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Thrombosis and Anticoagulation

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- Clinical focus: Thrombosis and Vascular Medicine
- Research focus: Thrombosis



DISCLOSURES

Research Grants: BMS/Pfizer, Janssen, Alexion, Bayer, Amgen, BSC, Regeneron, Esperion, NIH 1R01HL164717-01

Advisory Role: BSC, Amgen, PERC, NAMSA, BMS, Janssen, Thrombolex, Regeneron, Nectero



OBJECTIVES

1. Review the epidemiology and pathophysiology of VTE
2. Discuss the risk stratification of PE and DVT
3. Apply evidence- and pathophysiology-based strategies to manage PE patients



Association Between Black Race, Clinical Severity, and Management of PE

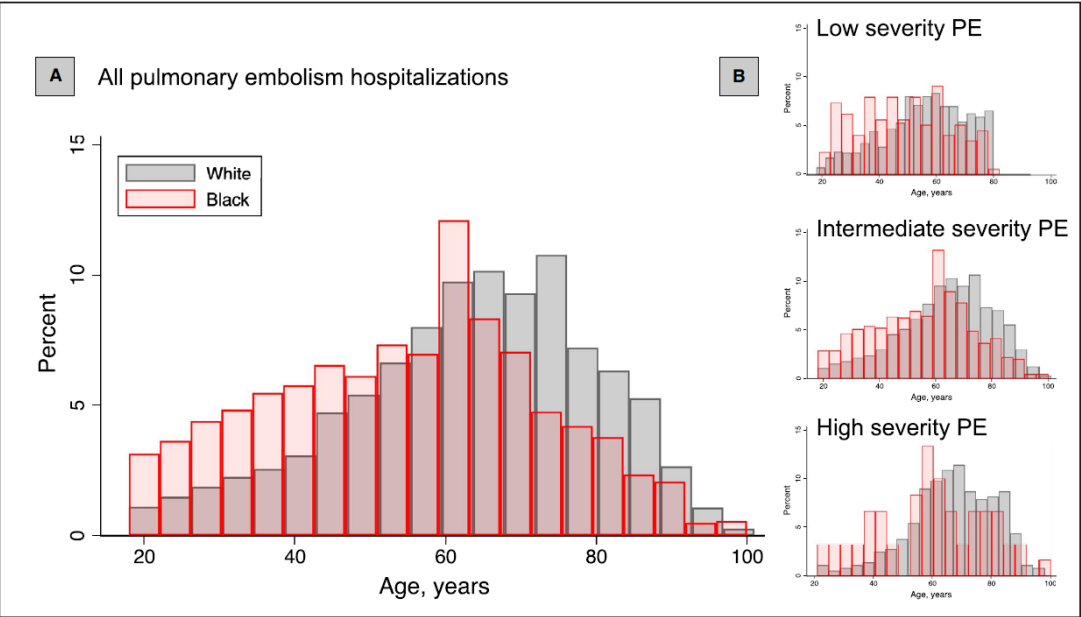


Figure 2. Age of hospitalization for pulmonary embolism by age, per classification for severity in the full cohort.

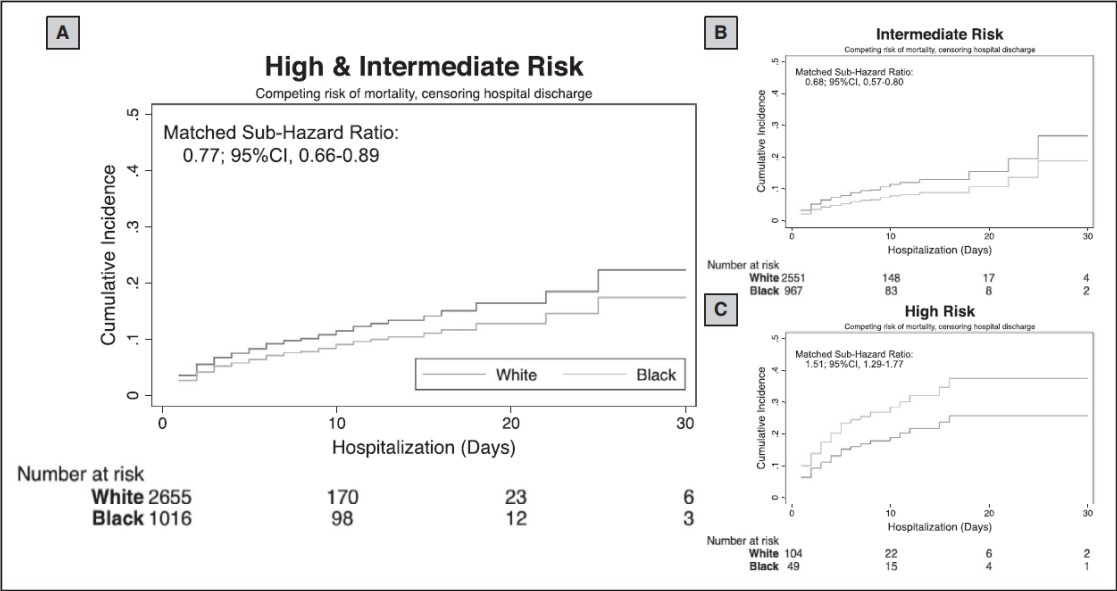




Figure 4. Cumulative hazard of the risk of in-hospital procedures overall among intermediate and high-severity pulmonary embolisms in the matched cohort together (A) and separately (B and C).

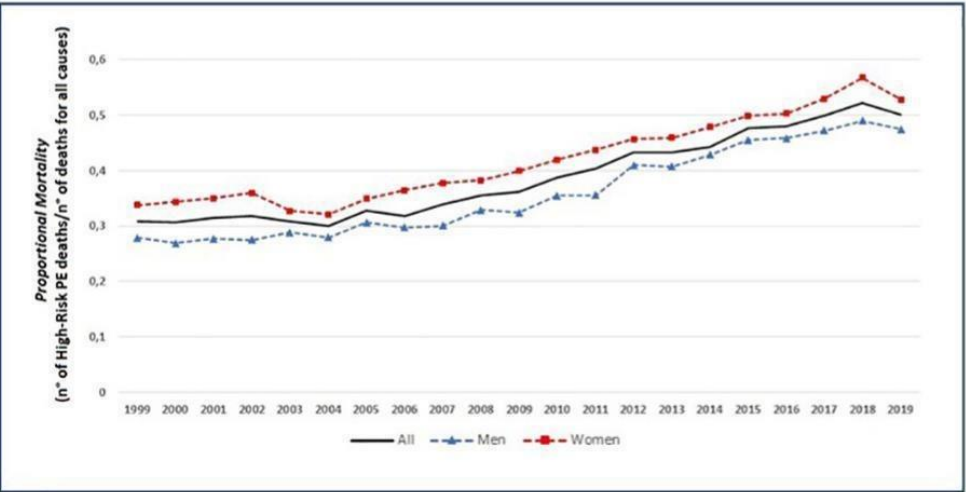


US Mortality Trends in Patients with High-Risk PE








CENTRAL ILLUSTRATION: Trends in mortality related to high-risk pulmonary embolism in US from 1999 to 2019

-  Study design
- Cross sectional study (1999-2019)
 - Mortality data from the Centers for Disease Control and Prevention's (CDC) Wide-ranging ONline Data for Epidemiologic Research (WONDER) dataset
 - Proportionate mortality from high-risk PE per 100 deaths
 - High-risk PE-related mortality per 100,000 US population and relative trends
-  Data analysis
- Joinpoint regression analysis

Outcomes




High-risk PE mortality
↑ 93.5%

	Males	AAPC: +1.9%
	Females	AAPC: +1.5%
	Blacks	AAPC: +1.4%
	Whites	AAPC: +1.6%
	<64 years	AAPC: +3.2%
	≥65 years	AAPC: +1.0%
	Rural areas	AAPC: +2.5%

AAPC: Average Annual Percent Change
APC: Annual Percent Change



US Mortality Trends in Early Adults with PE

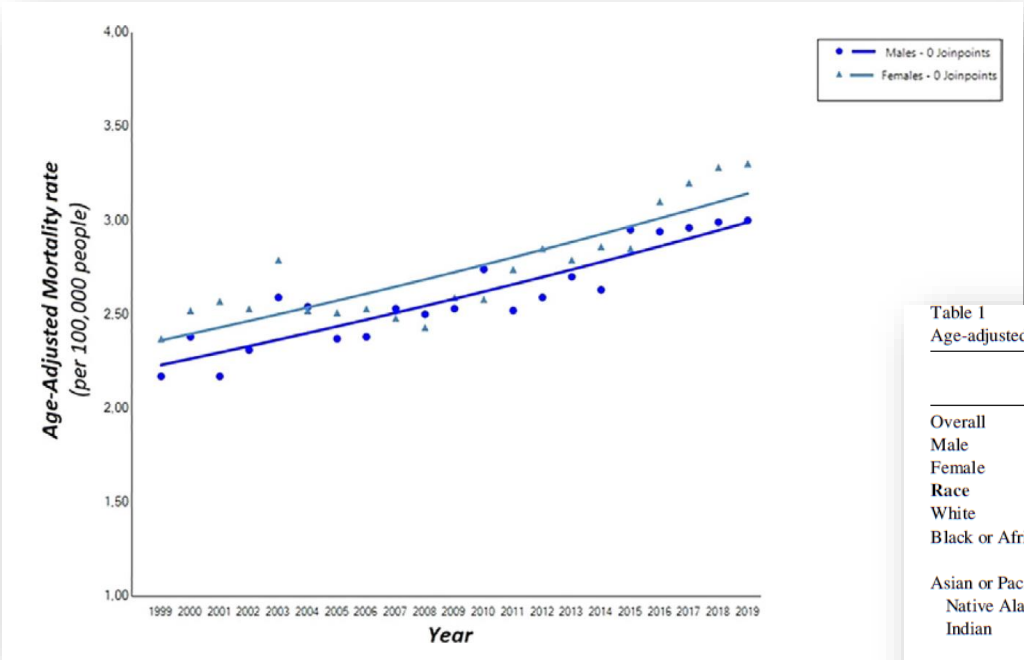


Table 1
Age-adjusted mortality rate trend in early adults with pulmonary embolism (25-44 years), 1999-2019, stratified by gender and race/ethnicity

	AAMR 1999 (95% CI)	AAMR 2019 (95% CI)	AAPC; (95% CI), p	Number of Joinpoints	Period 1 [years] APC; (95% CI), p	APC - period 2 [years] APC; (95% CI), p	p
Overall	2.27 (2.17 to 2.37)	3.20 (3.13 to 3.31)	1.4; (1.1 to 1.7), p<0.001	0	-	-	-
Male	2.17 (2.03 to 2.31)	3.00 (2.83 to 3.16)	1.5; (1.2 to 1.8), p<0.001	0	-	-	0.058
Female	2.37 (2.22 to 2.52)	3.36 (3.18 to 3.54)	1.4; (1.0 to 1.9), p<0.001	0	-	-	
Race							
White	1.86 (1.76–1.96)	2.74 (2.61–2.87)	1.7; (1.4 to 2.0), p<0.001	0	-	-	White vs Blacks: p=0.002
Black or African American	5.72 (5.27–6.17)	6.74 (6.27–7.21)	0.7; (0.3 to 1.0), p<0.001	1	[1999–2007] –0.3; (–1.0 to 0.5), p=0.44	[2007–2019] 1.3; (0.9 to 1.7), p<0.001	White vs Asian/Pacific Islander and Alaska/American Indian: p<0.001
Asian or Pacific Islander and Native Alaska/American Indian	0.61 (0.41 to 0.89)	1.14 (0.92 to 1.40)	2.5; (1.6 to 3.4), p<0.001	0	-	-	Blacks vs Asian/Pacific Islander and Alaska/American Indian: p= 0.003
Ethnicity							
Latinx/Hispanic	1.14 (0.93–1.35)	1.71 (1.51–1.91)	1.7; (0.6 to 3.0), p=0.003	1	[1999–2010] –0.9; (–2.3, to 0.6), p=0.23	[2010 to 2019] 5.0; (2.9 to 7.2), p<0.001	-

AAMR = age-adjusted mortality rate, expressed as deaths per 100,000 population; AAPC = average annual percent change; APC = annual percent change.



When Innovation Fails: Barriers to Health Equity

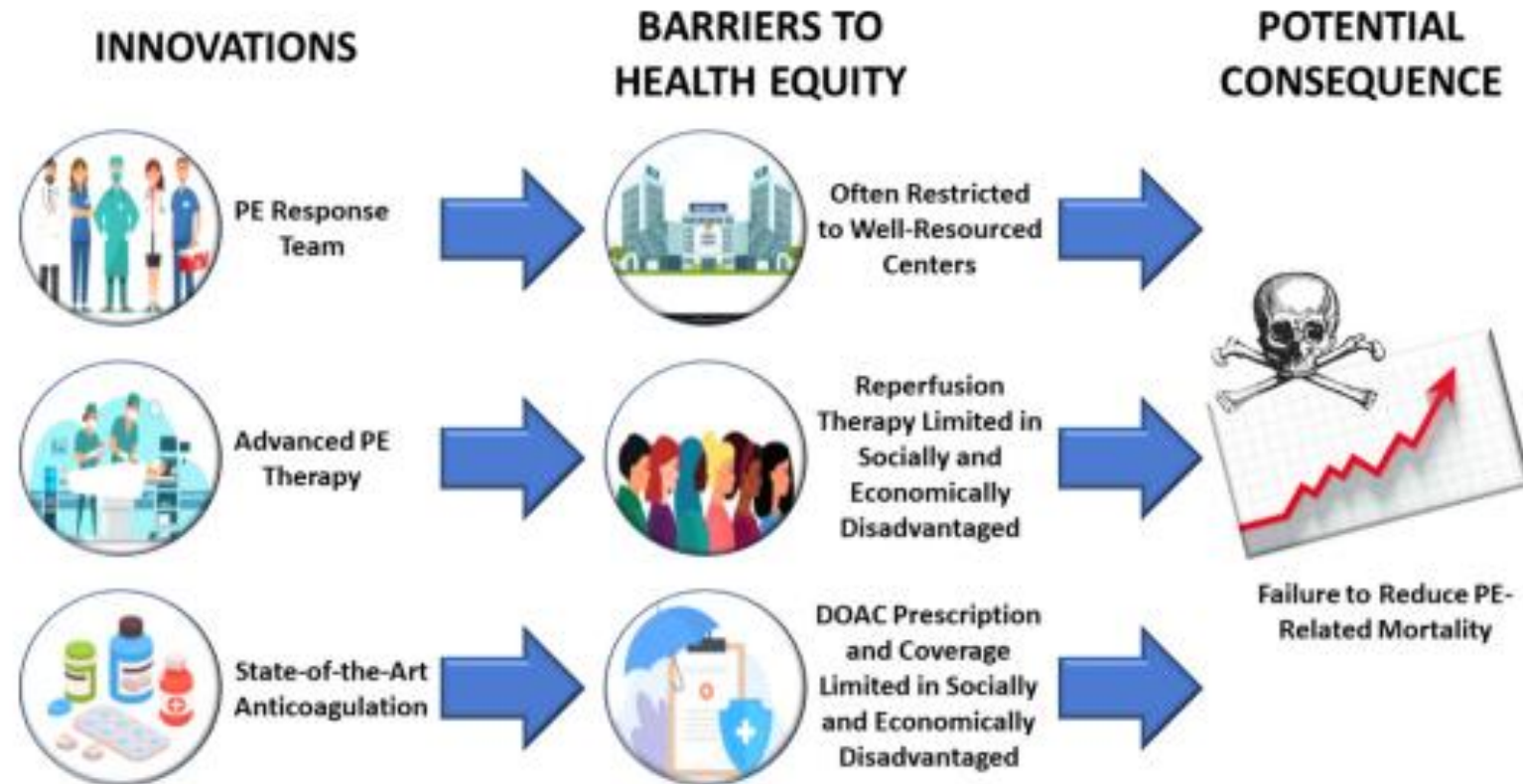
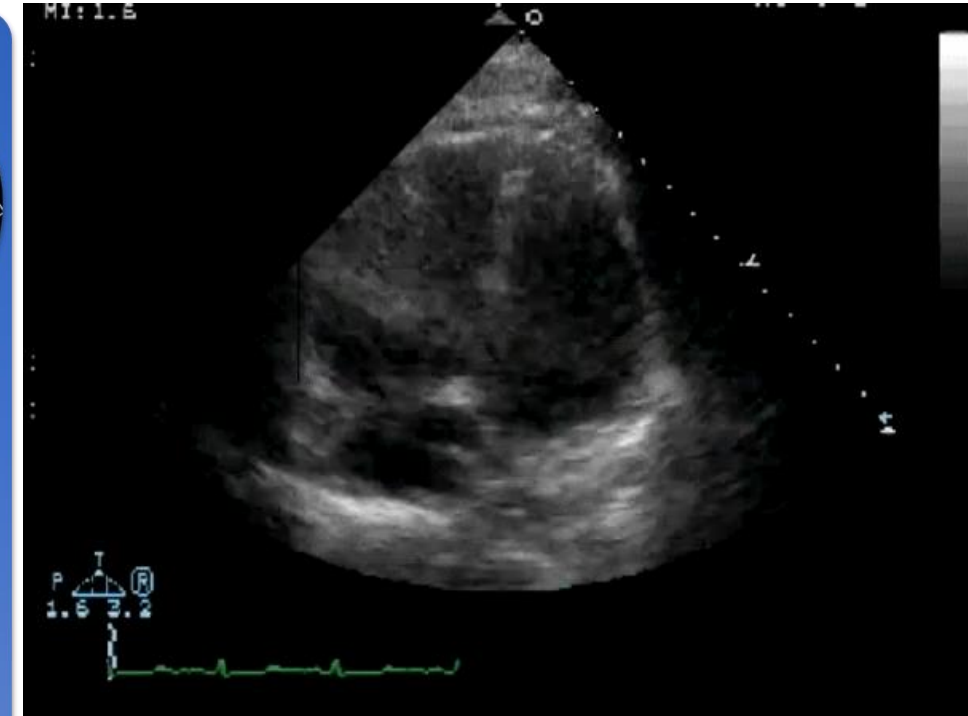
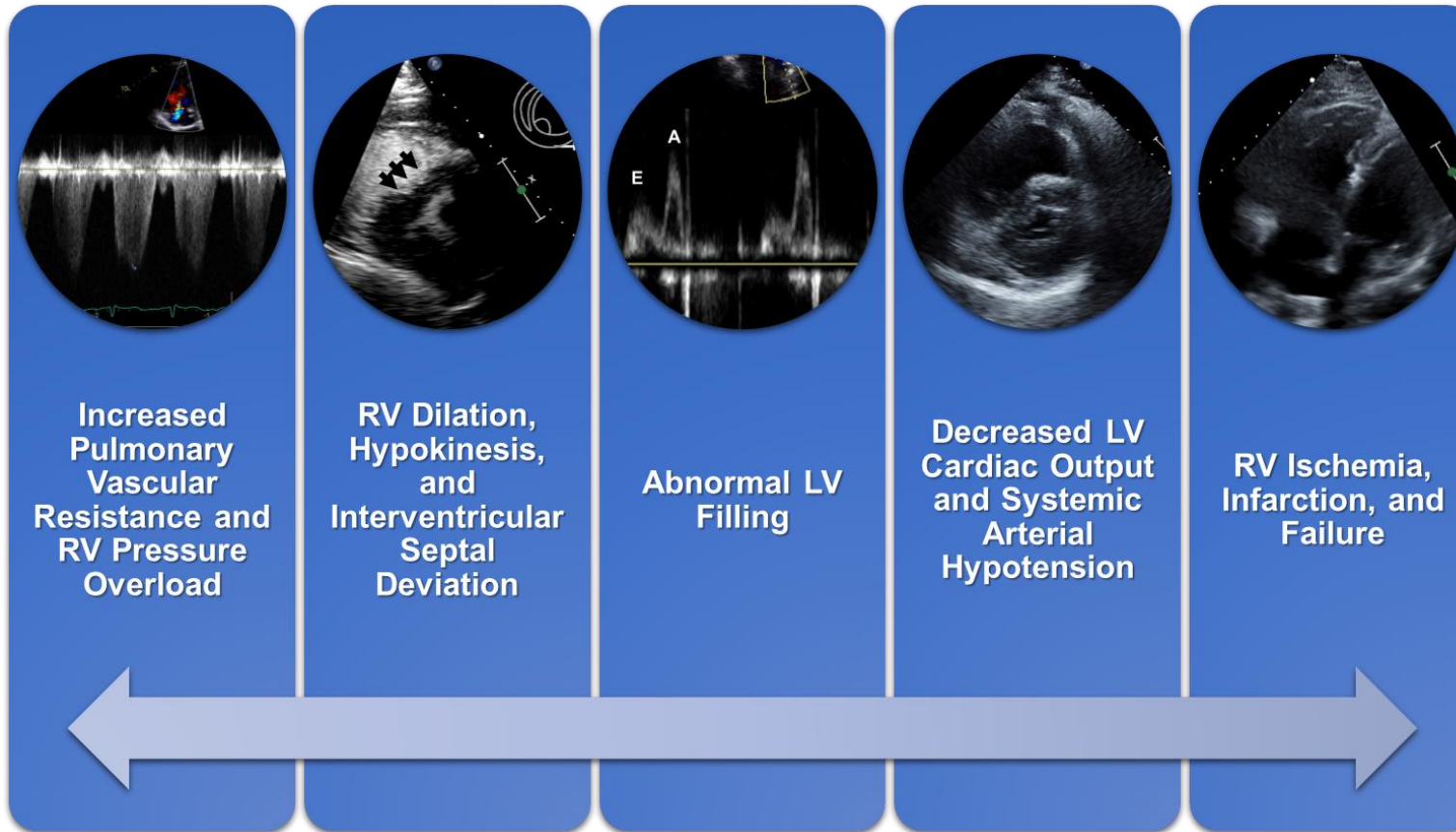
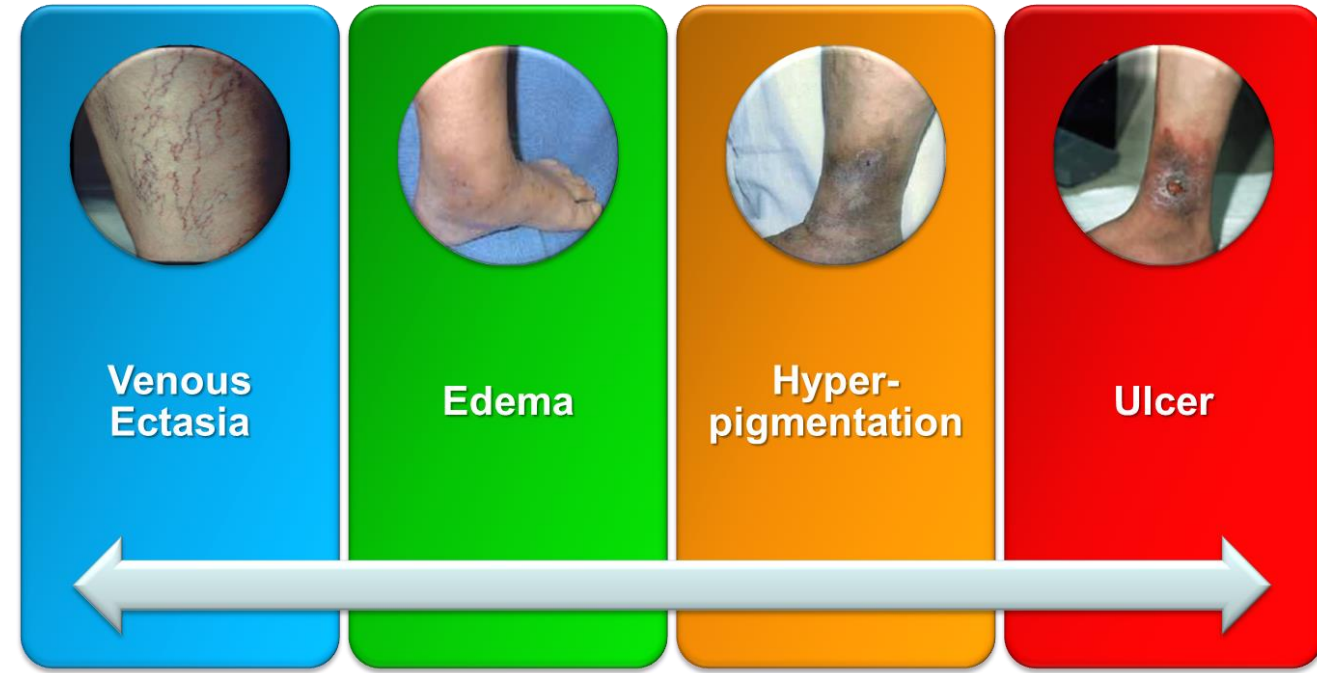
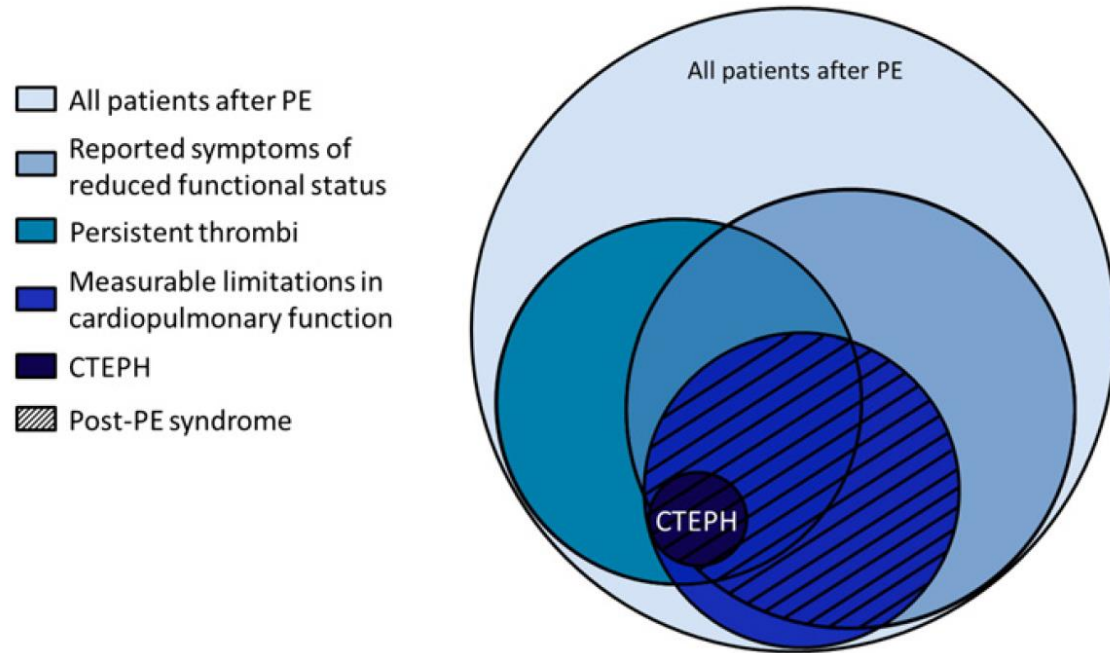


