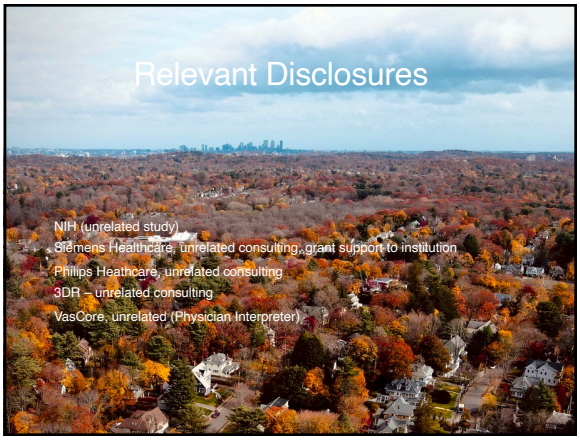
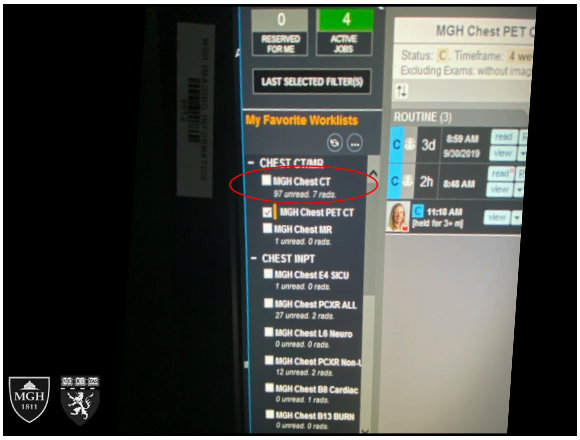
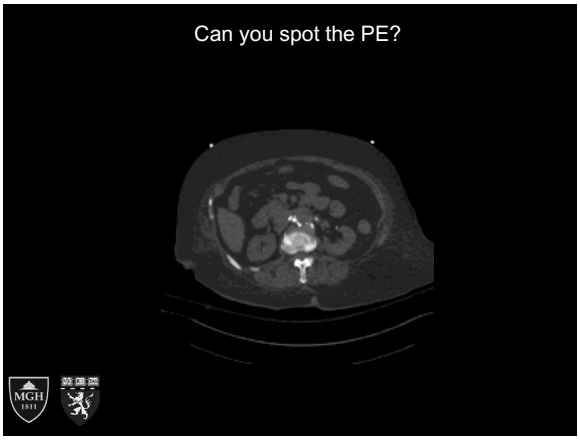
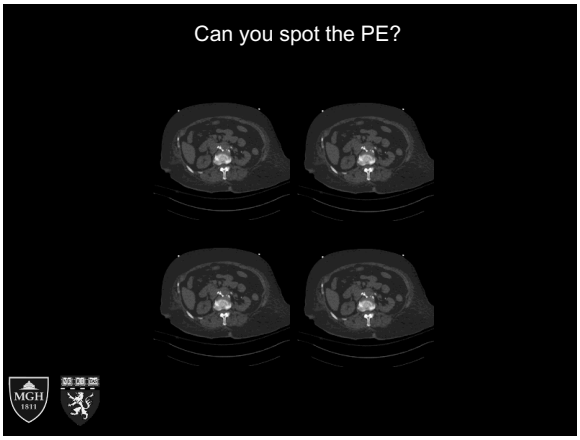

CTA Is All You Need To Manage Acute Submassive PE
VEITH 2024
SESSION 17: MANAGEMENT OF PULMONARY EMBOLISM: THE ULTIMATE TEAM APPROACH – PART 1
Moderator: Michael R. Jaff, DO
7:35 AM - 7:45 AM
Brian Ghoshhajra, MD, MBA
Academic Chief, Division of Cardiovascular Imaging
Associate Chair, Operations Analytics, Radiology
Associate Professor of Radiology, Harvard Medical School
Massachusetts General Hospital, Boston, MA

