide MR practitioners regarding MR safety issues and provide a basis for them to develop and implement their own MR policies and practices.	N/A	4
85. American College of Radiology. *Manual on Contrast Media*. Available at: http://www.acr.org/Quality-Safety/Resources/Contrast-Manual.	Review/Other-Dx	N/A	Guidance document on contrast media to assist radiologists in recognizing and managing risks associated with the use of contrast media.	N/A	4

Suspected Pulmonary Embolism
EVIDENCE TABLE

Reference	Study Type	Patients/ Events	Study Objective (Purpose of Study)	Study Results	Study Quality
86. Cahill AG, Stout MJ, Macones GA, Bhalla S. Diagnosing pulmonary embolism in pregnancy using computed-tomographic angiography or ventilation-perfusion. *Obstet Gynecol.* 2009;114(1):124-129.	Observational-Dx	304 total women (CTA in 108 and V/Q in 196)	Retrospective cohort study to estimate the rate of nondiagnosis for patients who initially undergo CTA compared with those who undergo V/Q to diagnose PE in pregnancy.	Women who underwent CTA tended to have a slightly higher rate of nondiagnostic study (17.0% compared with 13.2%, P=.38). Examining the subgroup of women with a normal chest radiograph, CTA was much more likely to yield a nondiagnostic result than V/Q, even after adjusting for relevant confounding effects (30.0% compared with 5.6%, adjusted OR 5.4, 95% CI, 1.4-20.1, P<.01). Pregnant or postpartum women with clinical suspicion of a PE and a normal chest radiograph are more likely to have a diagnostic study from a V/Q compared with a CTA. Evidence supports CTA as a better initial test than V/Q in patients with an abnormal chest radiograph.	2

Evidence Table Key

Study Quality Category Definitions

- *Category 1* The study is well-designed and accounts for common biases.
- *Category 2* The study is moderately well-designed and accounts for most common biases.
- *Category 3* There are important study design limitations.
- *Category 4* The study is not useful as primary evidence. The article may not be a clinical study or the study design is invalid, or conclusions are based on expert consensus. For example:
  a) the study does not meet the criteria for or is not a hypothesis-based clinical study (e.g., a book chapter or case report or case series description);
  b) the study may synthesize and draw conclusions about several studies such as a literature review article or book chapter but is not primary evidence;
  c) the study is an expert opinion or consensus document.
- M = Meta-analysis

Dx = Diagnostic

Tx = Treatment

Abbreviations Key

CI = Confidence interval

CT = Computed tomography

CTA = Computed tomography angiography

CTPA = Computed tomographic pulmonary angiography

DVT = Deep venous thrombosis

ECG = Electrocardiogram

LV = Left ventricular

MDCT = Multidetector computed tomography

MDCTA= Multidetector computed tomography angiography

MRA = Magnetic resonance angiography

MRI = Magnetic resonance imaging

NPV = Negative predictive value

OR = Odds ratio

PE = Pulmonary embolism

PPV = Positive predictive value

ROC = Receiver-operator characteristic

RV = Right ventricular

RVD = Right venticular dysfunction

SPECT = Single-photon emission tomography

TTE = Transthoracic echocardiography

US = Ultrasound

V/Q = Ventilation-perfusion lung scan

VTE = Venous thromboembolism