FIGURE Health equity barriers to innovation in pulmonary embolism clinical care and failure to reduce mortality. DOAC, direct oral anticoagulant; PE, pulmonary embolism.

Pathophysiology of PE



Long-Term Complications of PE and DVT



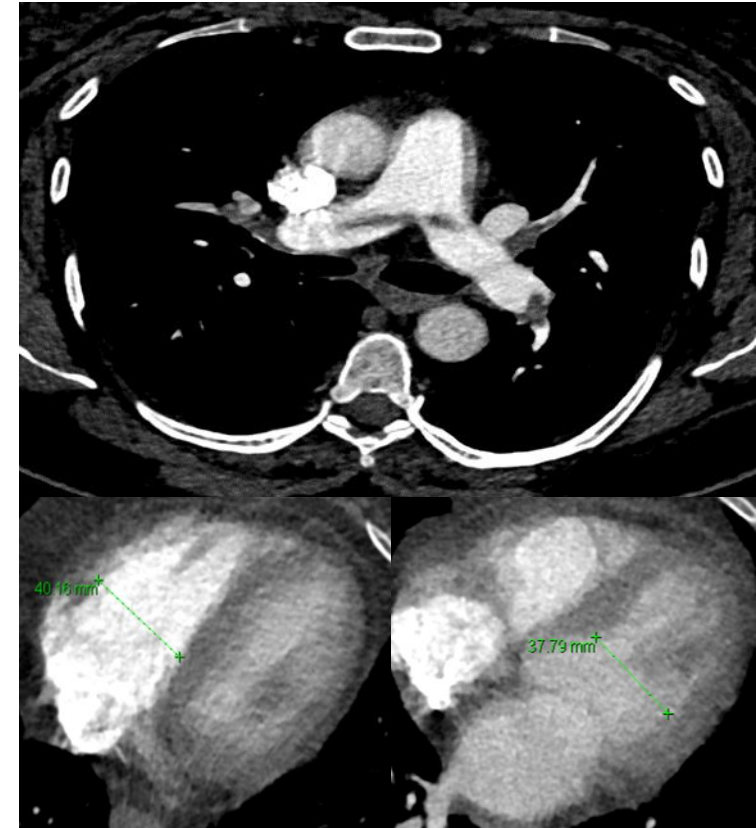
Case No. 1

A 66-year-old man with prostate cancer status post prostatectomy presents with sudden onset pleuritic pain, dyspnea, and right ankle edema.

He is tachycardic to 118 bpm, normotensive at 100/62 mmHg, and hypoxemic with an O₂ saturation of 92% on room air.

His high sensitivity cardiac troponin T is increased.

He undergoes chest CT angiography to assess for PE.



Question No. 1

In which 2026 AHA/ACC Guideline Clinical Category would you place this patient?

- a) A
- b) B
- c) C
- d) D
- e) E



Question No. 1

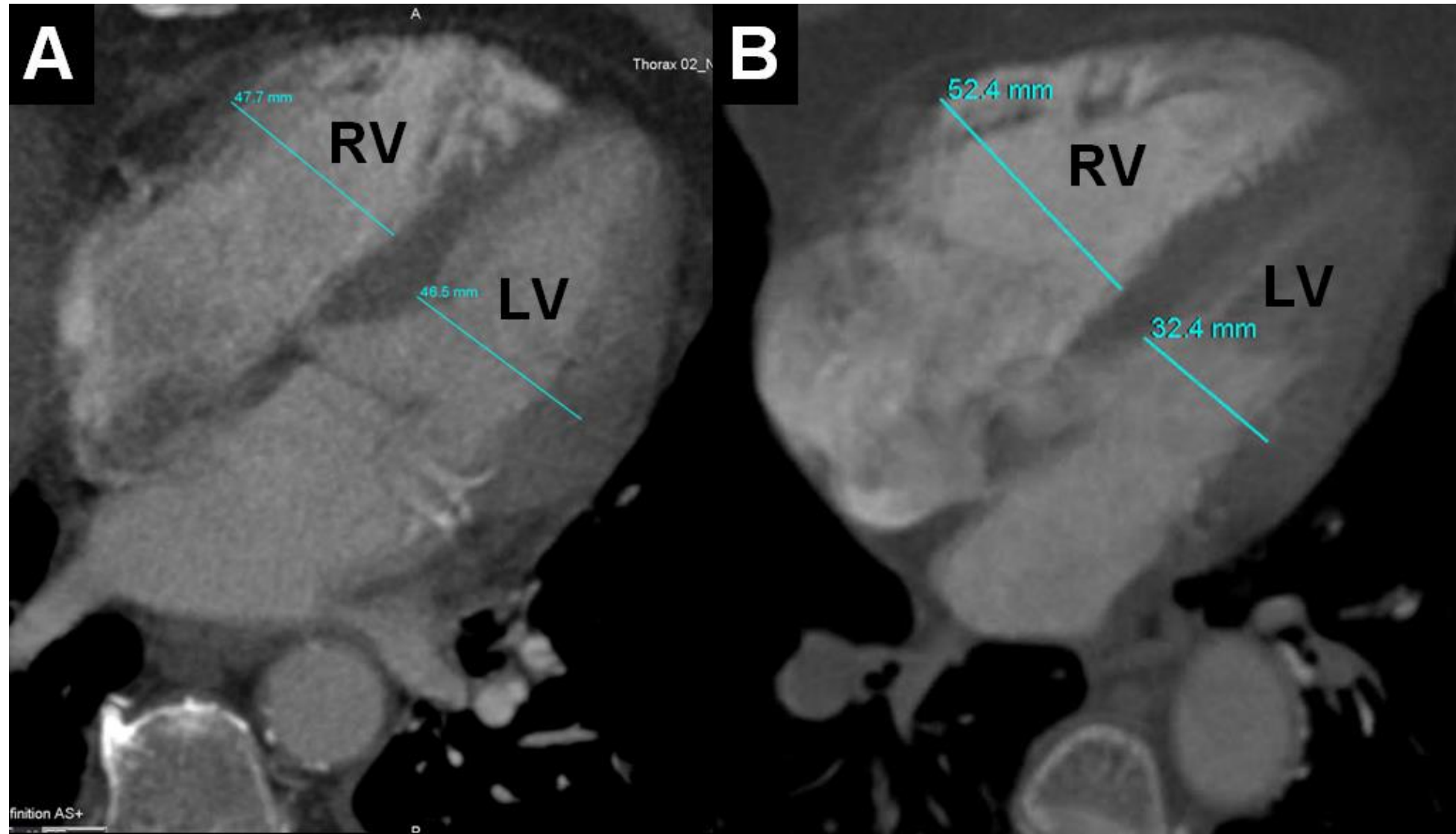
In which 2026 AHA/ACC Guideline Clinical Category would you place this patient?

- a) A
- b) B
- c) C
- d) D
- e) E

Explanation: Symptomatic PE with signs of increased clinical severity (tachycardia, etc) would fall into Clinical Category C (specifically C3 due to RV dysfunction and elevated troponin)

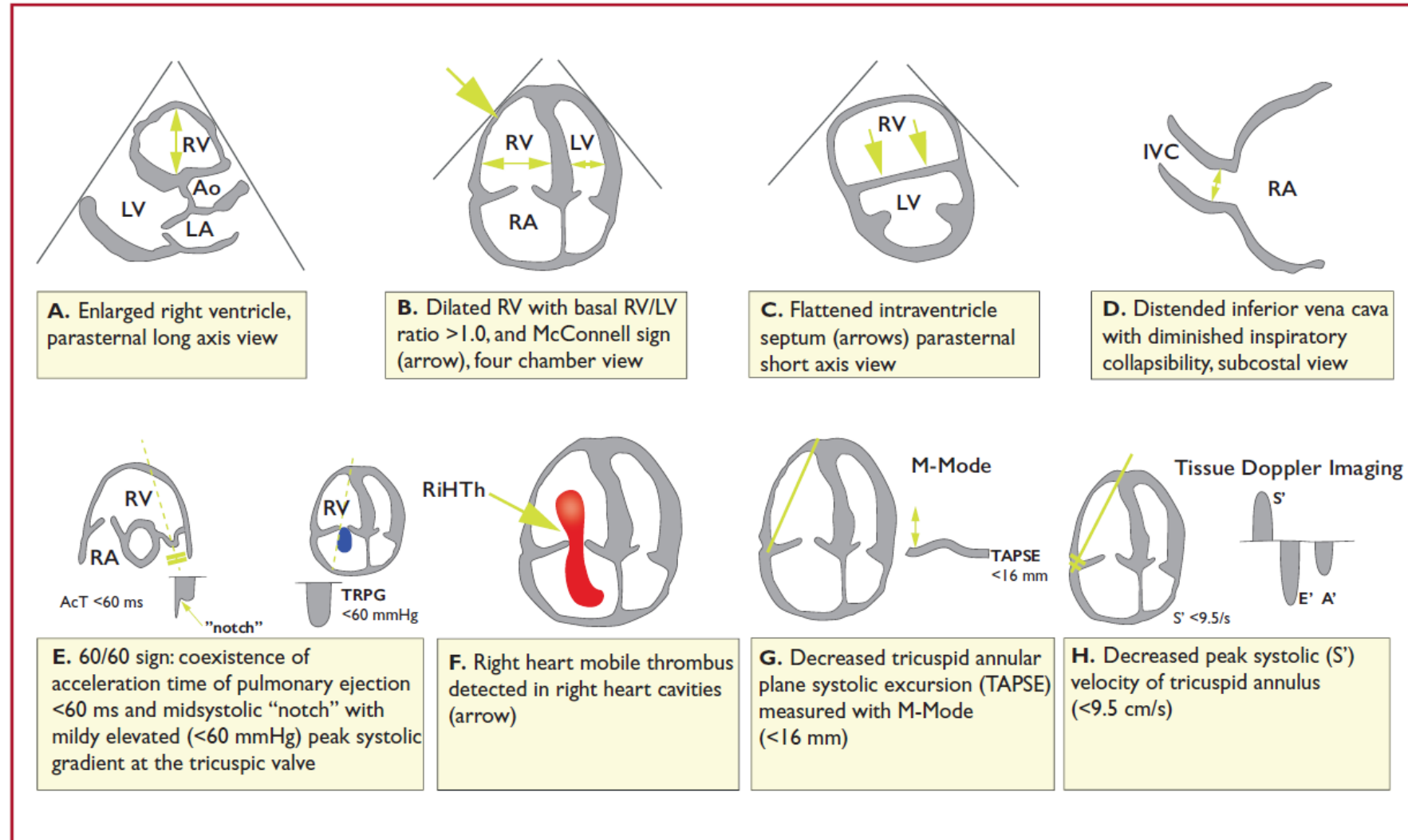


RV Enlargement on CT Predicts Increased 30-Day Mortality



Schoepf UJ, et al. Circulation 2004;110:3276

Echocardiographic Assessment of RV in PE



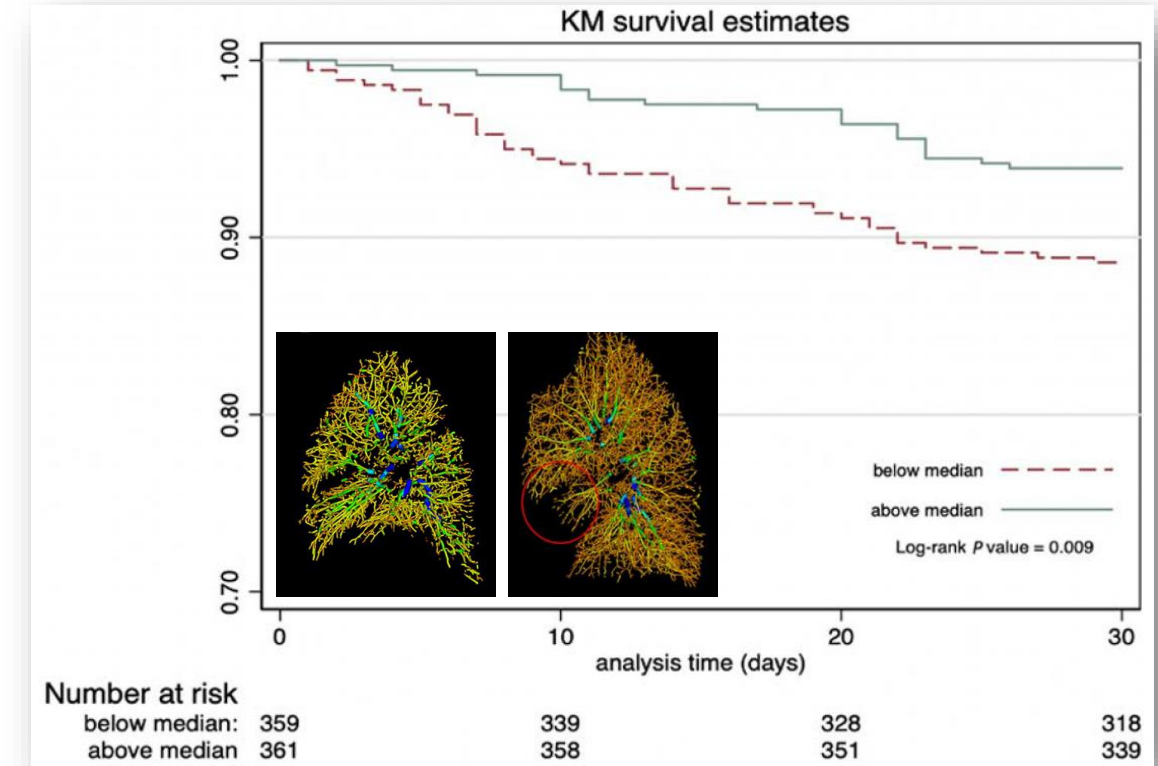
Clot-Burden: PE Outcomes

Variable	Survivors (n = 596)	Deceased Patients (n = 39)	PValue
No. of PEs*	2.0 (3.1 ± 3.1)	2.0 (2.5 ± 2.1)	.247
Proximal level of PE†			
Mediastinal PA	172 (28.8)	10 (25.6)	—
Lobar PA	145 (24.3)	6 (15.4)	.520
Segmental PA	183 (30.7)	19 (48.7)	.152
Subsegmental PA	96 (16.1)	4 (10.2)	.582
Qanadli score (%)*	12.5 (17.0 ± 15.9)	7.5 (17.1 ± 19.6)	.995
Mastora score (%)*	5.1 (10.4 ± 13.1)	3.2 (11.4 ± 17.1)	.659
Blood clot volume (mm³)*	927.3 (3556.4 ± 6598.3)	630.4 (3211.8 ± 679.7)	.750

Table 4. Cox Proportional Hazard Model Assessing the Hazard Ratio of a Reduction in Small Venous Blood Volume With 30- and 90-Day Mortality After Adjusting for Age, Sex, Lung Volume, Small Arterial Blood Volume, Abnormal RV:LV Ratio, and Presence of Cancer

Mortality	Univariable analysis			Multivariable analysis		
	HR	CI	P value	HR	CI	P value
30-day	1.47	0.95–2.32	0.08	2.52	1.51–4.45	<0.001
90-day	1.06	0.68–1.33	0.77	1.66	1.10–2.50	0.016

Hazard ratios reported here are per 1 SD (17.84 mL) decrease in small venous volume. HR indicates hazard ratio; LV, left ventricle; and RV, right ventricle.


































































Furlan A, et al. Radiology. 2012;265:283-293

Minhas J, et al. Circ Cardiovasc Imaging. 2021;14:e012347

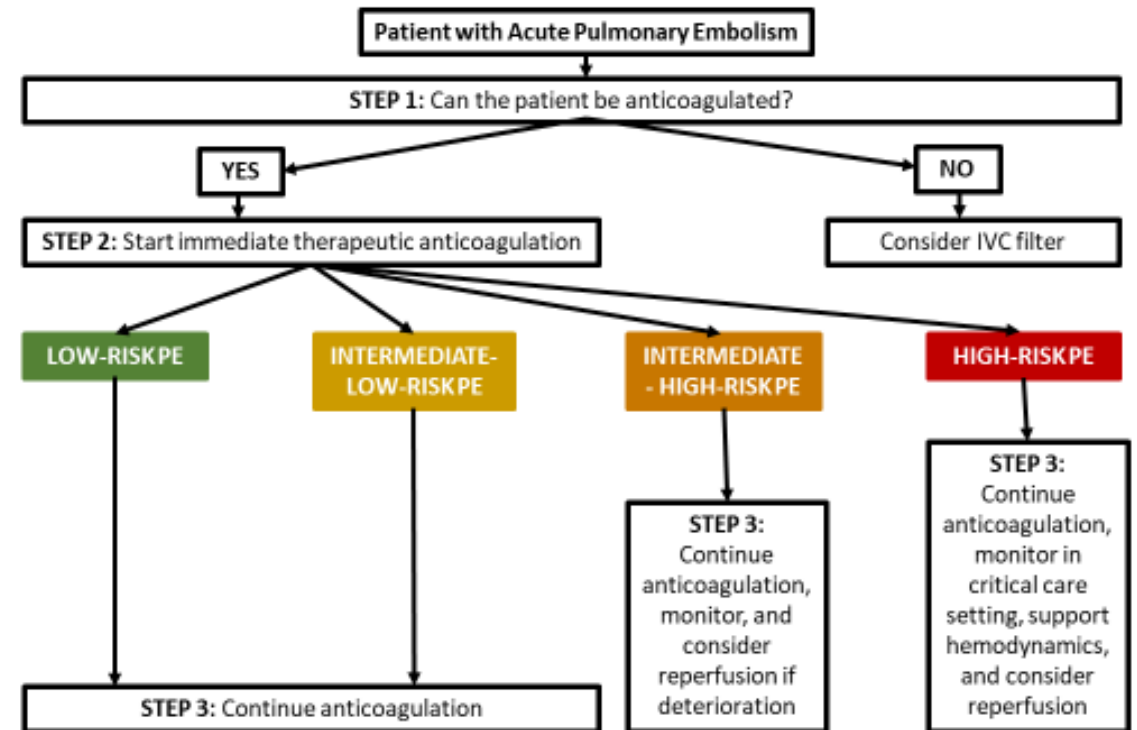
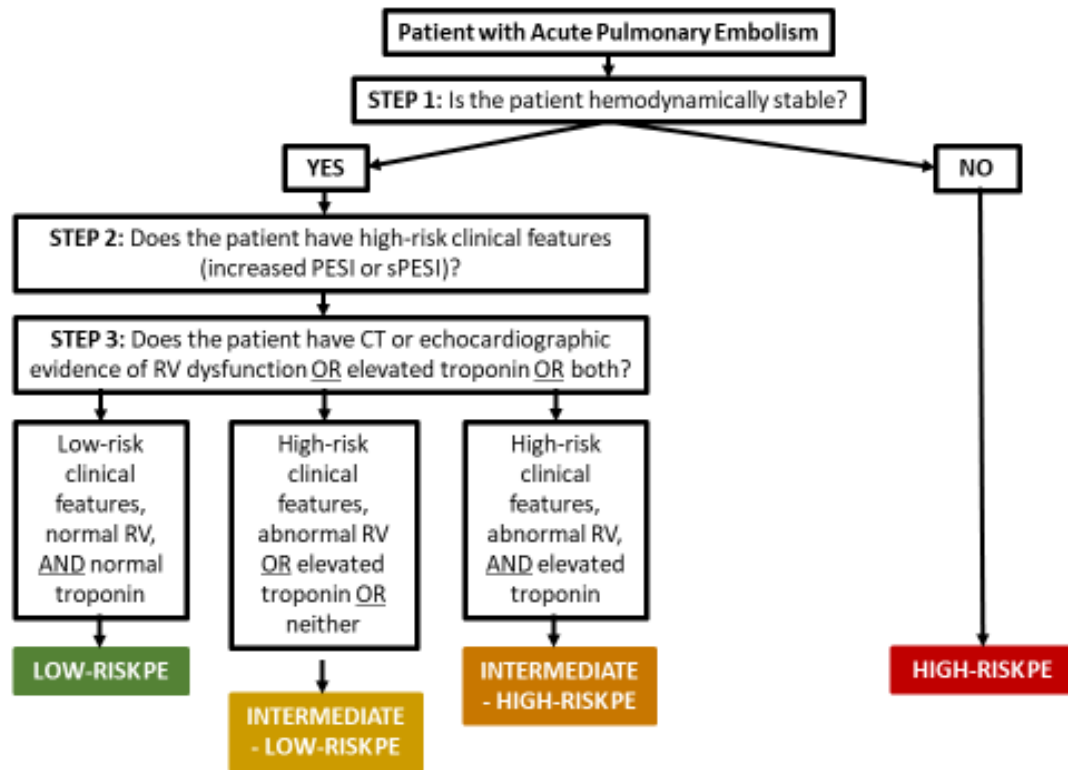