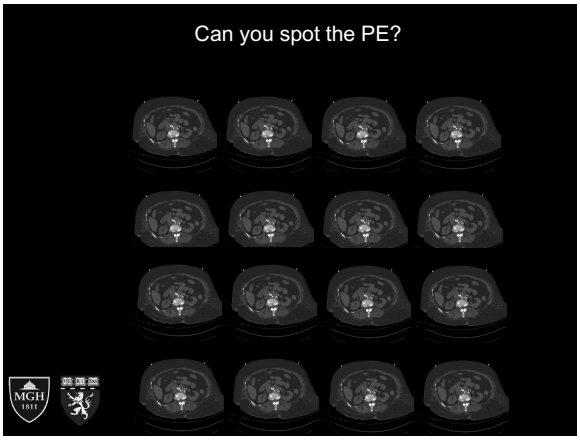

Relevant Disclosures
NIH (unrelated study)
Siemens Healthcare, unrelated consulting, grant support to institution
Philips Heathcare, unrelated consulting
3DR – unrelated consulting
VasCore, unrelated (Physician Interpreter)

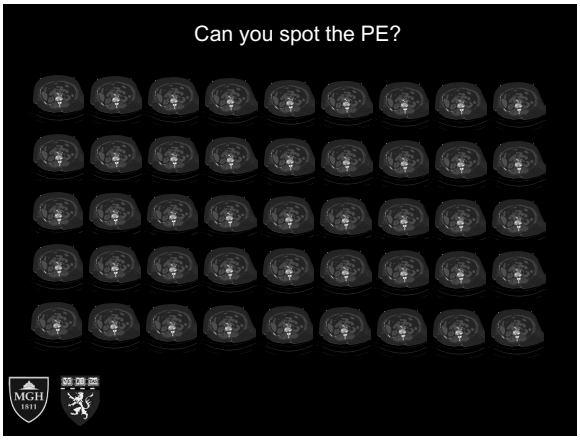

RESERVED FOR ME
ACTIVE JOBS
LAST SELECTED FILTER(S)
My Favorite Worklists
CHEST CT/MR
MGH Chest CT
MGH Chest PET CT
MGH Chest MR
CHEST INPT
ROUTINE (3)


Can you spot the PE?


Can you spot the PE?







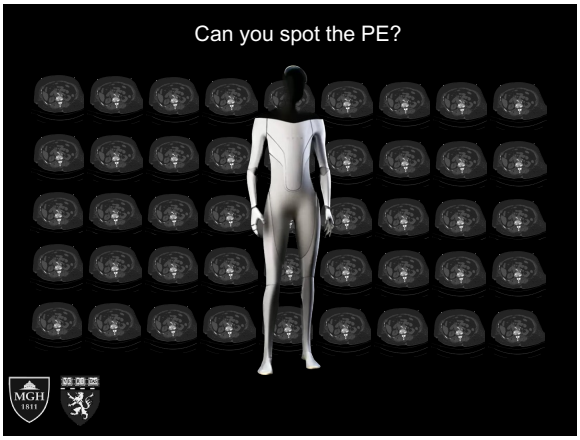


Table 1 Diagnostic accuracy measures of radiology report and AI algorithm on CTPA

	Radiology report	AI algorithm	*p* value
Sensitivity in % (95% CI)	91.6 (89.6–93.7)	96.8 (95.5–98.1)	$p < 0.001$
Specificity in % (95% CI)	99.7 (99.4–99.9)	99.9 (99.8–100.0)	$p = 0.035$
PPV in % (95% CI)	98.6 (97.8–99.5)	99.7 (99.3–100.0)	$p = 0.030$
NPV in % (95% CI)	97.8 (97.2–98.3)	99.1 (98.8–99.5)	$p < 0.001$

PPV = positive predictive value, NPV = negative predictive value, CI = confidence interval, *p* values concern the comparison between the diagnostic measures of the radiology report versus the AI algorithm

Langius-Wiffen et al. Insights into Imaging 2023

Abstract

Purpose To generate and extend the evidence on the clinical validity of an artificial intelligence (AI) algorithm to detect acute pulmonary embolism (PE) on CT pulmonary angiography (CTPA) of patients suspected of PE and to evaluate the possibility of reducing the risk of missed findings in clinical practice with AI-assisted reporting.

Methods Consecutive CTPA scan data of 3316 patients referred because of suspected PE between 24-2-2018 and 31-12-2020 were retrospectively analysed by a CE-certified and FDA-approved AI algorithm. The output of the AI was compared with the attending radiologists' report. To define the reference standard, discordant findings were independently evaluated by two readers. In case of disagreement, an experienced cardiothoracic radiologist adjudicated.

Results According to the reference standard, PE was present in 717 patients (21.6%). PE was missed by the AI in 23 patients, while the attending radiologist missed 60 PE. The AI detected 2 false positives and the attending radiologist 9. The sensitivity for the detection of PE by the AI algorithm was significantly higher compared to the radiology report (96.8% vs. 91.6%, $p < 0.001$). Specificity of the AI was also significantly higher (99.9% vs. 99.7%, $p = 0.035$). NPV and PPV of

rt.

agnostic accuracy for the detection of PE on CTPA

ng indicates that missed positive findings could be

daily clinical practice.

monary embolism can be prevented with the imple-

Radiology report	Reference +	Reference -	
+	657	9	666
-	60	2590	2650
	717	2599	3316

AI algorithm	Reference +	Reference -	
+	694	2	696
-	23	2597	2620
	717	2599	3316

Langius-Wiffen et al. Insights Img 2023

According to the reference standard, after re-evaluation by two readers and if needed adjudication, 717 CT patients were positive for PE, resulting in a prevalence of 21.6% (95% confidence interval 20.2–23.1%). Of those, 60 (8.4%) cases of PE were not reported by the attending radiologist and 23 (3.2%) were not detected by the AI algorithm. The cases of missed PE by the attending radiologist concerned two central/lobar, 12 segmental and 46 subsegmental PE. Solely peripheral PE were missed by the AI algorithm (7 segmental, 16 subsegmental). The attending radiologist reported 9 false positive findings, while the algorithm marked 2 false positives.

Overall, the algorithm showed significantly higher diagnostic accuracy measures compared to the radiology reports with sensitivity of 96.8% versus 91.6%, respectively, and specificity of 99.9% versus 99.7%. PPV and NPV of the AI algorithm were also significantly higher than of the radiology report (Table 1).

Langius-Wiffen et al. Insights Img 2023

ABSTRACT

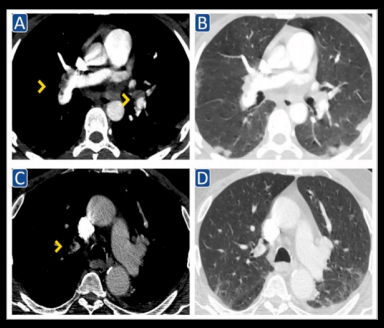
Purpose: We evaluated and compared performance of an acute pulmonary embolism (PE) triaging artificial intelligence (PE-AI) model in suboptimal and optimal CT pulmonary angiography (CTPA).

Methods: In an IRB approved, retrospective study we identified 104 consecutive, suboptimal CTPA which were deemed as suboptimal for PE evaluation in radiology reports due to motion, artifacts and/or inadequate contrast enhancement. We enriched this dataset, with additional 226 optimal CTPA (over same timeframe as suboptimal CTPA) with and without PE. Two thoracic radiologists (ground truth) independently reviewed all 330 CTPA for adequacy (to assess PE down to distal segmental level), reason for suboptimal CTPA (artifacts or poor contrast enhancement), as well as for presence and location of PE. CT values (HU) were measured in the main pulmonary artery. Same attributes were assessed in 80 patients who had repeat or follow-up CTPA following suboptimal CTPA. All CTPA were processed with the PE-AI (Aidoc).

Results: Among 104 suboptimal CTPA (mean age ± standard deviation 56 ± 15 years), 18/104 (17%) were misclassified as suboptimal for PE evaluation in their radiology reports but relabeled as optimal on ground truth evaluation. Of 226 optimal CTPA, 47 (21%) were reclassified as suboptimal CTPA. PEs were present in 97/330 CTPA. PE-AI had similar performance on suboptimal CTPA (sensitivity 100%; specificity 89%; AUC 0.89, 95% CI 0.80–0.98) and optimal CTPA (sensitivity 96%; specificity 92%; AUC 0.87, 95% CI 0.81–0.93).