Risk Stratification Recommendations

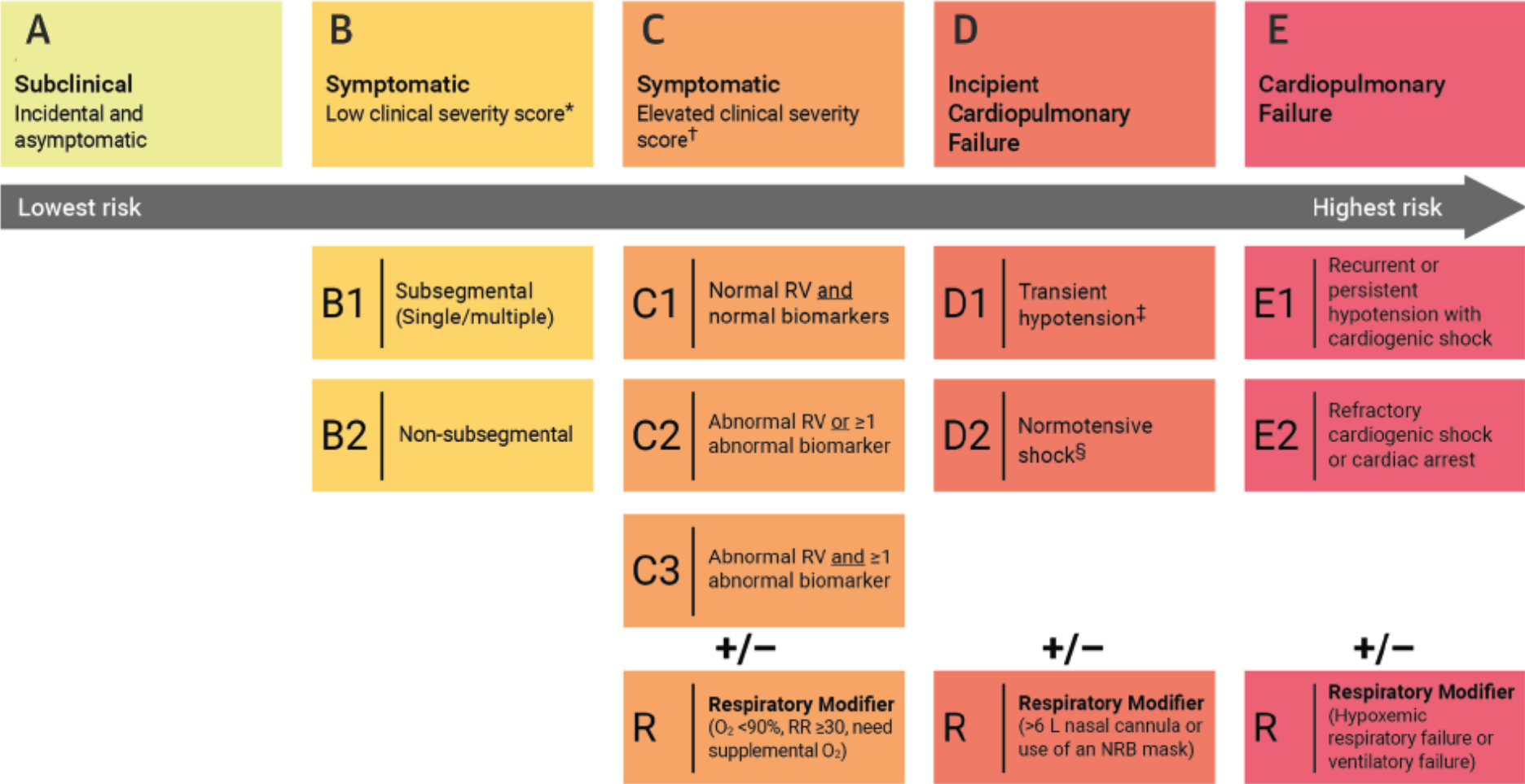
 Suggested  Not Addressed  Not Recommended	ESC/ ERS [2] 	PERT [12] 	CHEST [13] 	AHA [14] 	ASH [15] 	NICE [20] 
Recommendation for risk stratification			 a			
Definition provided for low-risk PE						
Definition provided for intermediate-risk (submassive) PE						
Definition provided for intermediate-low risk PE						
Definition provided for intermediate-high risk PE						
Definition provided for PE deterioration						
Definition provided for high-risk (massive) PE						
Early discharge or entirely home-based care for low-risk PE	 c			 b		
Use of a multidisciplinary PERT				 b	 d	



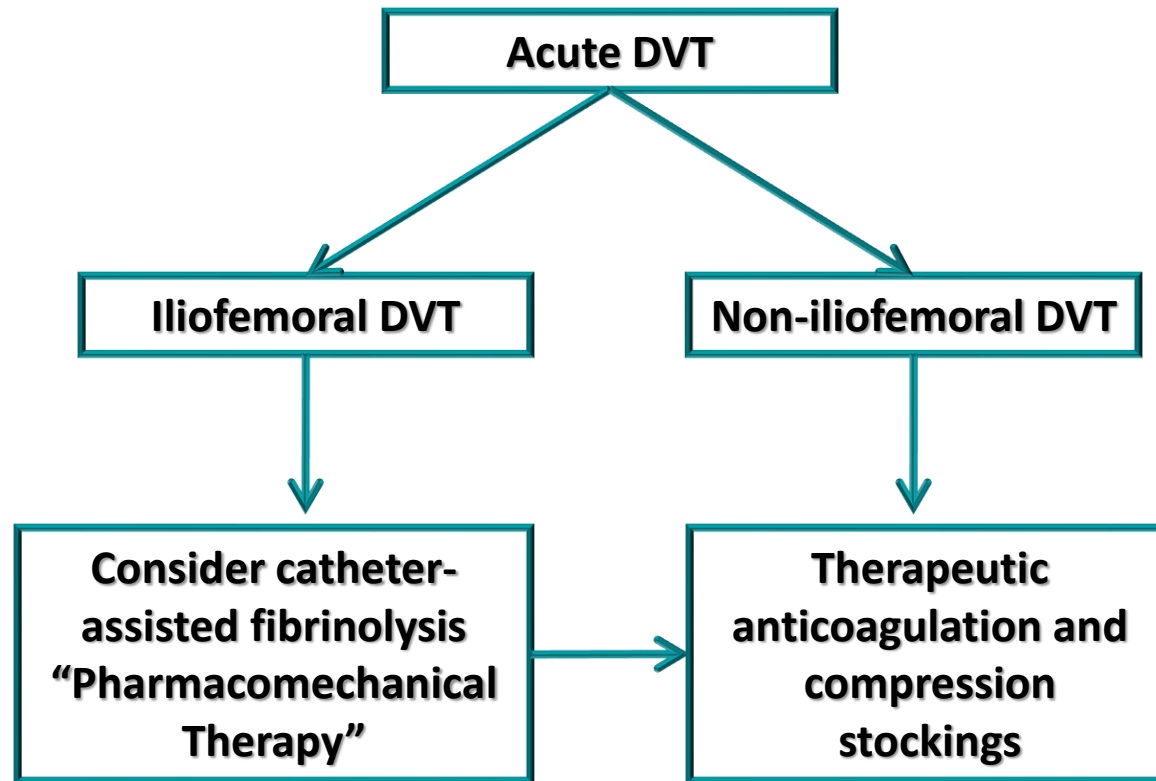
Risk Stratification for PE



2026 AHA/ACC Acute PE Guidelines



Risk Stratification for Acute DVT



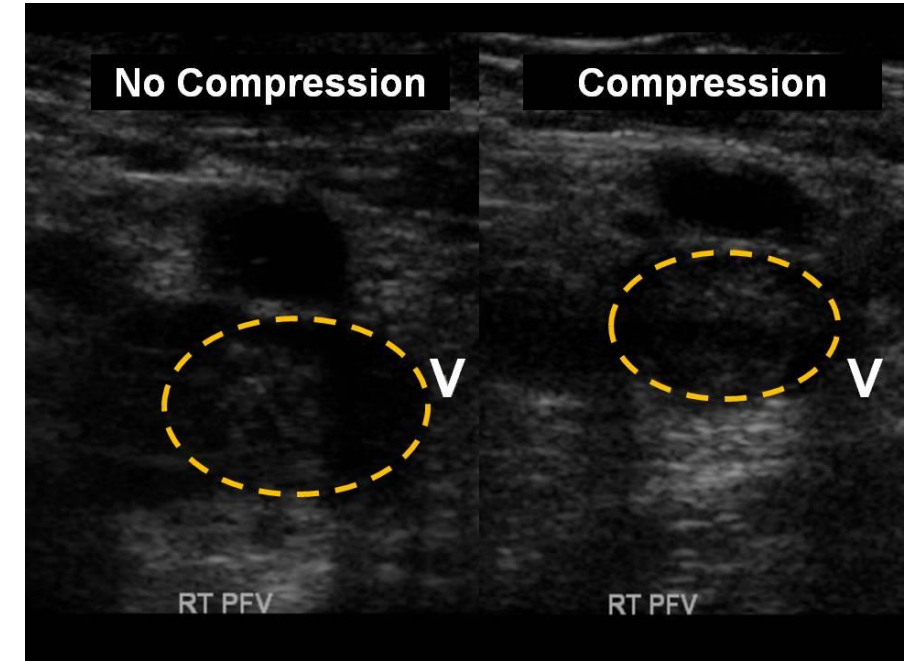
Case No. 2

A 41-year-old woman with obesity, prediabetes, and hypertension presents with right leg edema and pain 1 week after hysterectomy for fibroids.

She admits to being quite sedentary post-operatively and has mostly been sitting on the couch playing video games.

Venous ultrasound demonstrates right femoral DVT extending into the calf.

She has been managing her pain at home with acetaminophen.



Question No. 2

Which of the following is the most appropriate next step in management?

- a) Admit for IV unfractionated heparin bolus and infusion
- b) Start dabigatran 150 mg twice daily
- c) Start rivaroxaban 15 mg twice daily for 3 weeks then switch to 20 mg daily
- d) Start edoxaban 90 mg once daily
- e) Start apixaban 2.5 mg twice daily



Question No. 2

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- c) Start rivaroxaban 15 mg twice daily for 3 weeks then switch to 20 mg daily
- d) Start edoxaban 90 mg once daily
- e) Start apixaban 2.5 mg twice daily

Explanation: Rivaroxaban 15 mg twice daily for 3 weeks then 20 mg daily is the only correct FDA-approved regimen listed for acute DVT. Admission for IV heparin is not necessary.



Immediate Anticoagulation for PE: Lessons from PE Response Team Registries

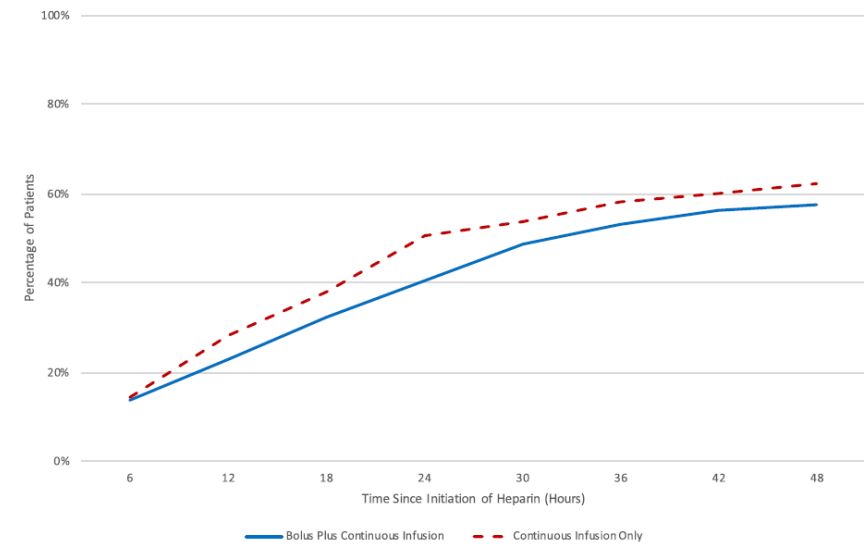
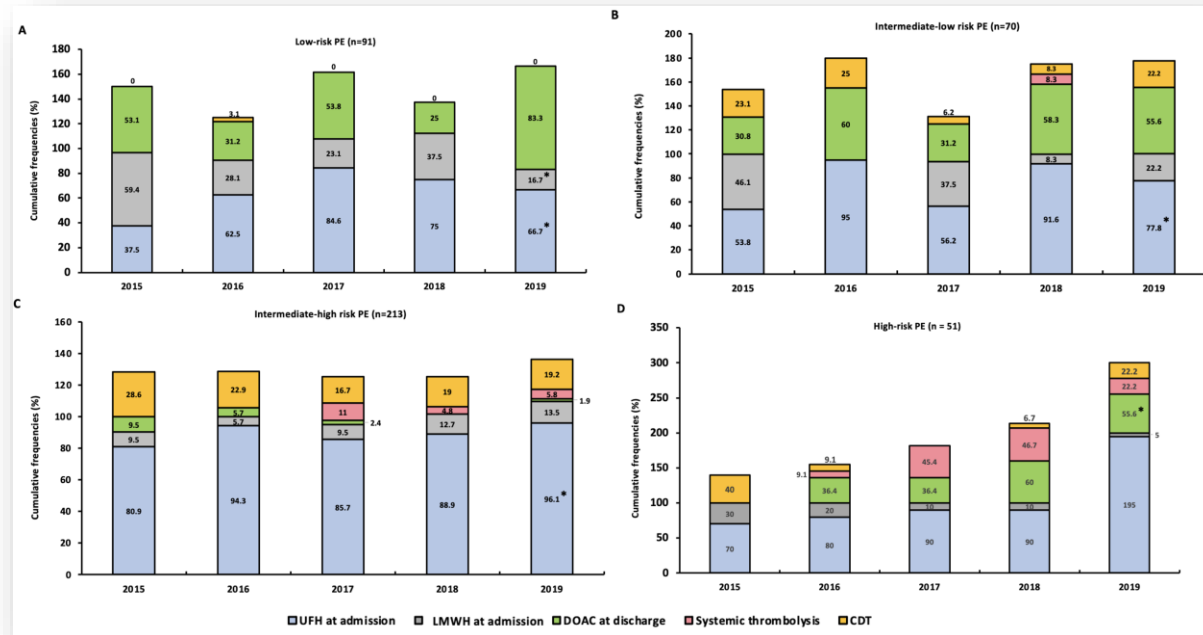


Figure 5 Percentage of patients in each dosing group who have ever had a therapeutic aPTT value over time. aPTT = activated partial thromboplastin time.



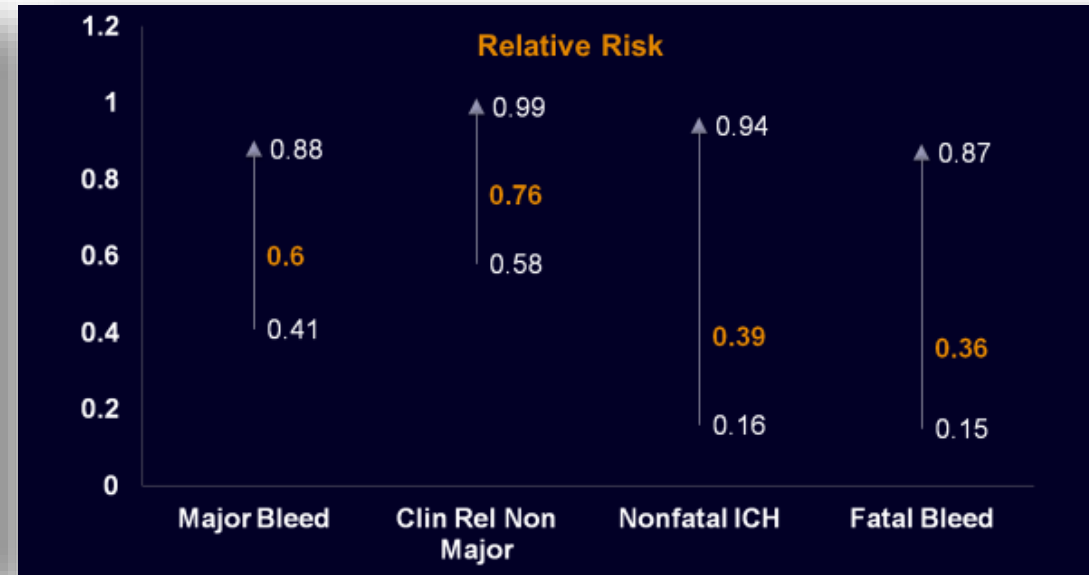
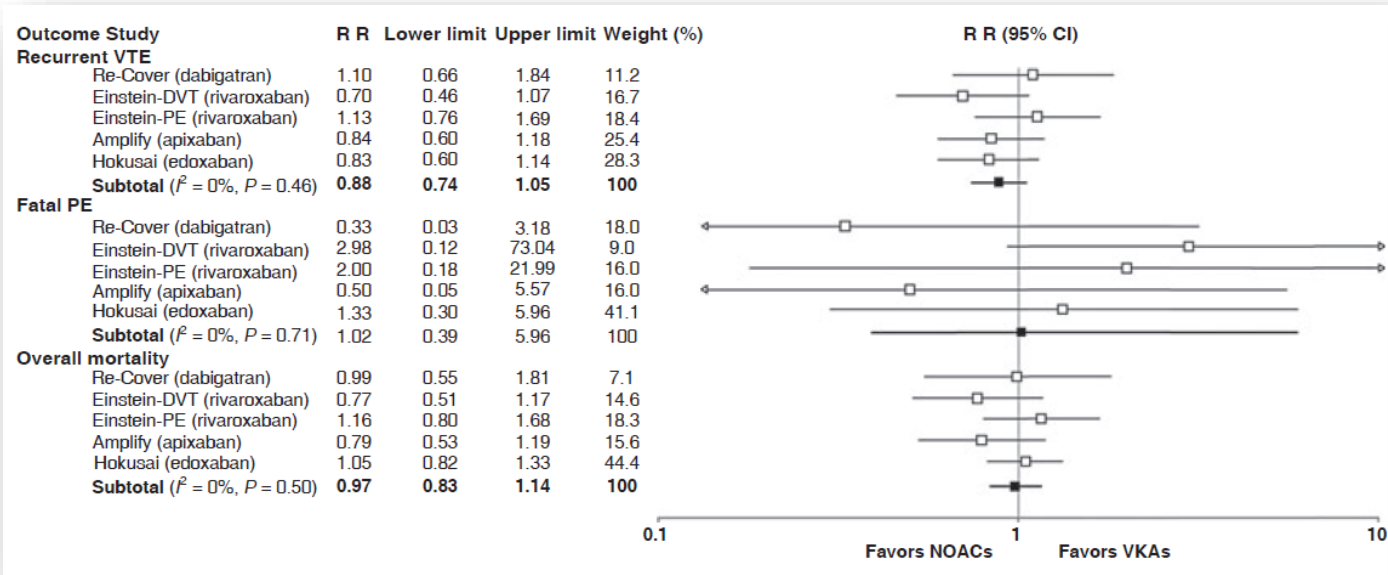
Immediate Management of PE: Recommendations by 2026 AHA/ACC Clinical Categories

Initial Assessment and Management by AHA/ACC Acute PE Clinical Categories								
Category A	Category B	Category C1	Category C2	Category C3	Category D1	Category D2	Category E1	Category E2
Subclinical	Symptomatic, Low Clinical Severity Score	Symptomatic, Elevated Clinical Severity Score	Symptomatic, Elevated Clinical Severity Score	Symptomatic, Elevated Clinical Severity Score	Incipient Cardiopulmonary Failure	Incipient Cardiopulmonary Failure	Cardiopulmonary Failure	Cardiopulmonary Failure
Initiate DOAC	1	Initiate LMWH					1	Initiate LMWH or UFH
Use HESTIA, PESI, and/or sPESI to assess short-term risk	1	Measure at least 1 cardiac biomarker			1			
		Measure lactate						1
		Evaluate RV size and function with CT and/or echo					1	VA-ECMO
								2a