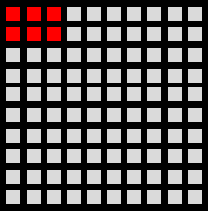
Conclusion: Suboptimal CTPA examinations do not impair the performance of PE-AI triage model; AI retains clinically meaningful sensitivity and high specificity regardless of diagnostic quality.

Ebrahimian S et al. Clin Img 2022



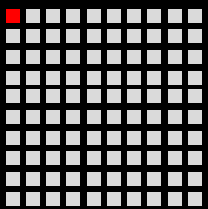
Ebrahimian S et al. Clin Img 2022

CTPA Yield



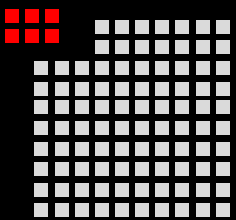
Adapted from Jaff MR et. al Circ 2011

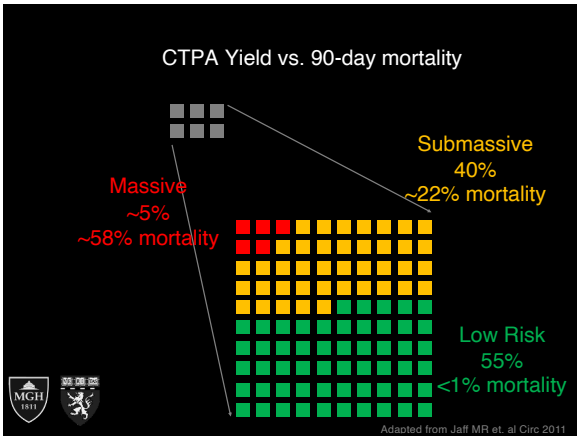
CTPA Yield, no thromboembolic risk factors

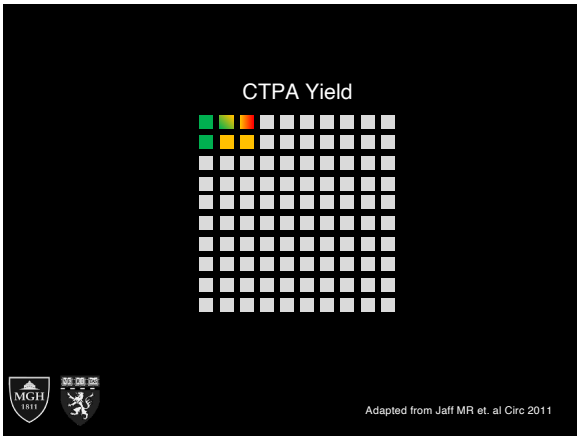


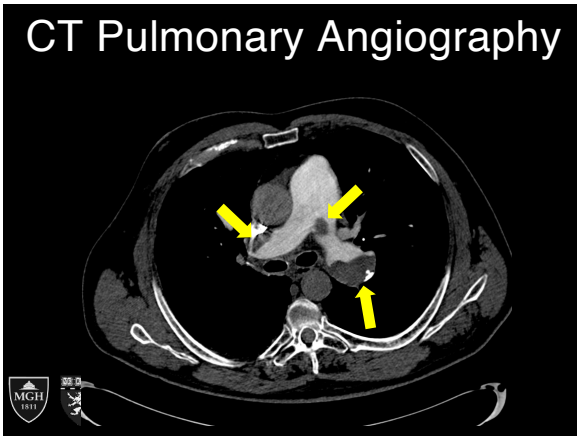
Adapted from Stein PD, et al. Am J Med 2006