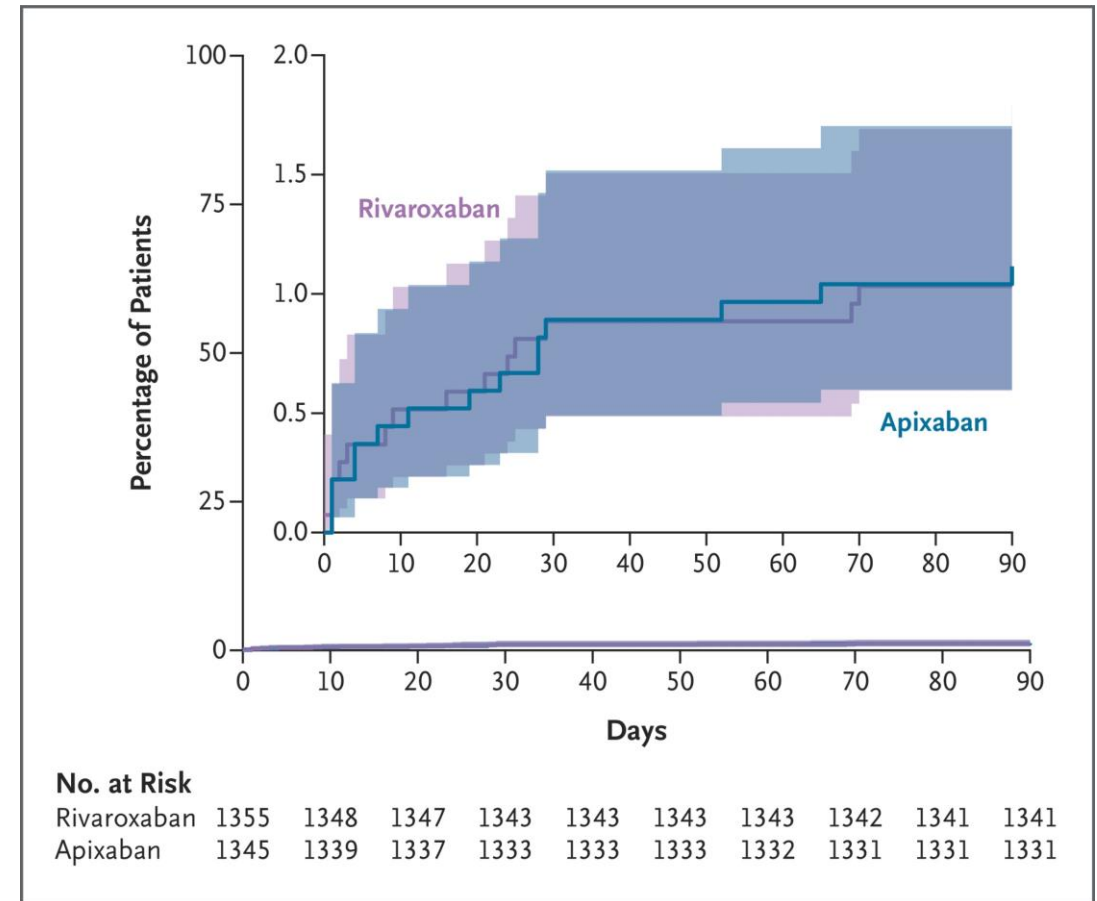
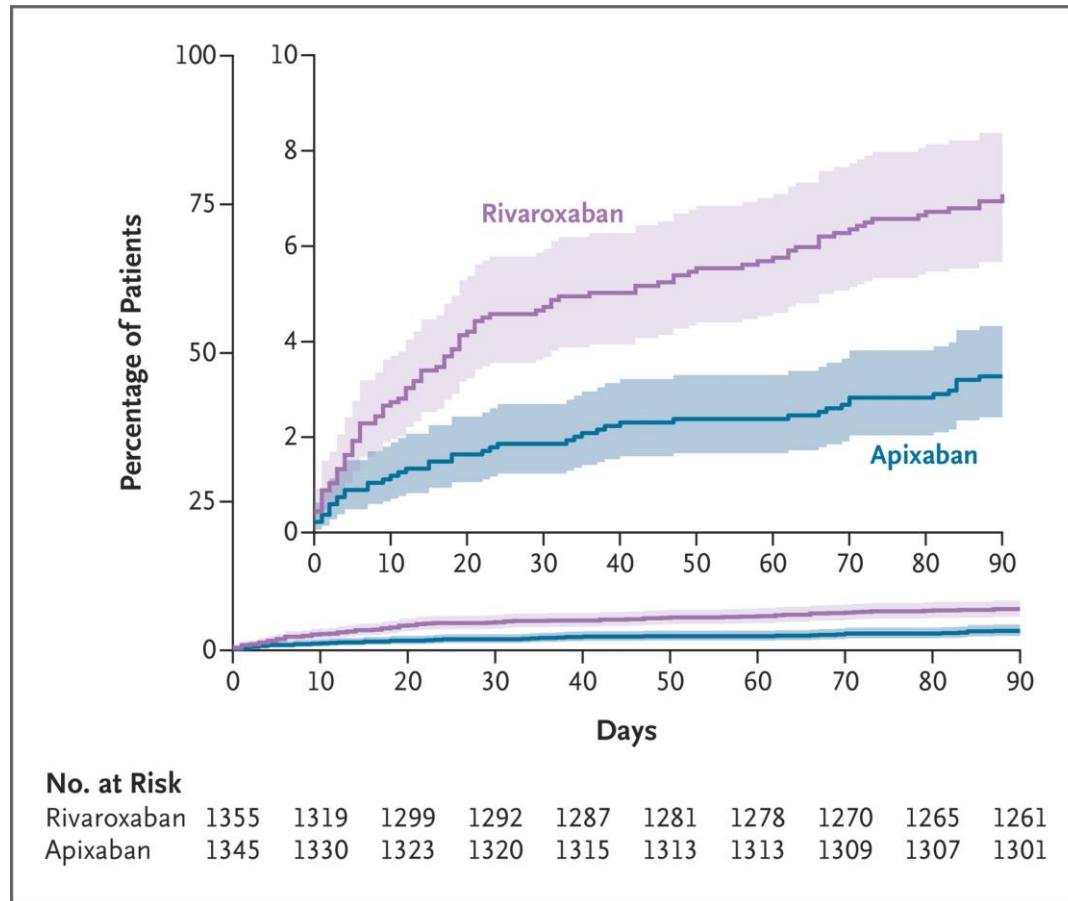
COR	LOE	GENERAL RECOMMENDATIONS
1	B-R	2. In patients with acute PE in AHA/ACC Categories C1-E1 who require parenteral anticoagulant therapy initially, LMWH is recommended over UFH to reduce recurrent VTE and major bleeding. ²



Efficacy and Safety of DOACs for VTE Treatment: Meta-Analysis



Bleeding Risk with Apixaban vs. Rivaroxaban in Acute Venous Thromboembolism: COBRRA

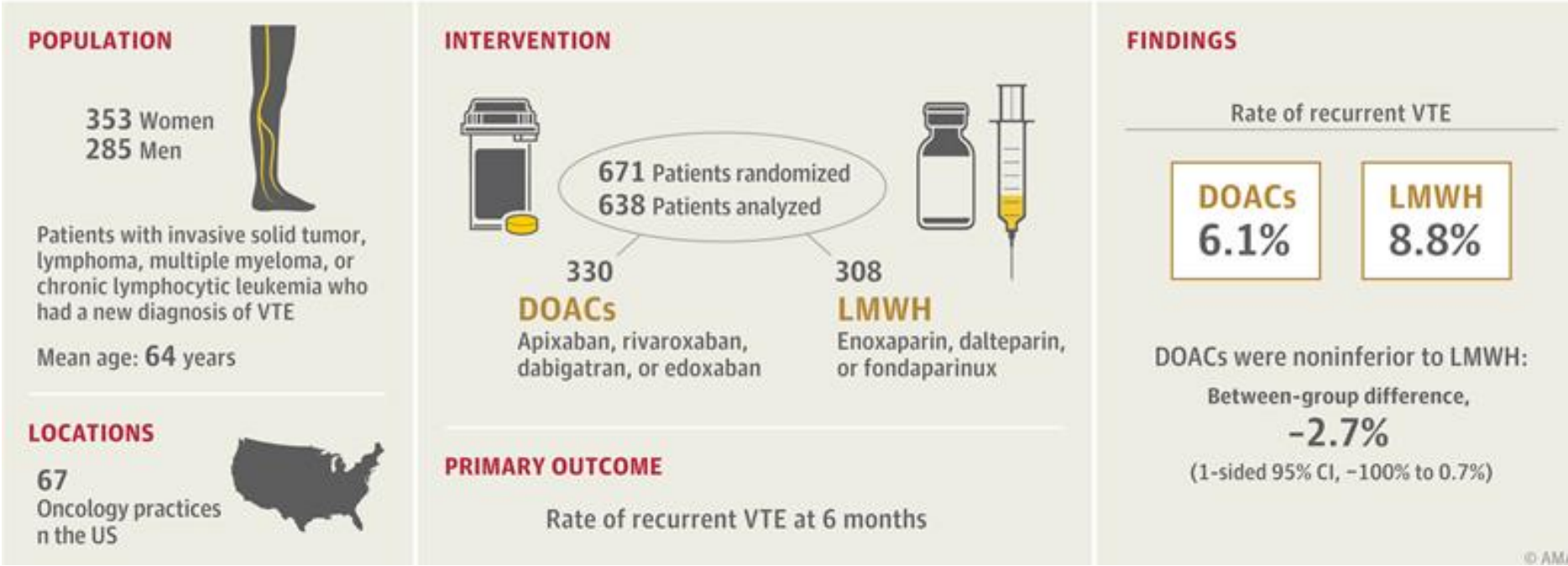


Comparative effectiveness DOAC vs LMWH for VTE in cancer

CANVAS Pragmatic Trial

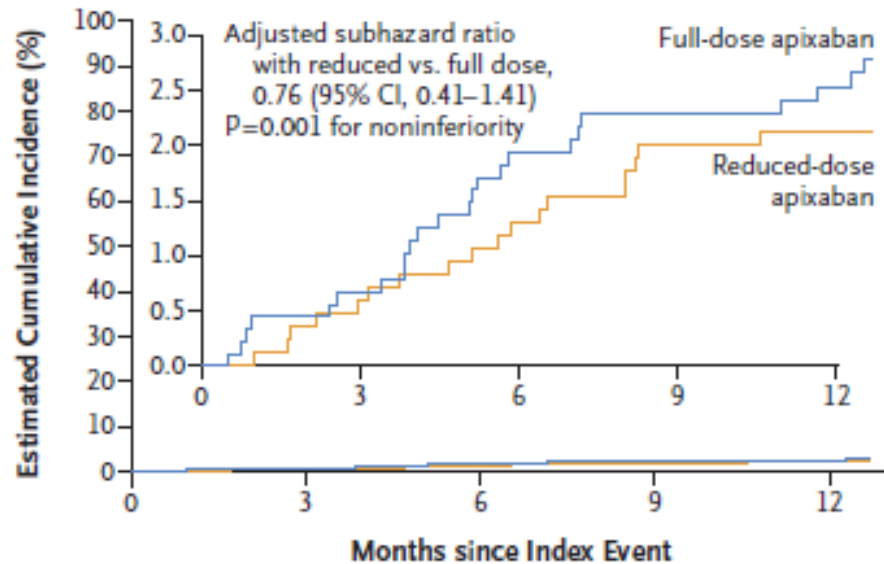
QUESTION Among patients with cancer and a venous thromboembolism (VTE) event, are direct oral anticoagulants (DOACs) noninferior to low-molecular-weight heparin (LMWH) for preventing recurrent VTE events?

CONCLUSION Among adults with cancer and VTE, DOACs were noninferior to LMWH for preventing recurrent VTE over 6-month follow-up.



API-CAT: Extended Reduced-Dose Apixaban for Cancer-Associated VTE

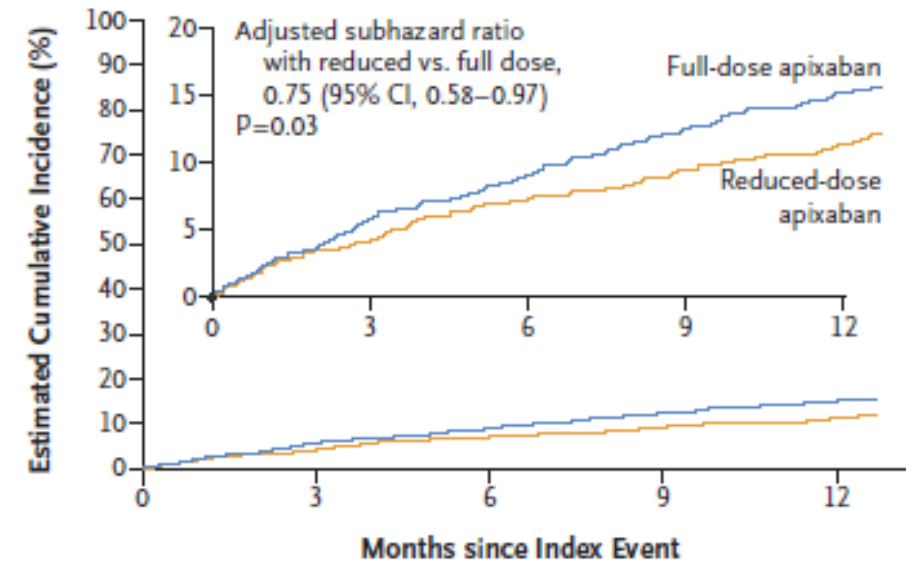
A Recurrent Venous Thromboembolism



No. at Risk

Full-dose apixaban	900	834	771	722	659
Reduced-dose apixaban	866	820	769	722	660

B Clinically Relevant Bleeding






















































No. at Risk

Full-dose apixaban	900	796	725	682	593
Reduced-dose apixaban	866	795	736	662	619

Mahé I, et al. N Engl J Med. 2025;392:1363



Anticoagulation for Acute PE: Evidence-Based Guideline Recommendations

 Suggested  Not addressed  Not recommended	ESC/ERS [2] 	PERT [12] 	CHEST [13] 	AHA [14] 	ASH [16] 	NICE [20] 
Therapeutic anticoagulation should be initiated while awaiting diagnostic results if the pretest probability of PE is intermediate or high and the bleeding risk is low						 a
Therapeutic anticoagulation should be given to all patients with confirmed PE who do not have a contraindication				 b		
Immediate anticoagulant choice in high-risk PE if advanced therapies are considered: unfractionated heparin						
Immediate anticoagulant in intermediate-high risk PE not requiring advanced therapies: LMWH or DOAC (unless contraindications)					 e	
Immediate anticoagulant choice in low-risk PE: DOAC (unless contraindications)					 e	
Immediate anticoagulant choice in patients with HIT or a history of HIT: parenteral direct thrombin inhibitor or fondaparinux	 c			 d	 f	
For oral anticoagulation in the treatment phase of PE, DOAC is recommended over VKA unless there is severe kidney disease, concomitant use of interacting drugs, or antiphospholipid syndrome	 d					

a. If PE unlikely, but D-dimer cannot be offered within 4 hours, NICE 2020 guidelines recommend interim anticoagulation while awaiting results
 b. Therapeutic anticoagulation with LMWH, IV/SC heparin, or fondaparinux is recommended for all patients with confirmed PE.
 c. No preference for parenteral or oral anticoagulation for intermediate or low-risk PE in the formal recommendations; LMWH or fondaparinux preferred over UFH.
 d. Recommends danaparoid, lepirudin, argatroban or bivalirudin; ESC 2019 recommends fondaparinux if allergy or adverse reaction to LMWH
 e. ASH does not differentiate the choice of agents based on acuity of care
 f. ASH provides specific comments on the management of HIT in VTE into a dedicated guidelines [18]



Advanced Therapies



Fibrinolysis



Catheter-Directed Therapy



Surgical Embolectomy




























































Mechanical Circulatory Support



IVC Filter

Advanced Therapies for Acute PE: Evidence-Based Guideline Recommendations

 Suggested  Not addressed  Not recommended	ESC/ERS [2] 	PERT [12] 	CHEST [13] 	AHA [10, 14] 	ASH [16] 	NICE [20] 
Systemic fibrinolysis in hemodynamically unstable PE patients						
Systemic fibrinolysis in hemodynamically stable experiencing hemodynamic and/or respiratory worsening						
Reduced dose systemic fibrinolysis		 b				
Routine use of systemic fibrinolysis in hemodynamically stable PE patients						
Surgical embolectomy in hemodynamically unstable PE patients						 e
CDIs in hemodynamically unstable PE patients in whom systemic fibrinolysis has failed or is contraindicated					 c	 f
CDIs in hemodynamically stable experiencing hemodynamic and/or respiratory worsening					 d	 f
Extracorporeal Membrane Oxygenation (ECMO)	 a					

a. ECMO may be considered in combination with surgical embolectomy or catheter-directed therapies in patients with refractory cardiogenic shock.
 b. In high-risk patients with relative contraindications to systemic fibrinolysis
 c. In centers with the appropriate infrastructure, clinical staff, and procedural experience
 d. Prefer systemic fibrinolysis and perform close cardiovascular monitoring to promptly identify the development of hemodynamic compromise.
 e. Surgical thrombectomy may occasionally be performed for patients with a life-threatening PE
 f. Catheter-based embolectomy should only be used within the confines of research protocols due the absence of adequate supporting clinical trials



Advanced Intervention for Acute PE

Recommendations for Systemic Thrombolysis Referenced studies that support recommendations are summarized in the Evidence Table.

COR	LOE	RECOMMENDATIONS
2a	C-LD	1. In patients with acute PE in AHA/ACC PE Categories E1-2 and acceptable bleeding risk, in whom advanced therapy is being considered, systemic thrombolysis and anticoagulation is reasonable over anticoagulation alone to reduce mortality and recurrent PE. ¹⁻³
2b	C-LD	2. In patients with acute PE in AHA/ACC PE Categories D1-2 and an acceptable bleeding risk, in whom advanced therapy is being considered, systemic thrombolysis and anticoagulation may be considered over anticoagulation alone to prevent further clinical deterioration. ^{1,4}
2b	C-LD	3. In patients with acute PE in AHA/ACC PE Category C3 and acceptable bleeding risk, in whom advanced therapy is being considered, the use of systemic thrombolysis and anticoagulation over anticoagulation alone to prevent further clinical deterioration is uncertain. ^{1,4,5}

Recommendations for Catheter-Directed Thrombolysis Referenced studies that support recommendations are summarized in the Evidence Table.

COR	LOE	RECOMMENDATIONS
2a	C-LD	1. In patients with acute PE in AHA/ACC PE Category E1, CDL plus anticoagulation is reasonable to prevent further clinical deterioration and early mortality. ^{1,8}
2b	B-NR	2. In patients with acute PE in AHA/ACC PE Categories D1-2 in whom advanced therapy is being considered, CDL plus anticoagulation may be considered to prevent further clinical deterioration. ²
2b	C-LD	3. In patients with acute PE in AHA/ACC PE Categories C2-3, the benefit of CDL plus anticoagulation compared with anticoagulation alone to prevent short-term fatal/nonfatal clinical deterioration, and improve long-term mortality, functional capacity, and quality of life is unclear. ³

Recommendations for Mechanical Thrombectomy Referenced studies that support recommendations are summarized in the Evidence Table.

COR	LOE	RECOMMENDATIONS
2a	B-NR	1. In patients with acute PE in AHA/ACC PE Category E1, it is reasonable to choose MT plus anticoagulation over anticoagulation alone to prevent further clinical decompensation and acute mortality. ¹⁻³
2b	B-NR	2. In patients with acute PE in AHA/ACC PE Categories D1-2 in whom advanced therapy is being considered, MT plus anticoagulation may be considered over anticoagulation alone to prevent further clinical deterioration. ⁴⁻⁶
2b	C-LD	3. In patients with acute PE in AHA/ACC PE Categories C2-3, the benefit of MT plus anticoagulation compared with anticoagulation alone is unclear in preventing short-term fatal/nonfatal clinical deterioration and improving long-term survival and functional capacity. ⁷



Systemic Fibrinolysis

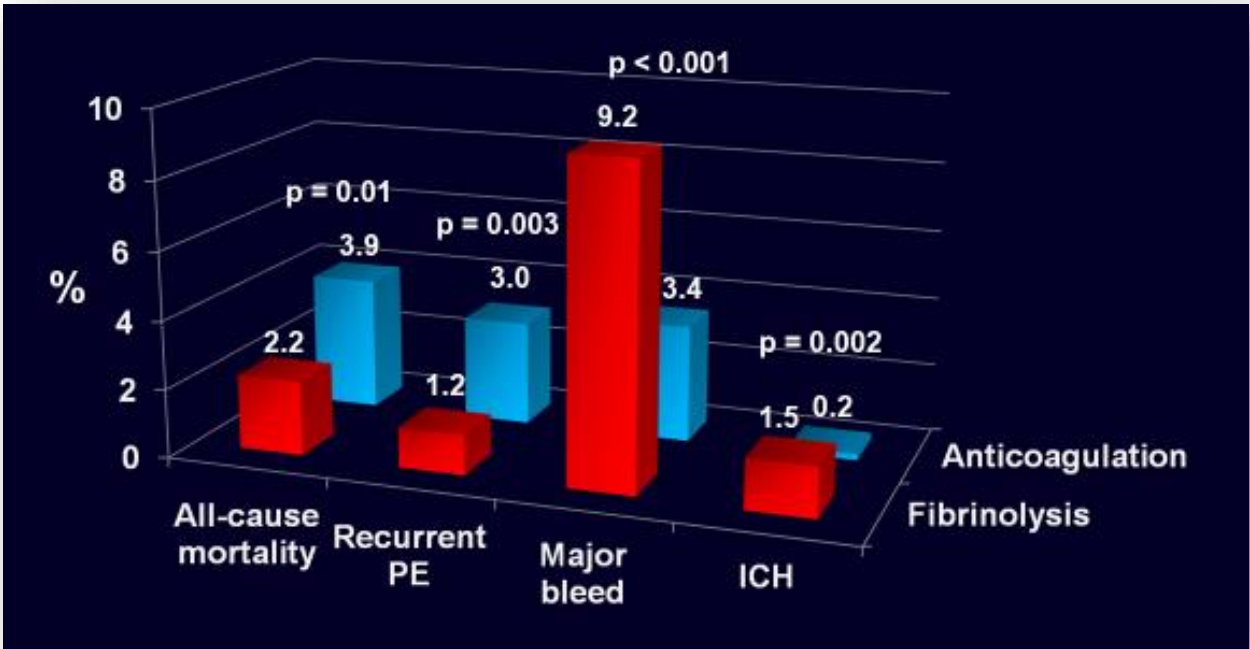
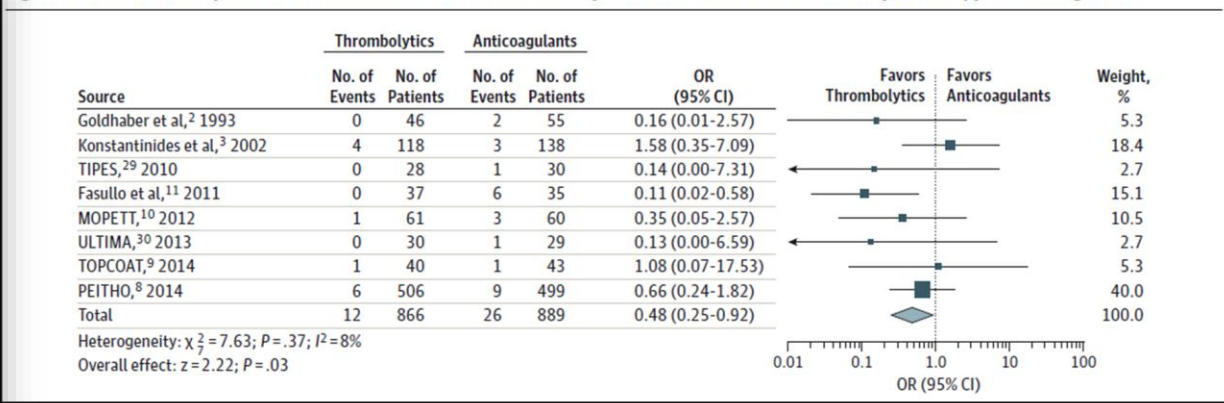
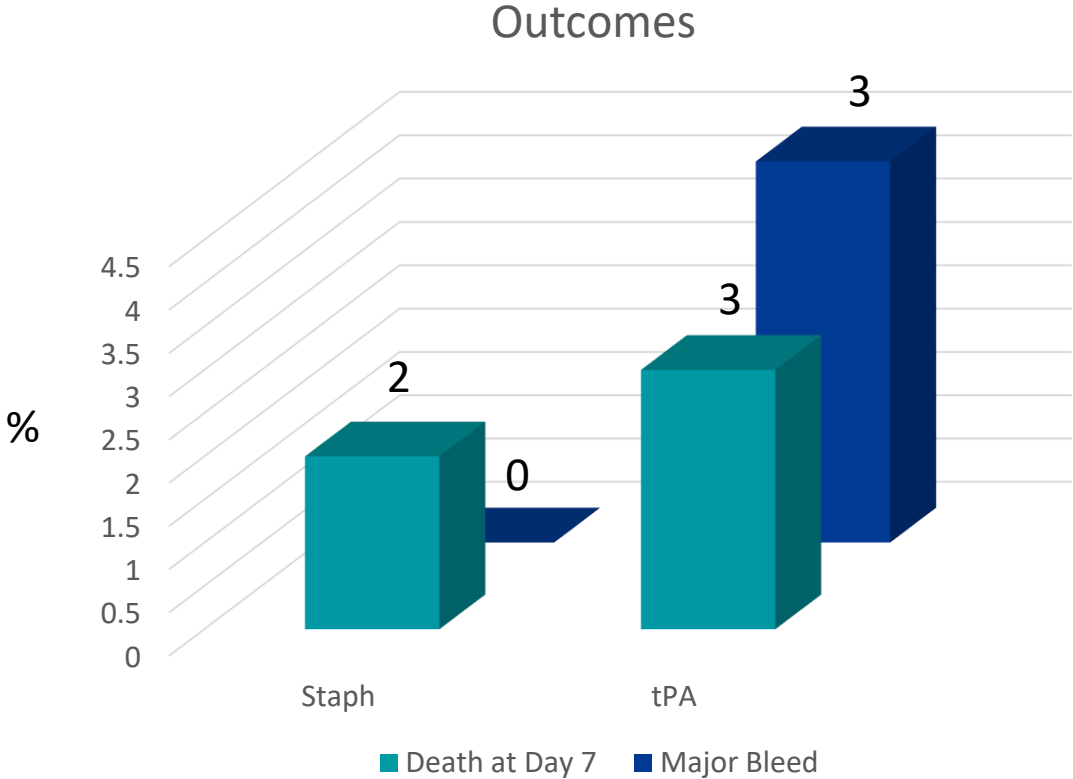
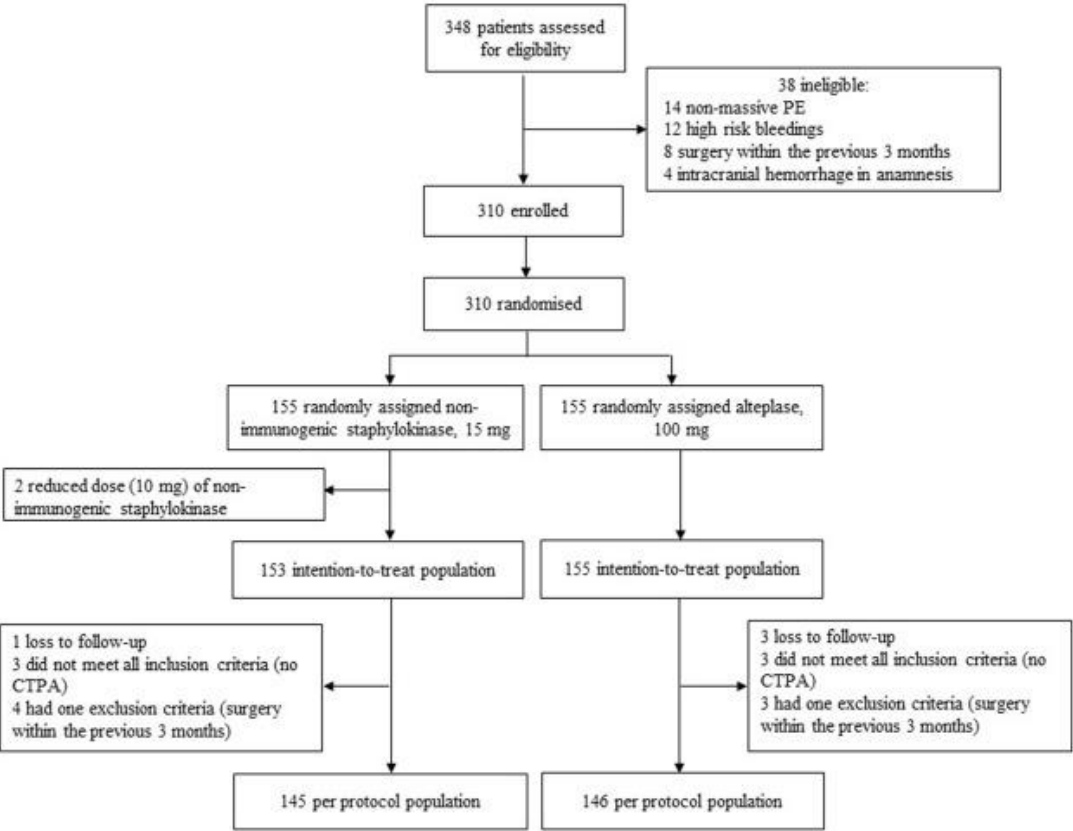


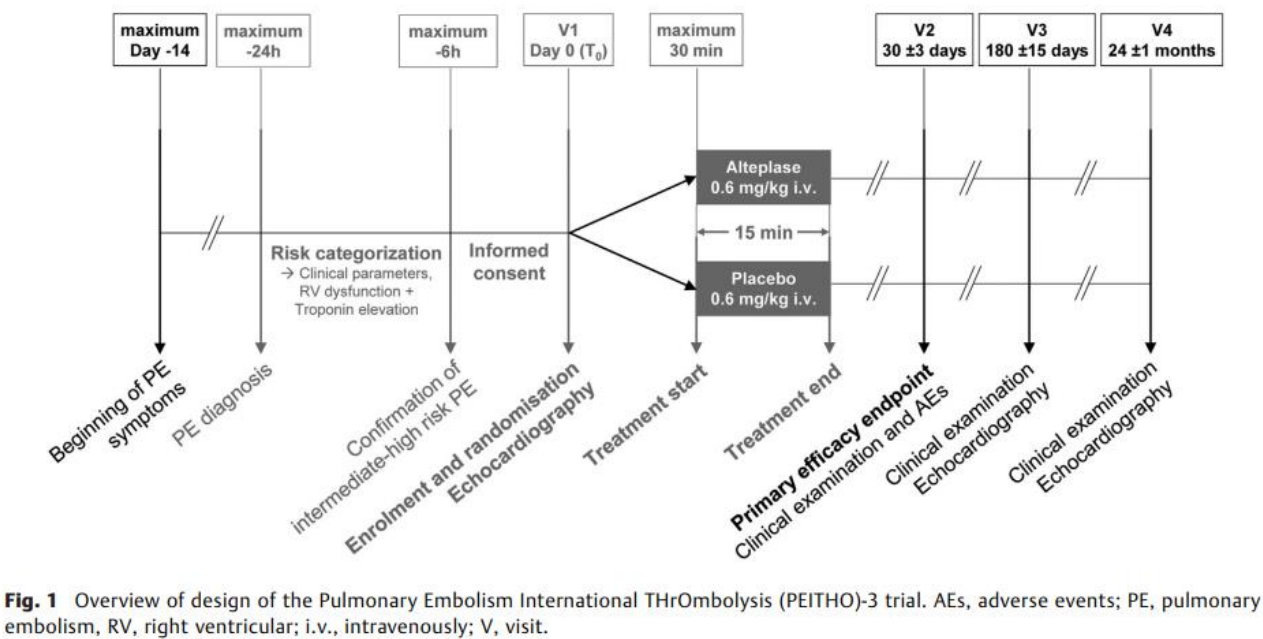
Figure 3. Odds of Mortality in Patients With Intermediate-Risk Pulmonary Embolism Treated With Thrombolytic Therapy vs Anticoagulation



FORPE: Non-immunogenic Recombinant Staphylokinase versus Alteplase for High-Risk PE



PEITHO-3: Reduced-Dose Intravenous Thrombolysis for Intermediate-High Risk PE

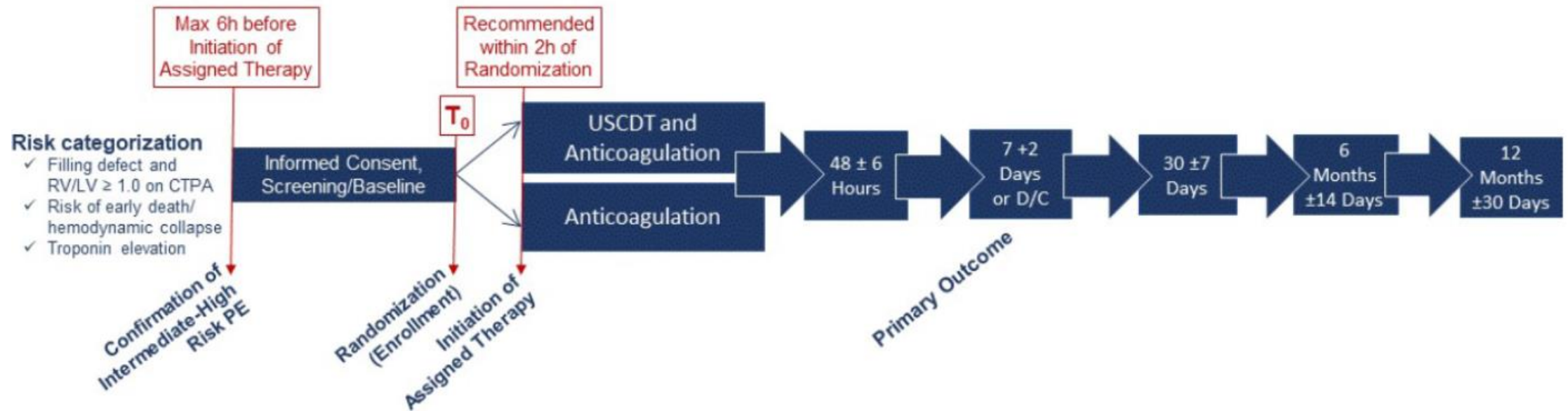


Primary outcome	Clinical composite of death from any cause or hemodynamic decompensation or objectively confirmed recurrent PE within 30 days of randomization
Secondary outcomes	<p>To be included in a hierarchical analysis:</p> <ol style="list-style-type: none"> 1. Fatal or GUSTO severe or life-threatening bleeding, defined as either intracranial bleeding or bleeding leading to significant hemodynamic compromise requiring treatment,³⁸ within 30 days 2. Net clinical benefit, defined as the composite of the primary efficacy outcome and GUSTO severe or life-threatening bleeding, within 30 days 3. All-cause mortality within 30 days <p>Not to be included in the hierarchical analysis:</p> <ol style="list-style-type: none"> 4. PE-related death within 30 days of randomization 5. Hemodynamic decompensation within 30 days 6. Recurrent PE within 30 days 7. Need for rescue thrombolysis, catheter-directed treatment, or surgical embolectomy within 30 days 8. Ischemic or hemorrhagic stroke within 30 days 9. Serious adverse events within 30 days 10. Utilization of health care resources within 30 days and 6 months 11. All-cause mortality at 2 years 12. Persisting dyspnea assessed by the Medical Research Council (MRC) scale at 6 months and at 2 years 13. Functional outcome, using the post-VTE functional scale,³⁹ at 6 months and at 2 years 14. Persistent RV dysfunction, defined as an intermediate or high probability of pulmonary hypertension on echocardiography according to ESC criteria,⁴⁰ at 6 months and 2 years 15. Confirmed chronic thromboembolic pulmonary hypertension according to ESC criteria⁴⁰ at 2 years

HI-PEITHO: Randomized Controlled Trial

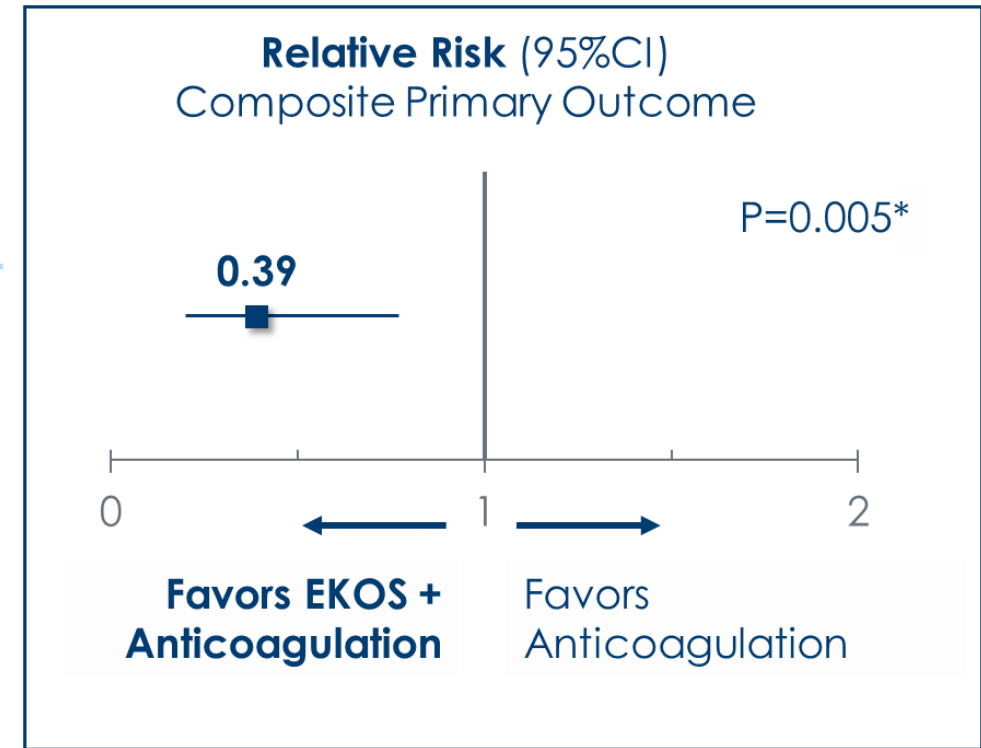
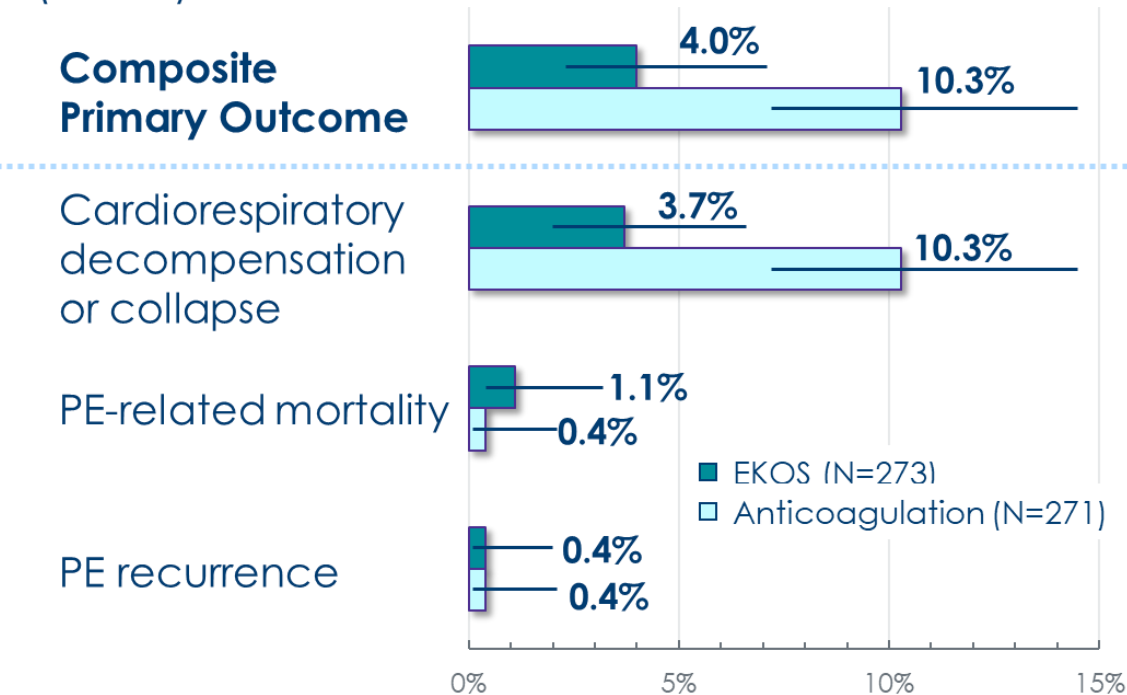
A randomized trial of ultrasound-facilitated, catheter-directed, thrombolysis versus anticoagulation
for acute intermediate-high risk pulmonary embolism:

The Higher-risk Pulmonary Embolism THrOmbolysis study (HI-PEITHO)



HI-PEITHO: Ultrasound-Facilitated, Catheter-Directed Fibrinolysis for Acute Pulmonary Embolism

Percentage of ITT Patients with Primary Outcome Events (95%CI)



Rosenfield K, et al. N Engl J Med. 2026. doi: 10.1056/NEJMoa2516567.
Konstantinides S, ACC26. Mar 28, 2026; New Orleans, USA.

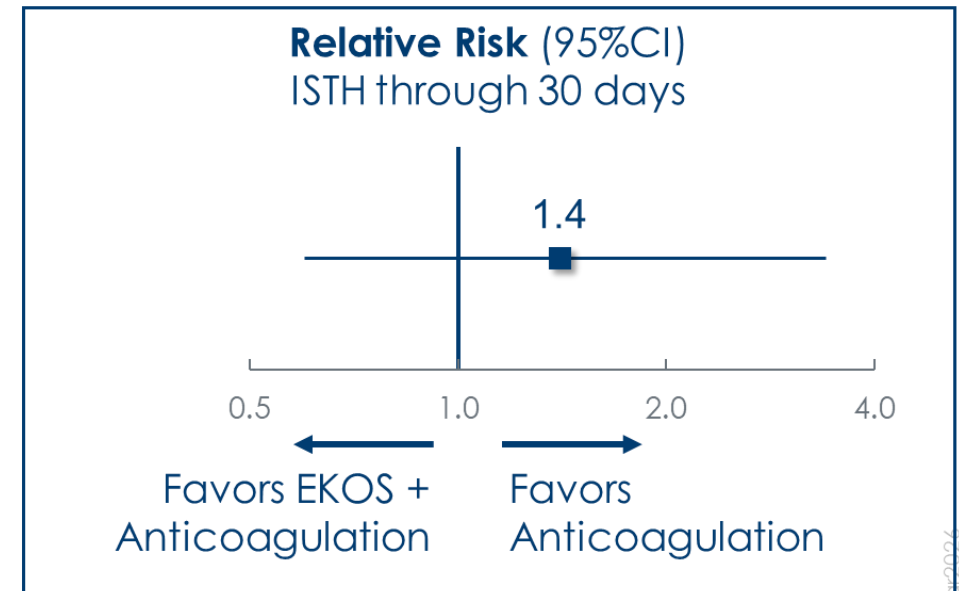
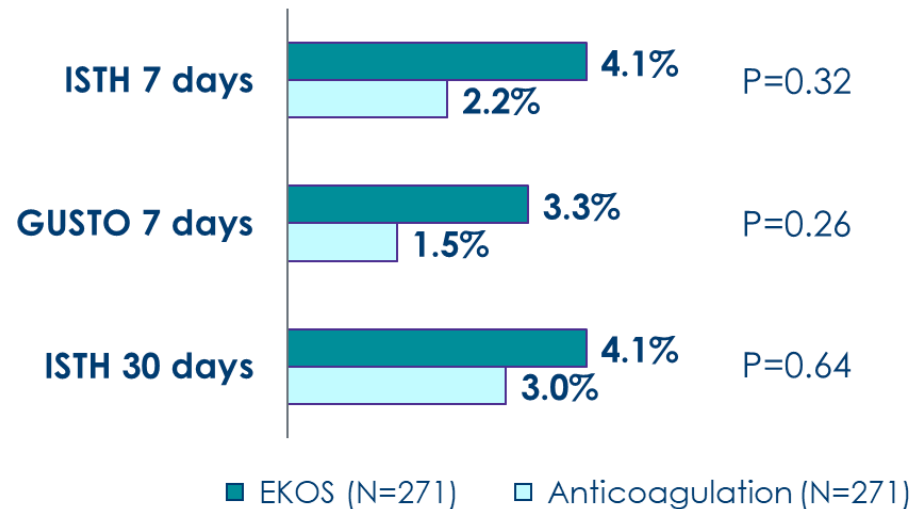
Primary outcome events occurred within 7 (+2) days of randomization or at discharge and were adjudicated by an independent, blinded clinical events committee.
* Two-sided P-value using Fisher's exact test; P-value <0.02938 indicates significance.

VT-2462014-AA Mar 2026



HI-PEITHO: Ultrasound-Facilitated, Catheter-Directed Fibrinolysis for Acute Pulmonary Embolism

Percentage of Treated Patients with Major Bleeding Events



No intracranial hemorrhage in either group through 30 days

Treated population; includes the 7(+2) day or 30(±7) day visit windows. Adjudicated by an independent, blinded clinical events committee. Two-sided P values using Fisher's exact test.

Rosenfield K, et al. N Engl J Med. 2026. doi: 10.1056/NEJMoa2516567.
Konstantinides S, ACC26. Mar 28, 2026; New Orleans, USA.

CI, confidence interval; GUSTO, Global Use of Strategies to Open Occluded Coronary Arteries; ISTH, International Society on Thrombosis and Haemostasis.