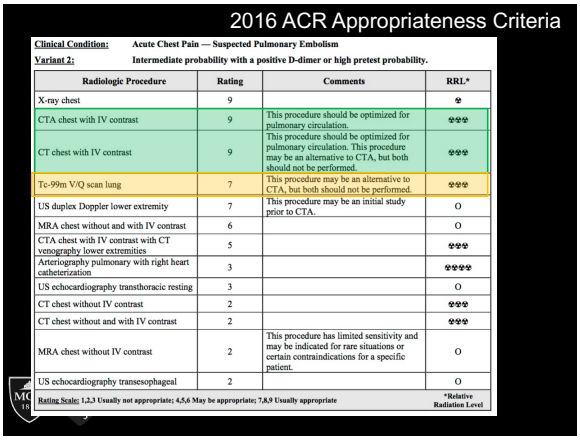
CTPA Yield











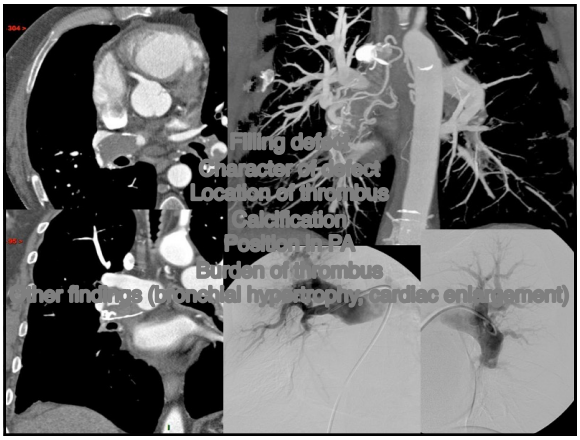
Clinical Condition: Acute Chest Pain — Suspected Pulmonary Embolism

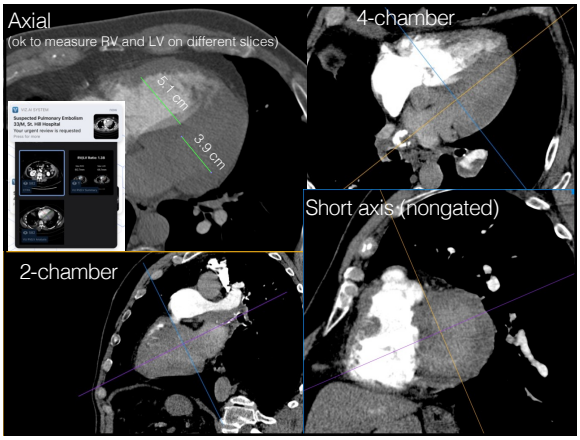
Variant 2: Intermediate probability with a positive D-dimer or high pretest probability.

Radiologic Procedure	Rating	Comments	RRL*
X-ray chest	9		☢
CTA chest with IV contrast	9	This procedure should be optimized for pulmonary circulation.	☢☢☢
CT chest with IV contrast	9	This procedure should be optimized for pulmonary circulation. This procedure may be an alternative to CTA, but both should not be performed.	☢☢☢
Tc-99m V/Q scan lung	7	This procedure may be an alternative to CTA, but both should not be performed.	☢☢☢
US duplex Doppler lower extremity	7	This procedure may be an initial study prior to CTA.	O
MRA chest without and with IV contrast	6		O
CTA chest with IV contrast with CT venography lower extremities	5		☢☢☢
Arteriography pulmonary with right heart catheterization	3		☢☢☢☢
US echocardiography transthoracic resting	3		O
CT chest without IV contrast	2		☢☢☢
CT chest without and with IV contrast	2		☢☢☢
MRA chest without IV contrast	2	This procedure has limited sensitivity and may be indicated for rare situations or certain contraindications for a specific patient.	O
US echocardiography transesophageal	2		O

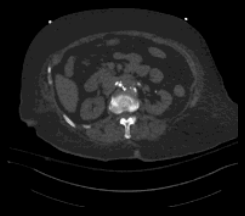
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate

*Relative Radiation Level

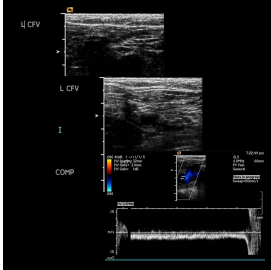


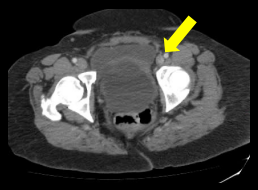


CTA PE Protocol



Incremental value of venous evaluation?





Lower Extremity venography
IVC / May-Thurner?