OPTALYSE-3D: Results

Significant increase in small and medium venous but not arterial vascular volumes after treatment with ultrasound-assisted, catheter-directed thrombolysis without a dose response

	Baseline	Post	p*
Central Measures			
MMI	20[20-21]	19[17-20]	<0.0001
RV/LV ratio	1.42[1.23-1.79]	1.06[[0.90-1.19]	<0.0001
Lung Volume (L)	3.84[3.05-4.50]	3.30[2.69-4.38]	0.01
Vascular Measures			
Small Size Arterial Volume	7.2[3.6-15.3]	7.6[3.4-16.1]	0.86
Small Size Venous Volume	4.3[2.9-10.1]	7.4[3.1-11.3]	0.0009
Medium Size Arterial Volume	14.6[10.8-20.0]	15.7[11.2-19.2]	0.54
Medium Size Venous Volume	8.9[6.7-12.3]	10.6[8.5-13.7]	<0.0001

No significant increase in small and medium venous volumes after large-bore catheter thrombectomy or heparin monotherapy, respectively

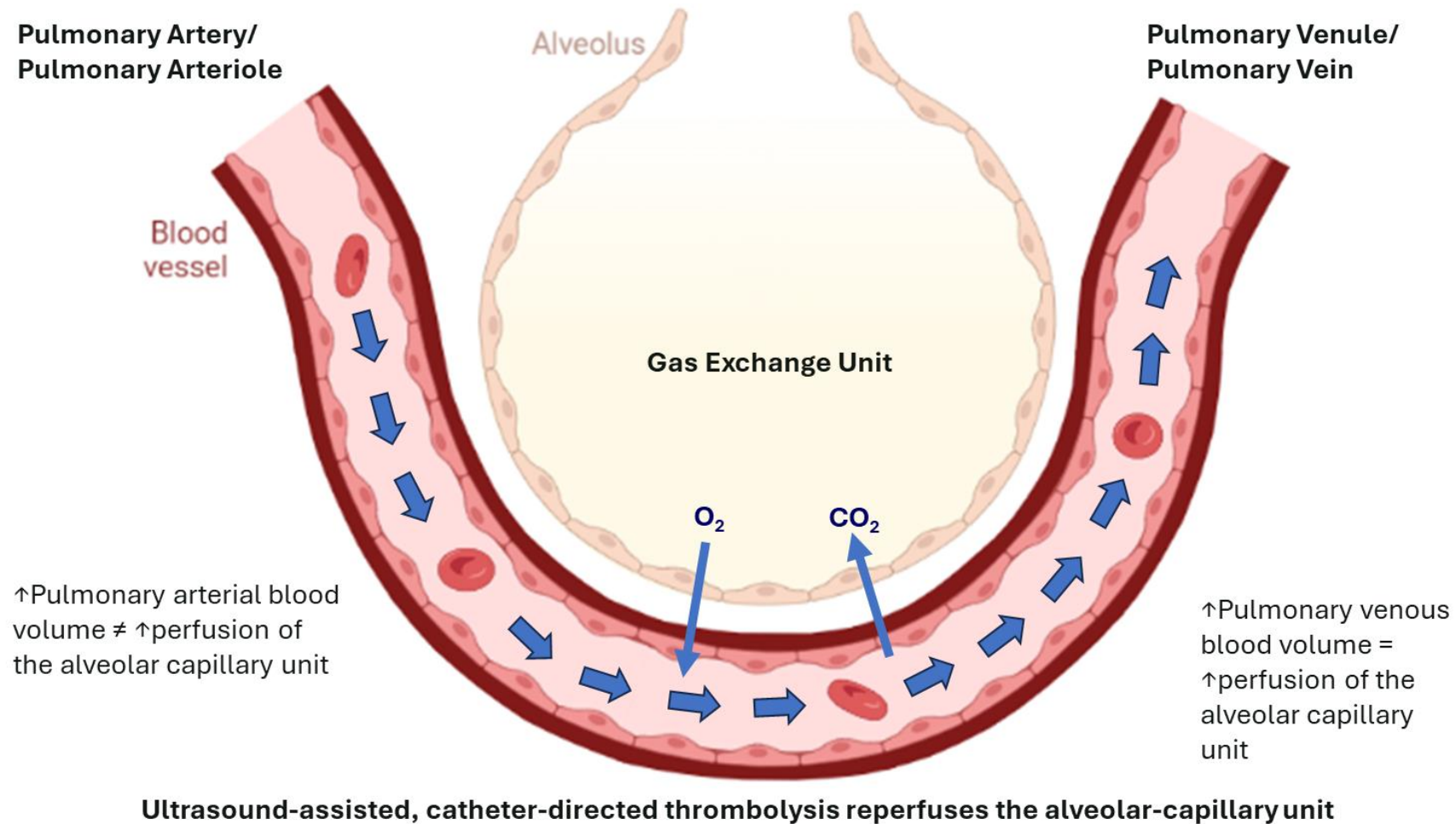
	Baseline	Post	p*
Large-Bore Catheter Thrombectomy Cohort (N = 10)#			
RV/LV ratio	1.40(0.25)	1.17(0.23)	
Lung Volume (L)	3.24[2.64-4.01]	3.31[3.01-3.94]	0.77
Vascular Measures			
Small Size Arterial Volume	20.4[15.1-23.3]	13.97[11.6-17.7]	0.28
Small Size Venous Volume	9.6[7.3-13.0]	8.7[7.1-10.0]	0.63
Medium Size Arterial Volume	13.4[11.2-15.1]	16.6[10.7-18.2]	0.32
Medium Size Venous Volume	6.0[5.5-9.2]	9.7[7.8-11.4]	0.049

Heparin Cohort (N = 10)			
RV/LV ratio	1.15(0.29)	1.10(0.25)	
Lung Volume (L)	2.90[2.36-4.57]	3.55[3.38-4.43]	0.16
Vascular Measures			
Small Size Arterial Volume	18.5[9.2-19.6]	16.4[13.9-16.9]	0.63
Small Size Venous Volume	10.7[4.8-12.9]	9.6[8.5-12.2]	0.85
Medium Size Arterial Volume	16.3[12.7-18.8]	13.0[10.1-15.6]	0.004
Medium Size Venous Volume	9.0[7.4-9.6]	9.0[7.6-10.7]	0.43

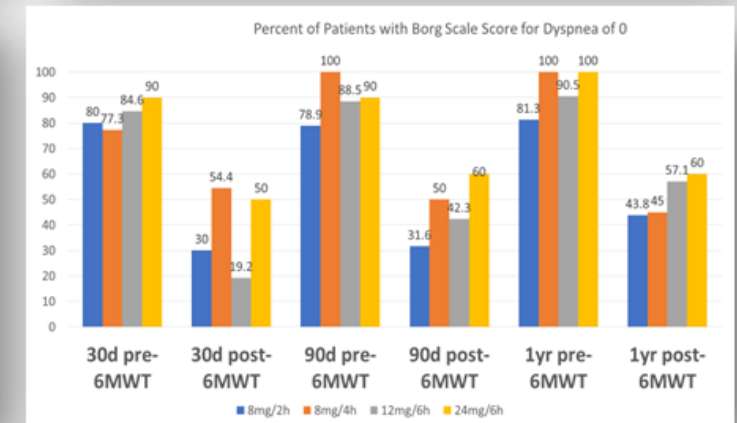
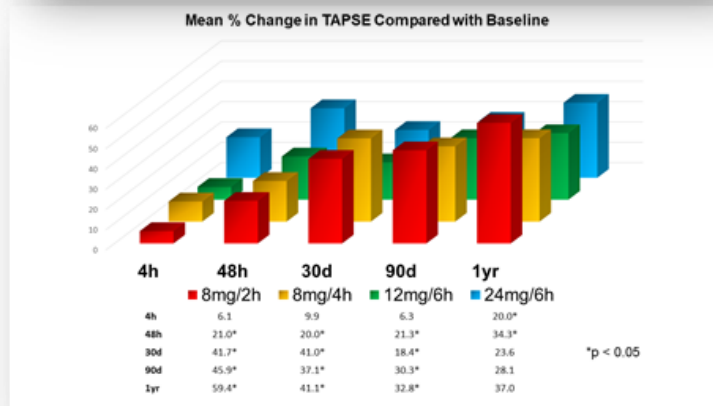
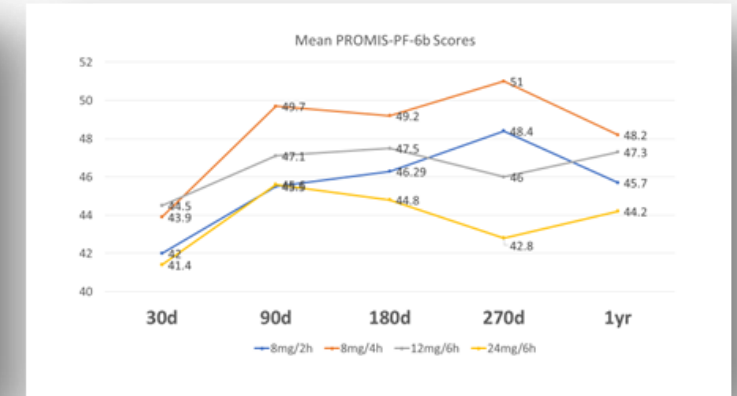
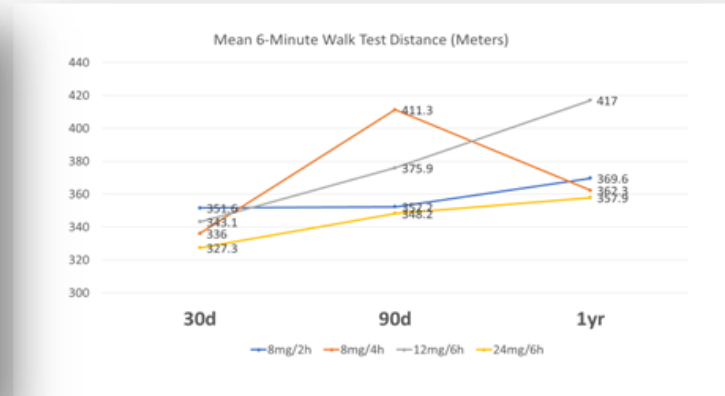
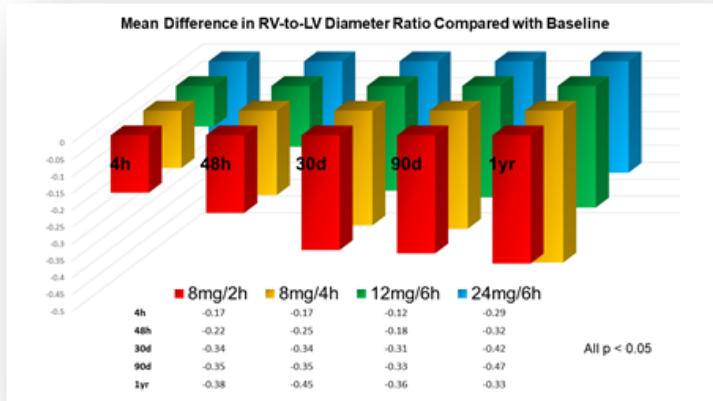
#In the Large-Bore Catheter Thrombectomy cohort, the pre-treatment scans were 1.0mm thick for 6 subjects, 2mm thick for two subjects, 1.5mm thick for one for one subject, and 0.5mm thick for one subject. All post-treatment scans were obtained at 1mm thickness.



OPTALYSE-3D: Implications for Gas Exchange



OPTALYSE-PE: Long-Term Recovery



Mechanical Thrombectomy in High-Risk PE: FLAME Registry

Table 1. Demographics, Medical History, and Clinical Presentation

	FlowTrievers arm (n=53)	Context arm (n=61)
Age, y	64.8±15.3	61.6±13.9
Female	26 (49.1%)	35 (57.4%)
BMI, kg/m ²	32.2±6.1	33.9±8.5
Race		
American Indian or Alaskan Native	0 (0.0%)	0 (0.0%)
Asian	0 (0.0%)	0 (0.0%)
Black or African American	16 (30.2%)	40 (65.6%)
Native Hawaiian or Pacific Islander	0 (0.0%)	0 (0.0%)
White	33 (62.3%)	18 (29.5%)
Other	0 (0.0%)	1 (1.6%)
Not provided	4 (7.5%)	2 (3.3%)

Clinical presentation at admission or time of high-risk PE diagnosis

SCAI shock stage*		
A	2 (3.8%)	1 (1.6%)
B	11 (20.8%)	6 (9.8%)
C	29 (54.7%)	22 (36.1%)
D	5 (9.4%)	12 (19.7%)
E	6 (11.3%)	20 (32.8%)
Systolic BP, mm Hg	97.4±21.4 n=49	93.5±33.4 n=59
Diastolic BP, mm Hg	65.5±14.7 n=49	57.8±23.5 n=59
Heart rate, bpm	99.9±22.6 n=48	103.1±29.4 n=58
Tachycardia, >100 bpm	29 (54.7%)	34 (55.7%)

Table 2. Primary End Point in the FlowTrievers Arm

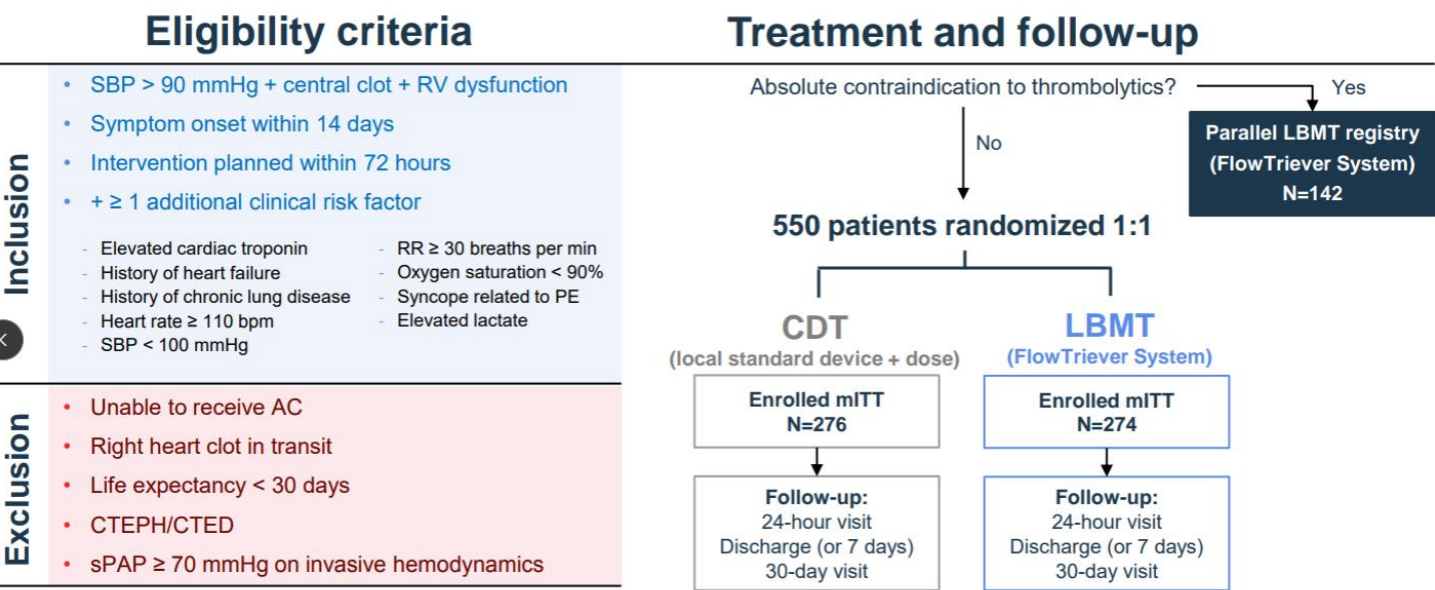
	FlowTrievers arm (n=53)	Performance goal
Primary end point*	9 (17.0%†; 8.1%–9.8%)	32.0%

CONCLUSIONS: Among patients selected for mechanical thrombectomy with the FlowTrievers System, a significantly lower associated rate of in-hospital adverse clinical outcomes was observed compared with a prespecified performance goal, primarily driven by low all-cause mortality of 1.9%.

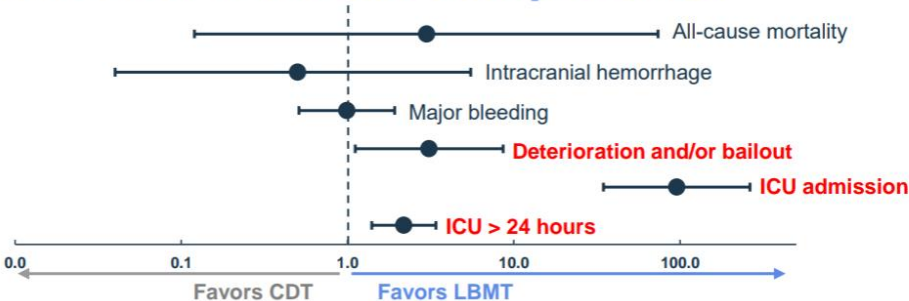


PEERLESS: No Difference in Clinical Outcomes

Trial design



Results: Win ratio components



Removing escalation to bailout patients (because of bias against CDT), there is no statistical difference (LBMT vs. CDT: 4 vs 10 patients; Fisher’s Exact 0.17).

	CDT events	LBMT events	Odds ratio [95% CI]	P value
All-cause mortality	1 (0.4)	0 (0.0)	2.99 [0.12–73.70]	1.00
Intracranial hemorrhage	1 (0.4)	2 (0.7)	0.50 [0.04–5.51]	0.62
Major bleeding	19 (6.9)	19 (6.9)	0.99 [0.51–1.92]	1.00
Clinical deterioration and/or escalation to bailout therapy	15 (5.4)	5 (1.8)	3.09 [1.11–8.63]	0.038
Postprocedural ICU admission	272 (98.6)	114 (41.6)	95.4 [34.6–263.6]	< 0.001
ICU stay > 24 hours*	178 (65.4)	53 (19.0)	2.18 [1.40–3.40]	< 0.001

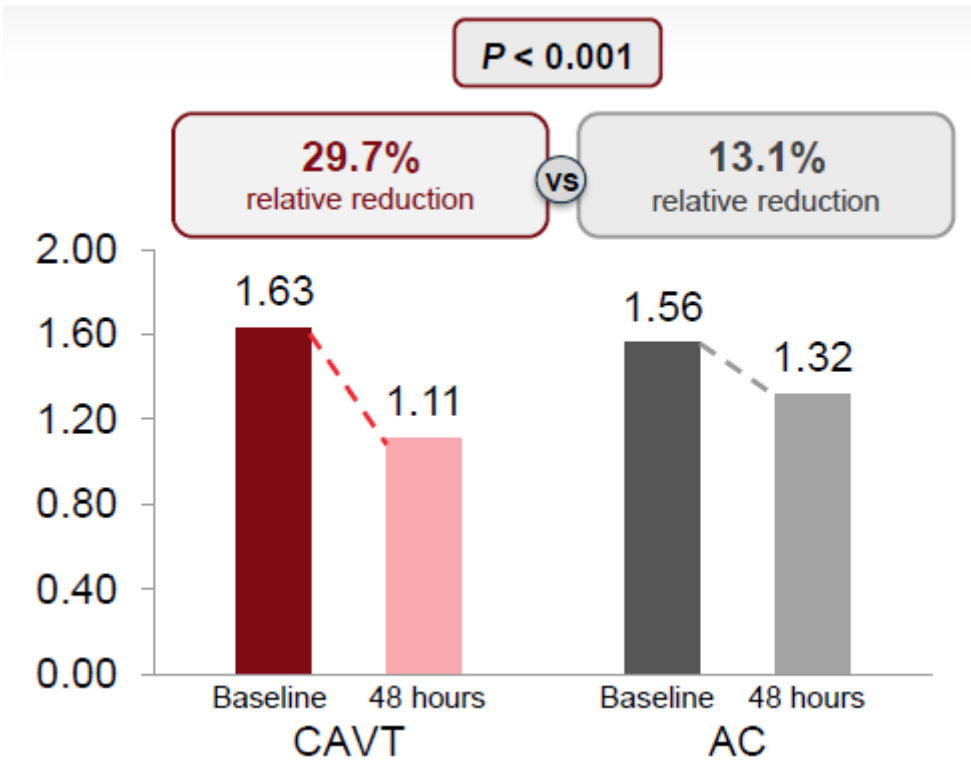
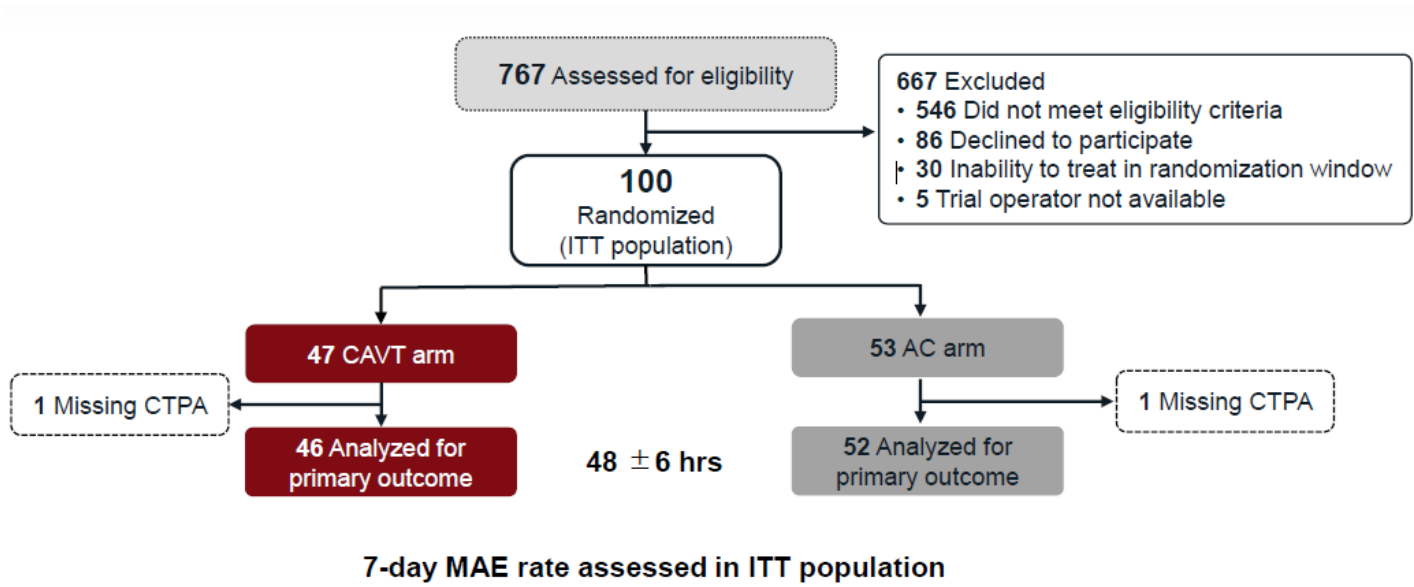
PEERLESS: No Difference in Major Bleeding

Bleeding events through discharge / 7 days

	CDT N = 276	LBMT N = 274	P value
Major bleeding (ISTH)	19 (6.9)	19 (6.9)	1.00
Adjudicated reasons for major bleeding			
Fatal bleeding*	1 (0.4)	0 (0)	
Symptomatic bleeding in a critical area or organ‡	2 (0.7)	2 (0.7)	
Intracranial hemorrhage†	1	2	
Hemarthrosis	1	0	
Hgb drop ≥ 2 g/dL (1.24 mmol/L) and/or transfusion ≥ 2 units	16 (5.8)	17 (6.2)	
Access site source	10	8	
Transfusions administered	8	1	
# units transfused	3.3 ± 1.8	2.0	
Clinically relevant non-major bleeding events‡	9 (3.3)	7 (2.6)	0.80
Minor bleeding events‡	1 (0.4)	6 (2.2)	0.07



STORM-PE



Lookstein RA, et al. Circulation. 2026; 153:21



PE-TRACT: An NIH-Funded Trial

PE-TRACT SPOTLIGHT



DESIGN

Open-label,
assessor-blinded,
phase 3
randomized trial



OBJECTIVE

To compare CDT and anticoagulation
with anticoagulation alone in patients with
submassive PE, proximal artery thrombus,
and RV dilation