Clinical Condition: Acute Chest Pain — Suspected Pulmonary Embolism

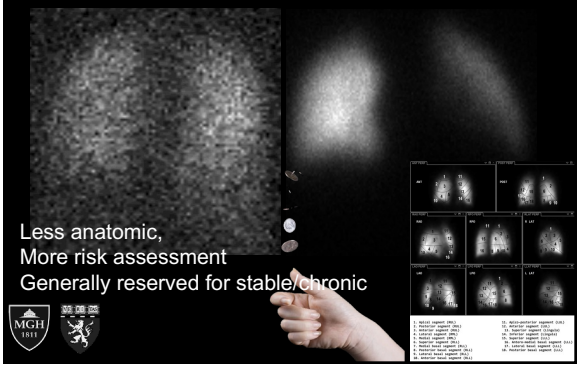
Variant 2: Intermediate probability with a positive D-dimer or high pretest probability.

Radiologic Procedure	Rating	Comments	RRL*
X-ray chest	9		☢
CTA chest with IV contrast	9	This procedure should be optimized for pulmonary circulation.	☢☢☢
CT chest with IV contrast	9	This procedure should be optimized for pulmonary circulation. This procedure may be an alternative to CTA, but both should not be performed.	☢☢☢
Tc-99m V/Q scan lung	7	This procedure may be an alternative to CTA, but both should not be performed.	☢☢☢
US duplex Doppler lower extremity	7	This procedure may be an initial study prior to CTA.	O
MRA chest without and with IV contrast	6		O
CTA chest with IV contrast with CT venography lower extremities	5		☢☢☢
Arteriography pulmonary with right heart catheterization	3		☢☢☢☢
US echocardiography transthoracic resting	3		O
CT chest without IV contrast	2		☢☢☢
CT chest without and with IV contrast	2		☢☢☢
MRA chest without IV contrast	2	This procedure has limited sensitivity and may be indicated for rare situations or certain contraindications for a specific patient.	O
US echocardiography transesophageal	2		O

Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate

*Relative Radiation Level

V/Q Scintigraphy?



Less anatomic,
More risk assessment
Generally reserved for stable/chronic

Cardiac MRI?

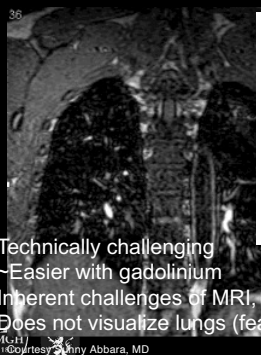


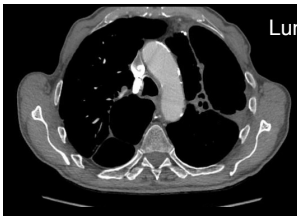
Table 3. Results of MRA and Combined MRA and MRV, by Reference Test

Test Result	Reference Test Result, *n*		Total, *n*
	Positive for PE	Negative for PE	
MRA result			
Positive	59	2	61
Negative	17	201	218
Technically inadequate	28	64	92
Total	104	267	371
MRA and MRV result*			
Positive	65	4	69
Negative	6	101	107
Technically inadequate	33	161	194
Total†	104	266	370

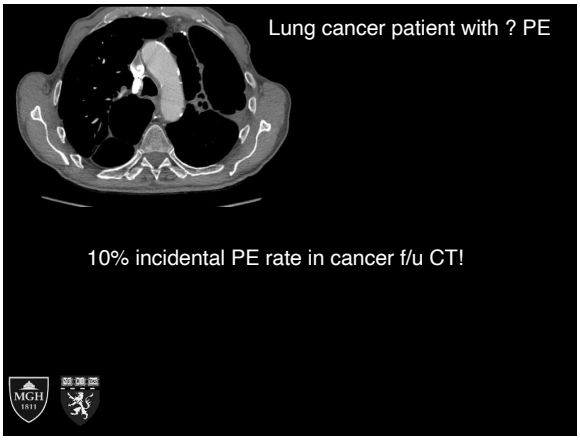
PIOPED 3: Stein PD et al, Annals of Int Med 2010