ESTIMATED STUDY START DATE

May 2023



ESTIMATED STUDY COMPLETION DATE

January 2028



TARGET ENROLLMENT

500 patients



INCLUSION CRITERIA

Age \geq 18 years, symptomatic PE diagnosed by contrast-enhanced CTA with involvement of a main or lobar pulmonary artery branch, and RV dilation defined by RV/LV ratio $>$ 1.0 on CTA

INTERVENTION

CDT + anticoagulation

- CDT consists of mechanical thrombectomy or intrathrombus catheter-directed thrombolysis
- Anticoagulation for a minimum of 3 months

Anticoagulation alone

- Consists of standard anticoagulant therapy for a minimum of 3 months

1ST

PRIMARY OUTCOME MEASURES

- Peak oxygen consumption at 3 months
- NYHA classification at 12 months
- Incidence of major adverse events at 7 days (ISTH definition)

2ND

SECONDARY OUTCOME MEASURES

- 6MWT at 12 months
- SF-36 score at 12 months
- Incidence of clinical deterioration (fatal and nonfatal) at 7 days
- Cost and cost-effectiveness of CDT



Long-Term Outcomes of Mechanical Thrombectomy Versus Catheter-Directed Thrombolysis

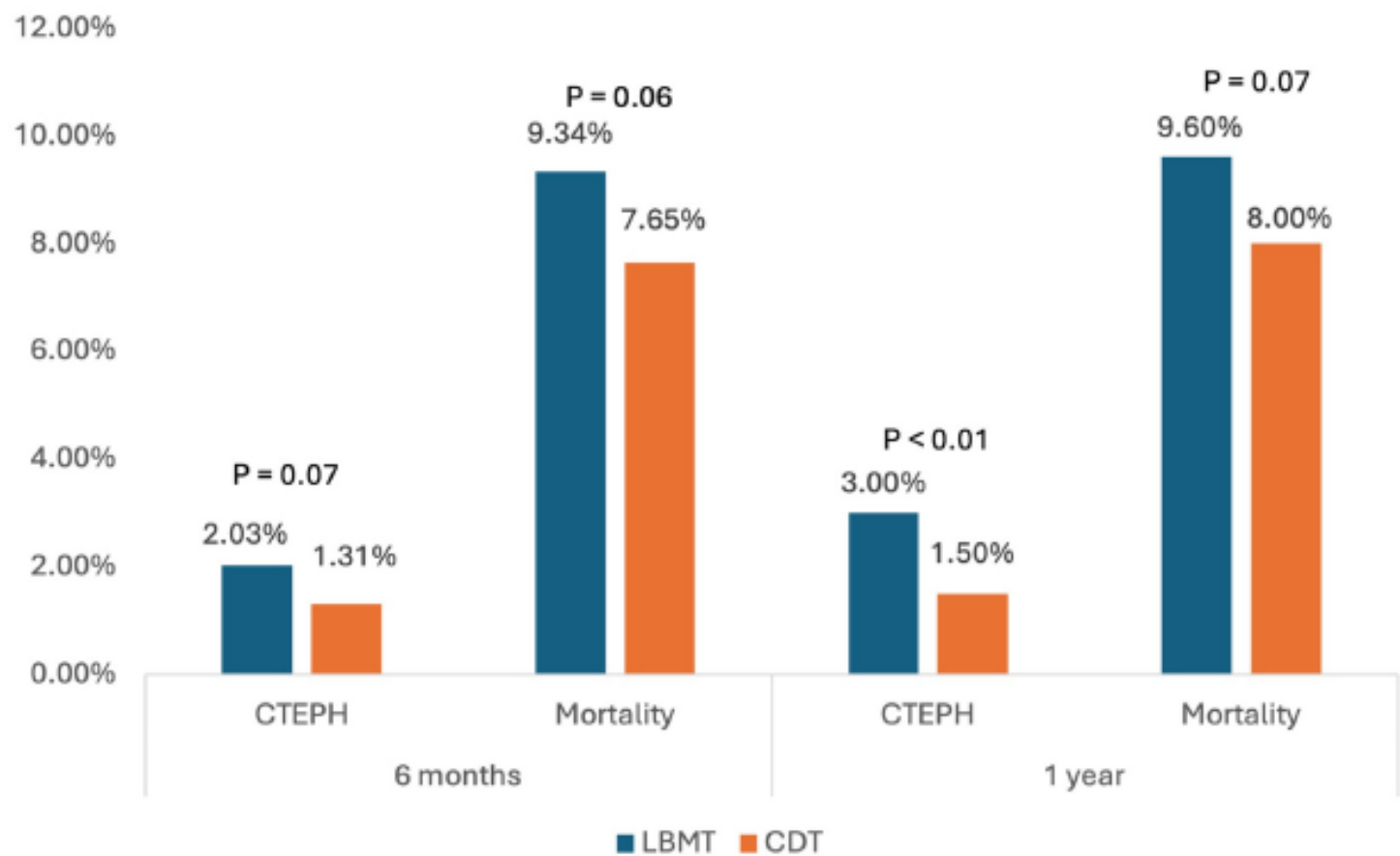


Figure 1. Catheter-directed thrombolysis (CDT) vs large-bore mechanical thrombectomy (LBMT) in patients with pulmonary embolism. Six-month and 1-year incidence of mortality and chronic thromboembolic pulmonary hypertension in LBMT (blue) vs CDT (orange).

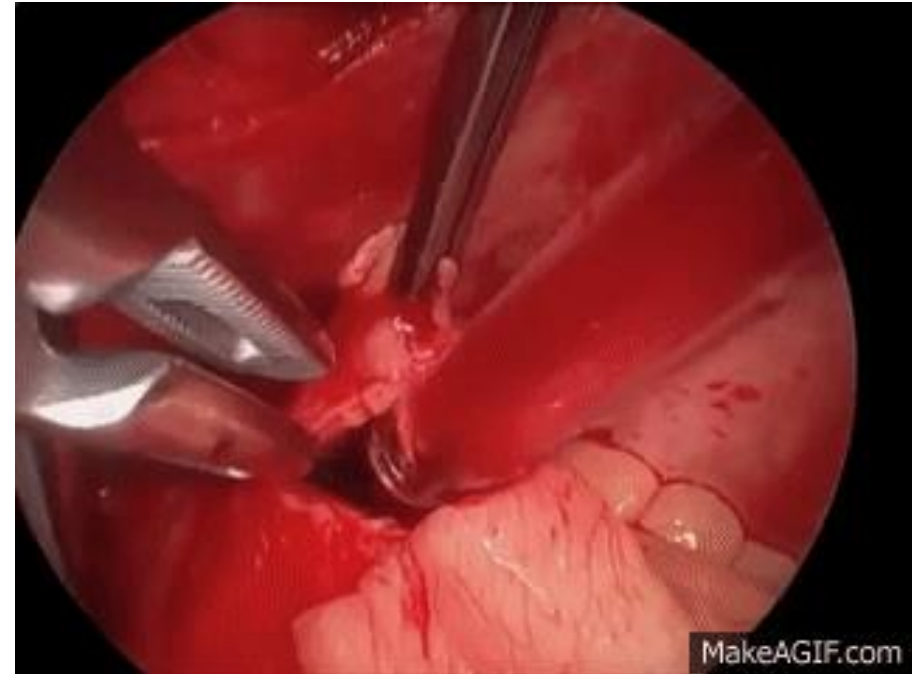


Surgical Embolectomy

TABLE 2. Indications for surgical embolectomy (n = 47)

Indication	N (%)
Contraindications to thrombolysis	21 (45%)
Recent surgical intervention	10 (21%)
Active bleeding	3 (6%)
Stroke	4 (9%)
Other	4 (9%)
Failed medical treatment	5 (10%)
Failure of thrombolytics	4 (9%)
Failure of catheter embolectomy	1 (2%)
Large RA-RV thrombus	5 (10%)
RV hemodynamic dysfunction	15 (32%)
Large PFO	1 (2%)

RA-RV, Right atrium–right ventricle; *PFO*, patent foramen ovale.



Surgical embolectomy requires a median sternotomy and cardiopulmonary bypass.



Leacche M, et al. J Thorac Cardiovasc Surg 2005;129:1018
<https://www.youtube.com/watch?v=SzsQWIMYbN8>

6.60
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MakeAGIF.com

ECMO for Catastrophic PE

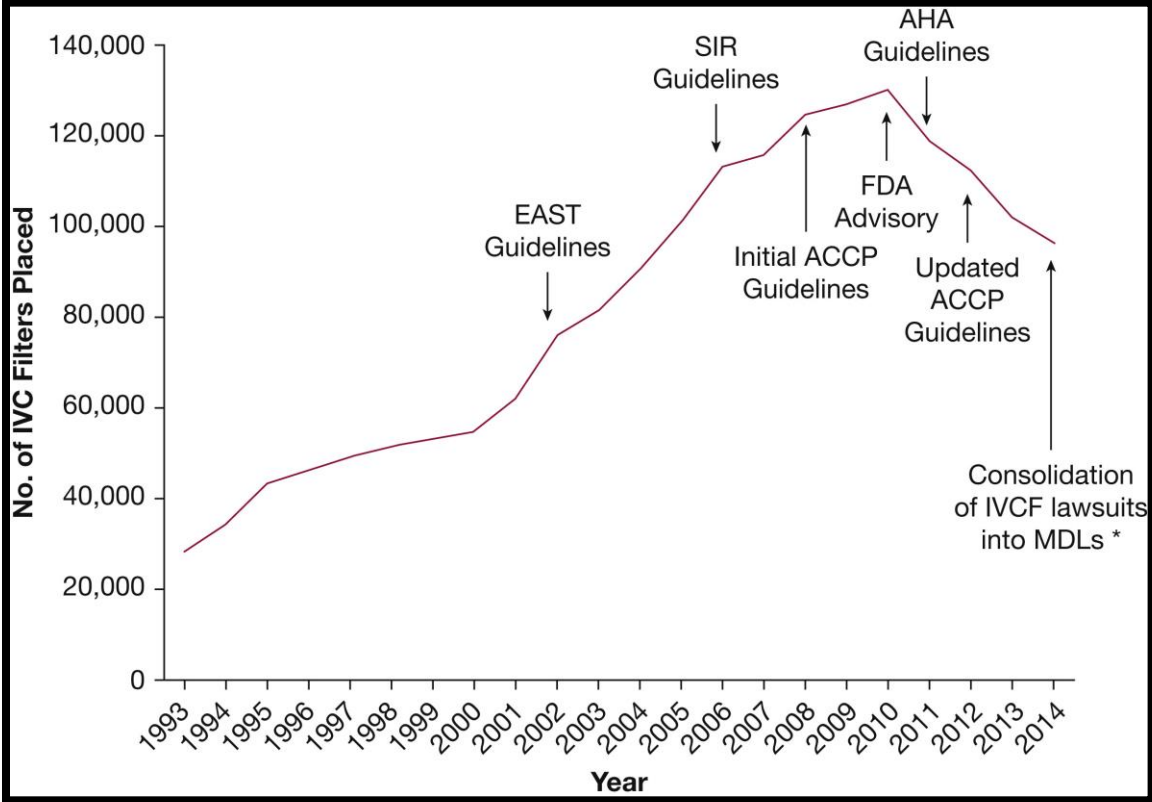
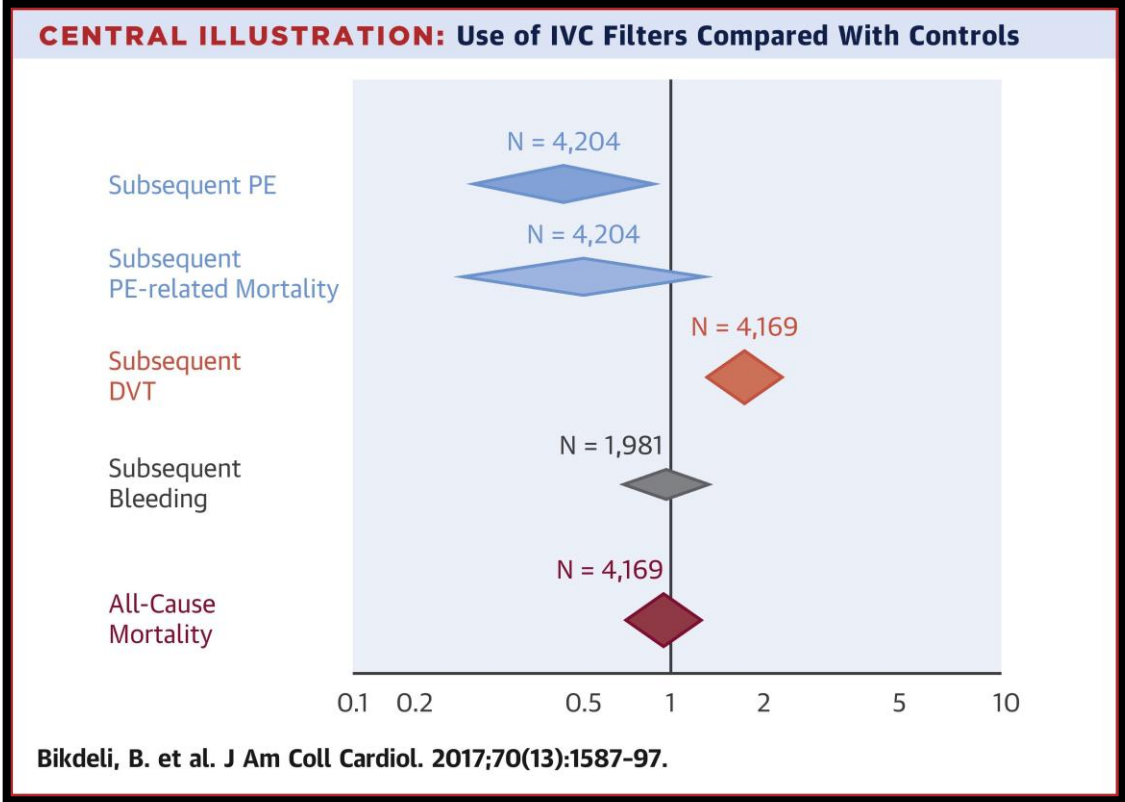
20 years of case reports and series of PE patients treated with ECMO demonstrate 70% survival.

Survival rates are similar whether ECMO was used alone or with another advanced therapy.

Veno-arterial (VA) ECMO has been used effectively to bridge to surgical or catheter embolectomy or simply to “buy time.”



Inferior Vena Cava Filters

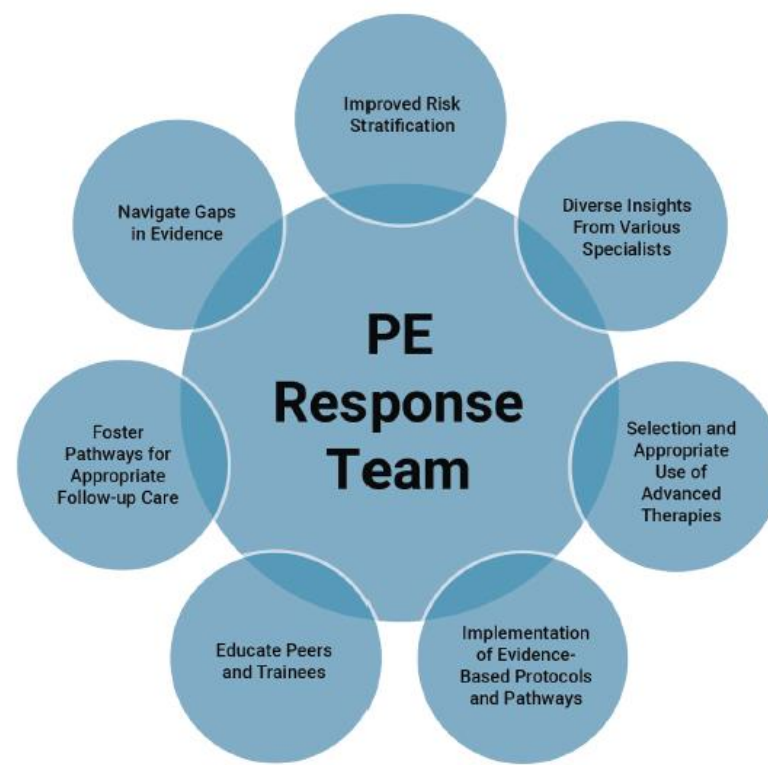


Bikdeli B, et al. J Am Coll Cardiol. 2017;70:1587
 Ahmed O, et al. CHEST. 2017;151:1402