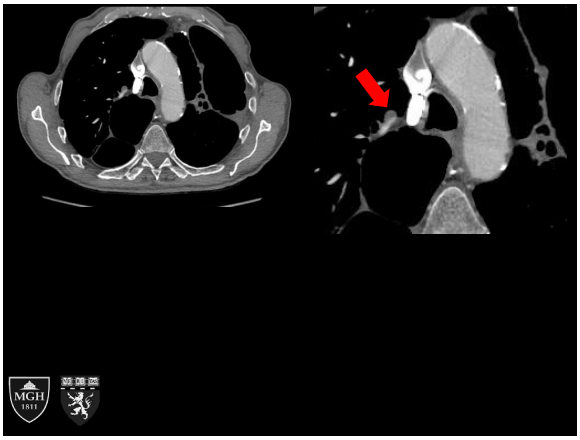
Technically challenging
~Easier with gadolinium
Inherent challenges of MRI, MRA
Does not visualize lungs (feature vs. bug?)

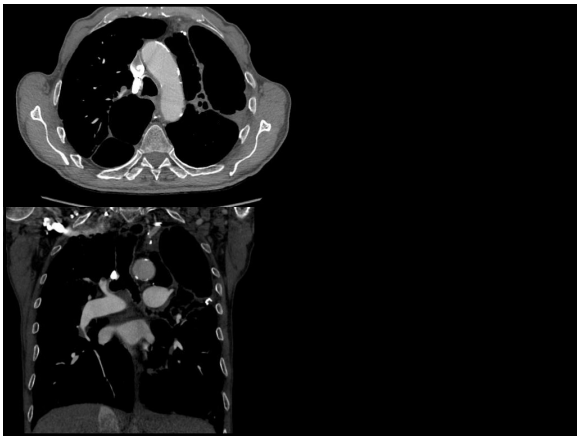
Courtesy Johny Abbara, MD

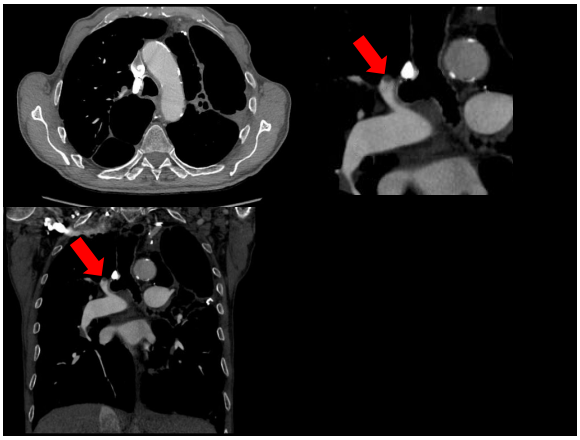


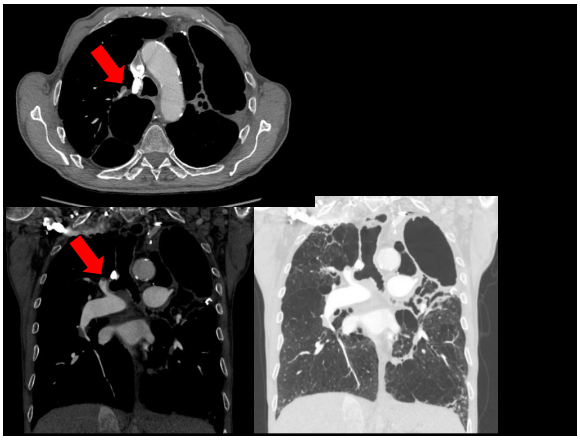
Lung cancer patient with ? PE

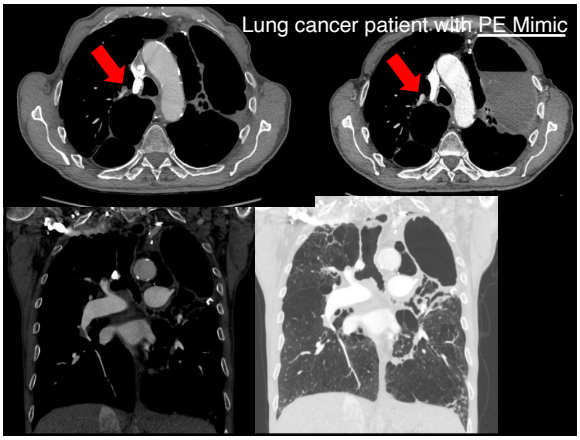

Lung cancer patient with ? PE
10% incidental PE rate in cancer f/u CT!



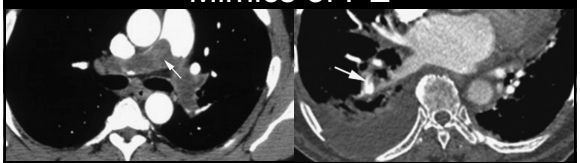




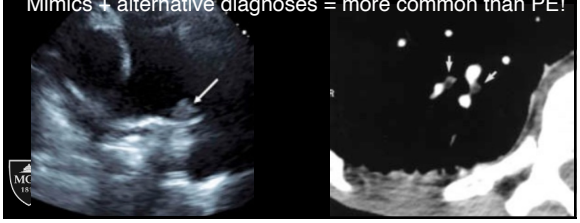



Lung cancer patient with PE Mimic

Mimics of PE

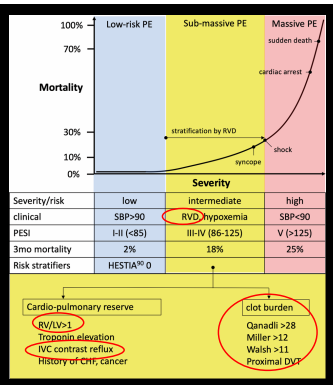


Mimics + alternative diagnoses = more common than PE!



Larche M et al. J Clin Med 2019

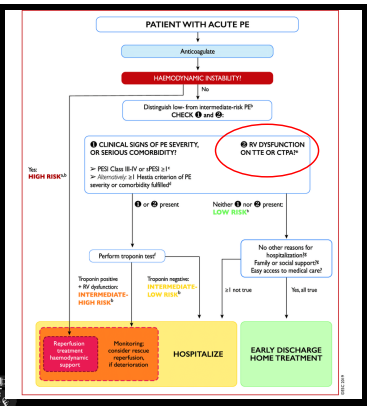
	Low-risk PE	Sub-massive PE	Massive PE
Severity/risk	low	intermediate	high
clinical	SBP>90	RVD, hypoxemia	SBP<90
PESI	I-II (<85)	III-IV (86-125)	V (>125)
3mo mortality	2%	18%	25%
Risk stratifiers	HESTIA[90] 0		



Cardio-pulmonary reserve
- RV/LV>1
- Troponin elevation
- IVC contrast reflux
- History of CHF, cancer

clot burden
- Qanadli >28
- Miller >12
- Walsh >11
- Proximal DVT

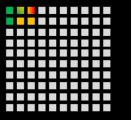
Cumpelik, A., Parakh, A., Ghoshhajra, B., Rosovsky, R. (2024). Thrombus Burden and Pulmonary Embolism. In: Grodzin, C.J., Merli, G.J., Ross, C.B., Rosovsky, R. (eds) PERT Consortium Handbook of Pulmonary Embolism. Springer, Cham.



Konstantinides SV, et al. 2019 ESC guidelines

Summary of key points:

CTPA Yield



CTA is first line…and second line for initial Dx

Filling defect + supporting signs; use MPRs

Signs of instability should be reported

Remember the overall low yield (~6%) of CT PA, signs of risk

Welcome help from AI but will always need intelligent oversight.

Radiology 101: Consider mimics of PE

There's no "I" in PERT… (the "team" is Emerg Med, Gen Med, General Rads Subspecialty Rads, Heme/Onc, Pulm, Vasc Med, Vasc Surg, Interv Rad, CT Surg!)

Thank you

@ ghoshhajra

Jo-Anne Shepard
Shaunagh McDermott
Michael Lu
Alexi Otrakji
Michael Lev
Rachel Rosovsky
Ido Weinberg
Dave Dudzinski
Allison Witkin
Michael Jaff
Kenny Rosenfield
Bob Schainfeld
Sandeep Hedgire
MGH PERT Team
VEITH Symposium