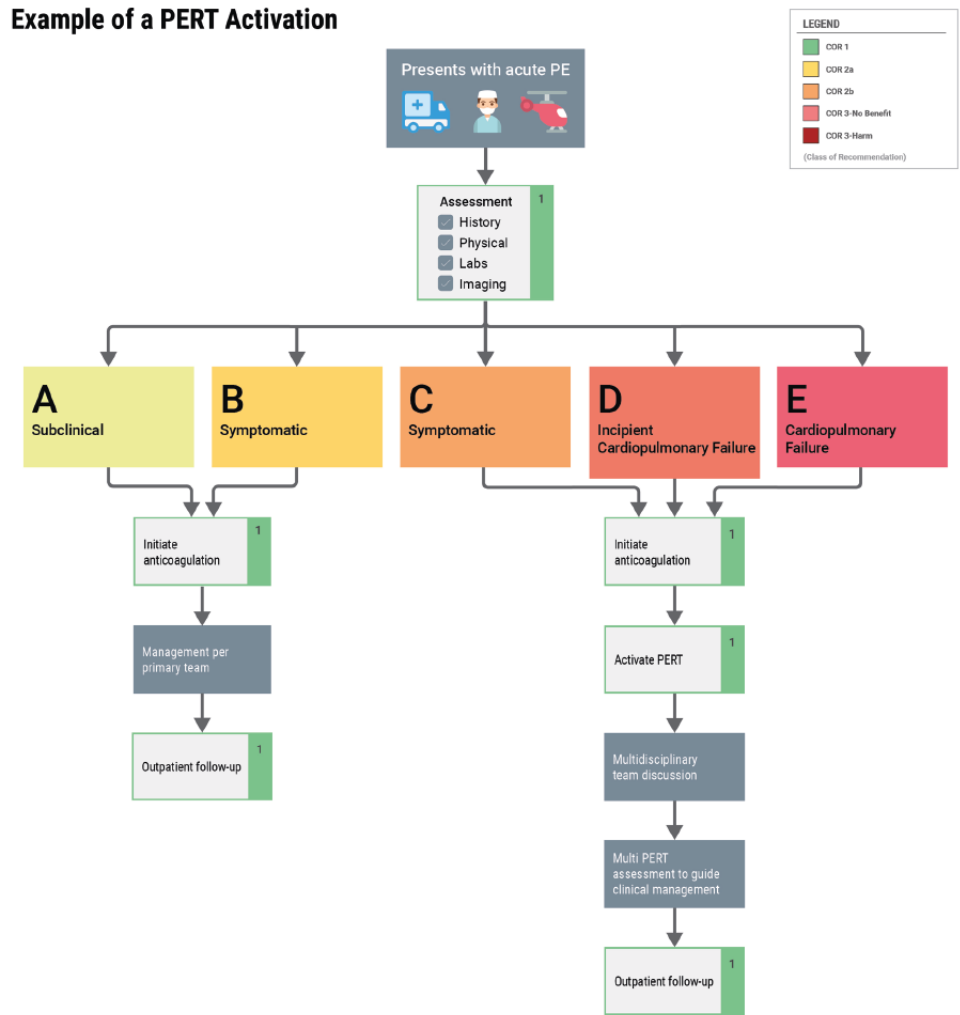


PE Response Teams

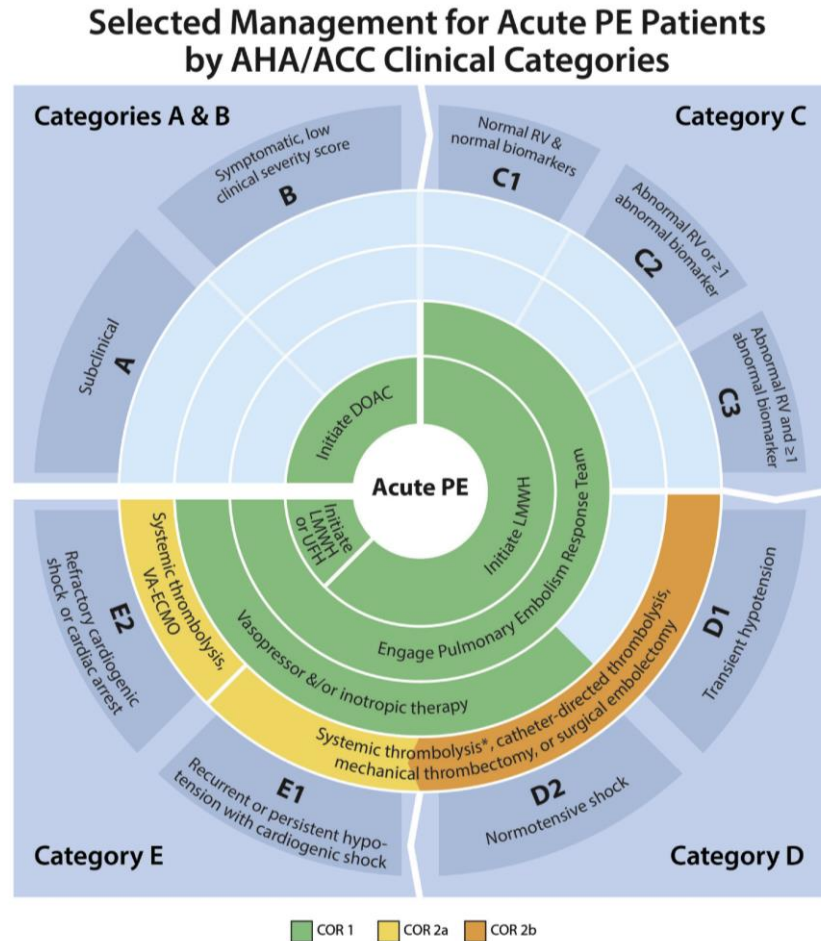
Benefits of a PERT Program



Example of a PERT Activation

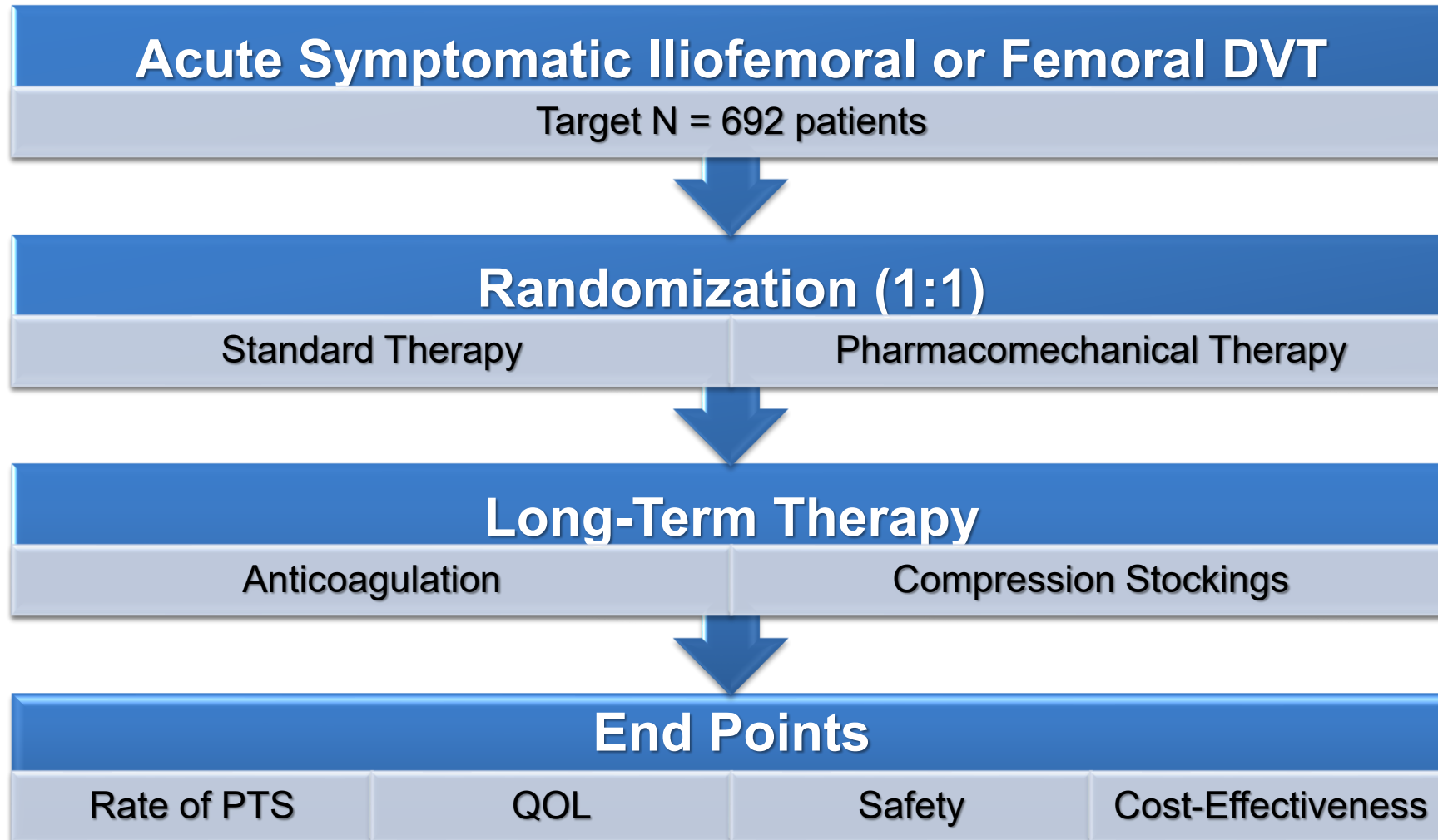


2026 Acute PE Guideline-at-a-Glance



1. A new clinical classification scheme is presented, entitled “Acute Pulmonary Embolism Clinical Categories,” with 5 categories (A-E) and subcategories, ranging from low to high risk for adverse outcomes, in order to enhance the precision of severity classification, prognosis assessment, and evidence-based therapeutic decision-making for patients presenting with acute PE.
2. Patients with acute PE who are asymptomatic (AHA/ACC PE Category A) can safely be discharged home from the emergency room and do not need to be hospitalized.
3. Early hospital discharge is generally recommended for patients with acute PE who are symptomatic but have a low clinical severity score (AHA/ACC PE Category B).
4. Advanced therapies, including systemic thrombolysis, catheter-based thrombolysis, mechanical thrombectomy, and surgical embolectomy are reasonable for patients with acute PE in AHA/ACC PE Category E1 and can be considered for patients with acute PE in AHA/ACC PE Category D1-2.
5. PE response teams (PERTs) are recommended to improve timeliness of care (AHA/ACC PE Category C-E).
6. In patients with acute PE who require initial parenteral anticoagulant therapy, low-molecular-weight heparin is recommended over unfractionated heparin.

ATTRACT Trial: Pharmacomechanical Therapy for Iliofemoral and Femoral DVT



Pharmacomechanical Therapy for DVT: ATTRACT

Outcome	Pharmacomechanical N=336	No- Pharmacomechanical N=355	p-value																								
Major bleeding (10 days)	1.7%	0.3%	0.049																								
Any bleeding (10 days)	4.5%	1.7%	0.034																								
Fatal bleeding	0	0	<table><tr><th>Outcome (24 months)</th><th>Pharmacomechanical N=336</th><th>No- Pharmacomechanical N=355</th><th>p-value</th></tr><tr><td>Any PTS</td><td>46.7%</td><td>48.2%</td><td>0.56</td></tr><tr><td>Recurrent VTE</td><td>12.5%</td><td>8.5%</td><td>0.09</td></tr><tr><td>SF-36 (Overall QOL)</td><td>11.8</td><td>10.1</td><td>0.37</td></tr><tr><td>VEINES (Venous QOL)</td><td>27.7</td><td>23.5</td><td>0.08</td></tr><tr><td>Moderate or Severe PTS</td><td><u>Overall</u> 17.9% <u>Iliofemoral</u> 18.4% <u>Femoral-popliteal</u> 17.1%</td><td><u>Overall</u> 23.7% <u>Iliofemoral</u> 28.2% <u>Femoral-popliteal</u> 18.1%</td><td>0.035</td></tr></table>	Outcome (24 months)	Pharmacomechanical N=336	No- Pharmacomechanical N=355	p-value	Any PTS	46.7%	48.2%	0.56	Recurrent VTE	12.5%	8.5%	0.09	SF-36 (Overall QOL)	11.8	10.1	0.37	VEINES (Venous QOL)	27.7	23.5	0.08	Moderate or Severe PTS	<u>Overall</u> 17.9% <u>Iliofemoral</u> 18.4% <u>Femoral-popliteal</u> 17.1%	<u>Overall</u> 23.7% <u>Iliofemoral</u> 28.2% <u>Femoral-popliteal</u> 18.1%	0.035
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Intracranial hemorrhage	0	0																									



Case No. 3

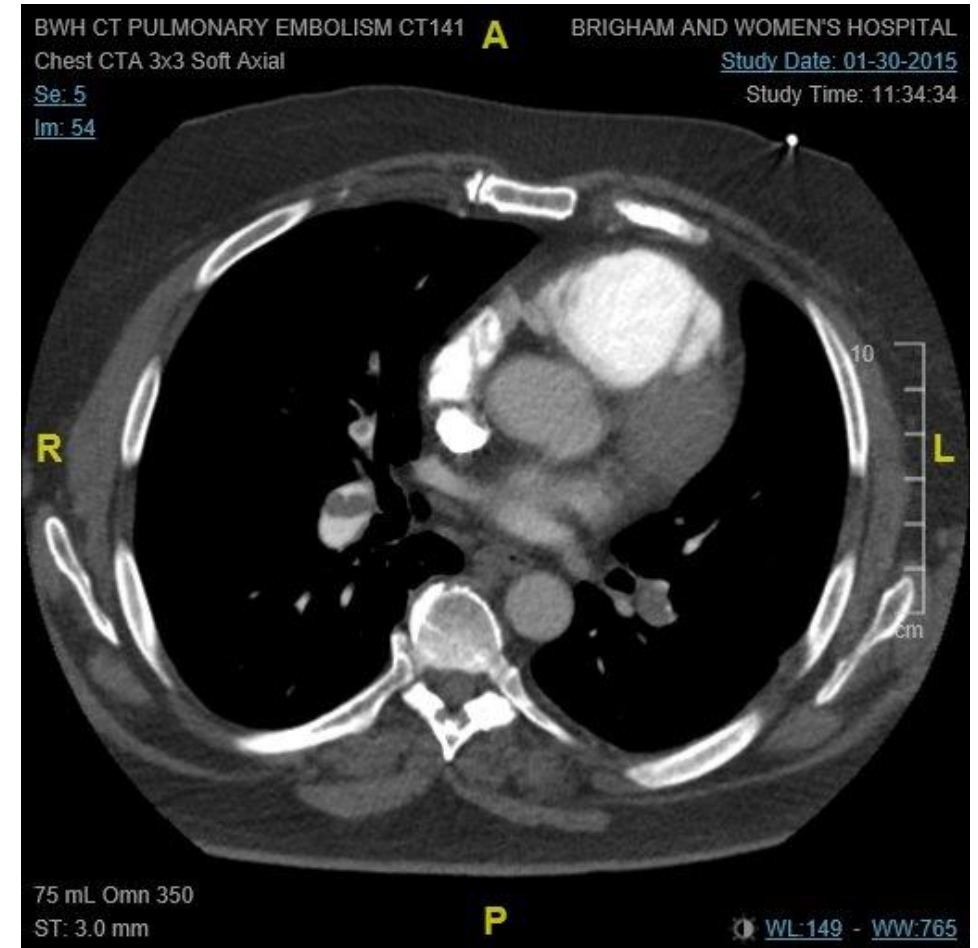
A 73-year-old man with obesity, coronary artery disease, and carotid artery disease presents with right-sided pleuritic pain and dyspnea.

He denies any recent trauma, surgery, or immobility.

His heart rate is 104 bpm, blood pressure 138/68 mmHg, and O₂ saturation 90% on room air.

His high sensitivity cardiac troponin T is normal.

He undergoes CT angiography.



Question No. 3

The patient is admitted and started on heparin with a goal PTT of 60-80 seconds. He improves steadily and is ready for discharge 4 days later. Which is the preferred regimen for oral anticoagulation in this patient?

- a) Warfarin with an INR target of 2-3 for 12 months then 1.5-2 thereafter
- b) Apixaban 5 mg twice daily for 6 months and then 2.5 mg twice daily indefinitely
- c) Dabigatran 150 mg twice daily for 6 months and then 75 mg twice daily indefinitely
- d) Enoxaparin 120 mg twice daily indefinitely



Question No. 3

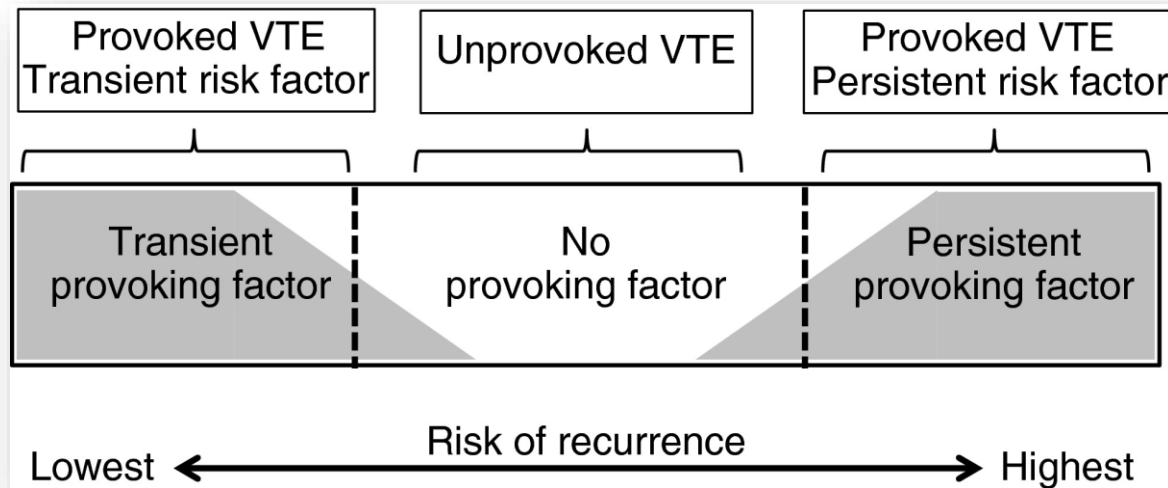
The patient is admitted and started on heparin with a goal PTT of 60-80 seconds. He improves steadily and is ready for discharge 4 days later. Which is the preferred regimen for oral anticoagulation in this patient?

- a) Warfarin with an INR target of 2-3 for 12 months then 1.5-2 thereafter
- b) Apixaban 5 mg twice daily for 6 months and then 2.5 mg twice daily indefinitely
- c) Dabigatran 150 mg twice daily for 6 months and then 75 mg twice daily indefinitely
- d) Enoxaparin 120 mg twice daily indefinitely

Explanation: For unprovoked VTE, indefinite duration anticoagulation is recommended. Low-intensity apixaban offers the best safety and efficacy of the options given for this patient. This has been shown in a number of clinical trials including AMPLIFY-EXT and HI-PRO.



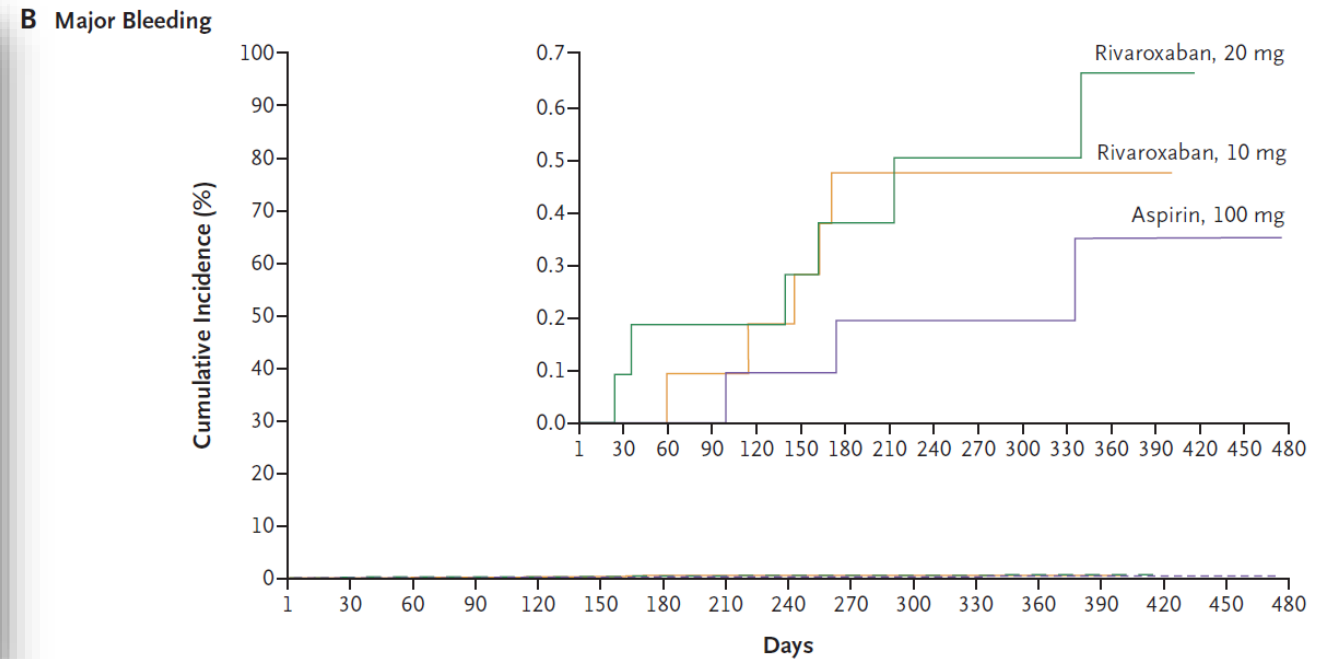
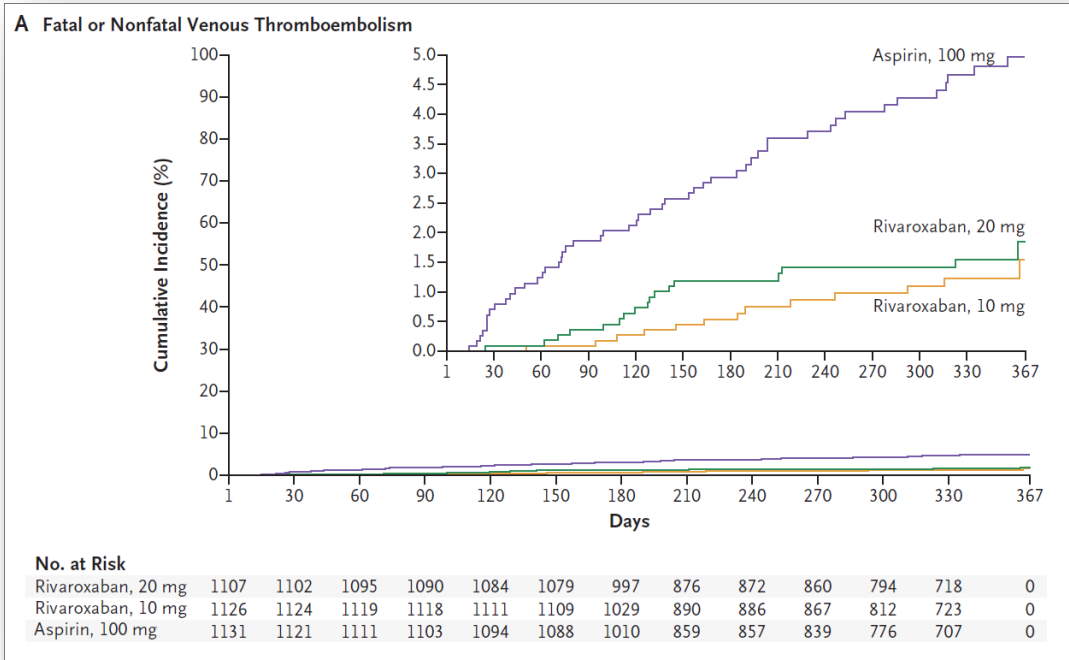
Risk of Recurrence: ISTH and ESC Guidelines



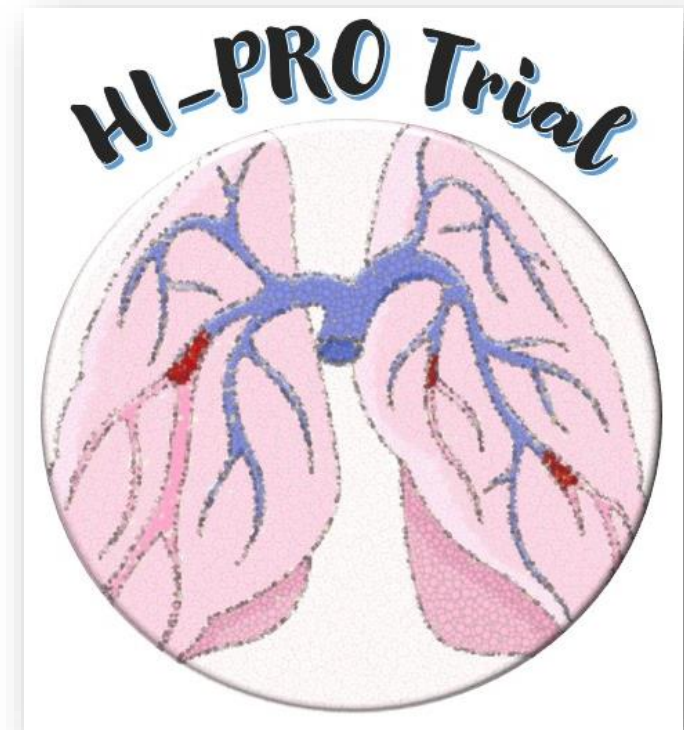
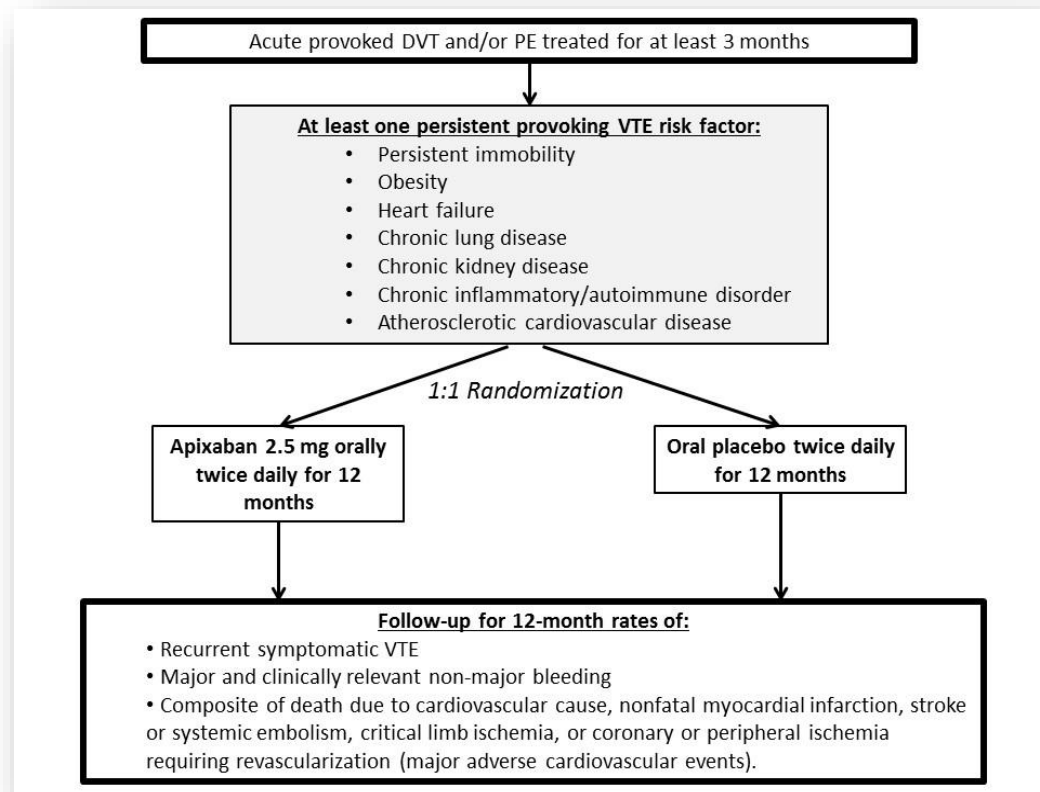
Estimated risk for long-term recurrence ^a	Risk factor category for index PE ^b	Examples ^b
Low (<3% per year)	Major transient or reversible factors associated with >10-fold increased risk for the index VTE event (compared to patients without the risk factor)	<ul style="list-style-type: none"> • Surgery with general anaesthesia for >30 min • Confined to bed in hospital (only "bathroom privileges") for ≥3 days due to an acute illness, or acute exacerbation of a chronic illness • Trauma with fractures
Intermediate (3–8% per year)	Transient or reversible factors associated with ≤10-fold increased risk for first (index) VTE	<ul style="list-style-type: none"> • Minor surgery (general anaesthesia for <30 min) • Admission to hospital for <3 days with an acute illness • Oestrogen therapy/contraception • Pregnancy or puerperium • Confined to bed out of hospital for ≥3 days with an acute illness • Leg injury (without fracture) associated with reduced mobility for ≥3 days • Long-haul flight
	Non-malignant persistent risk factors	<ul style="list-style-type: none"> • Inflammatory bowel disease • Active autoimmune disease
	No identifiable risk factor	
High (>8% per year)		<ul style="list-style-type: none"> • Active cancer • One or more previous episodes of VTE in the absence of a major transient or reversible factor • Antiphospholipid antibody syndrome



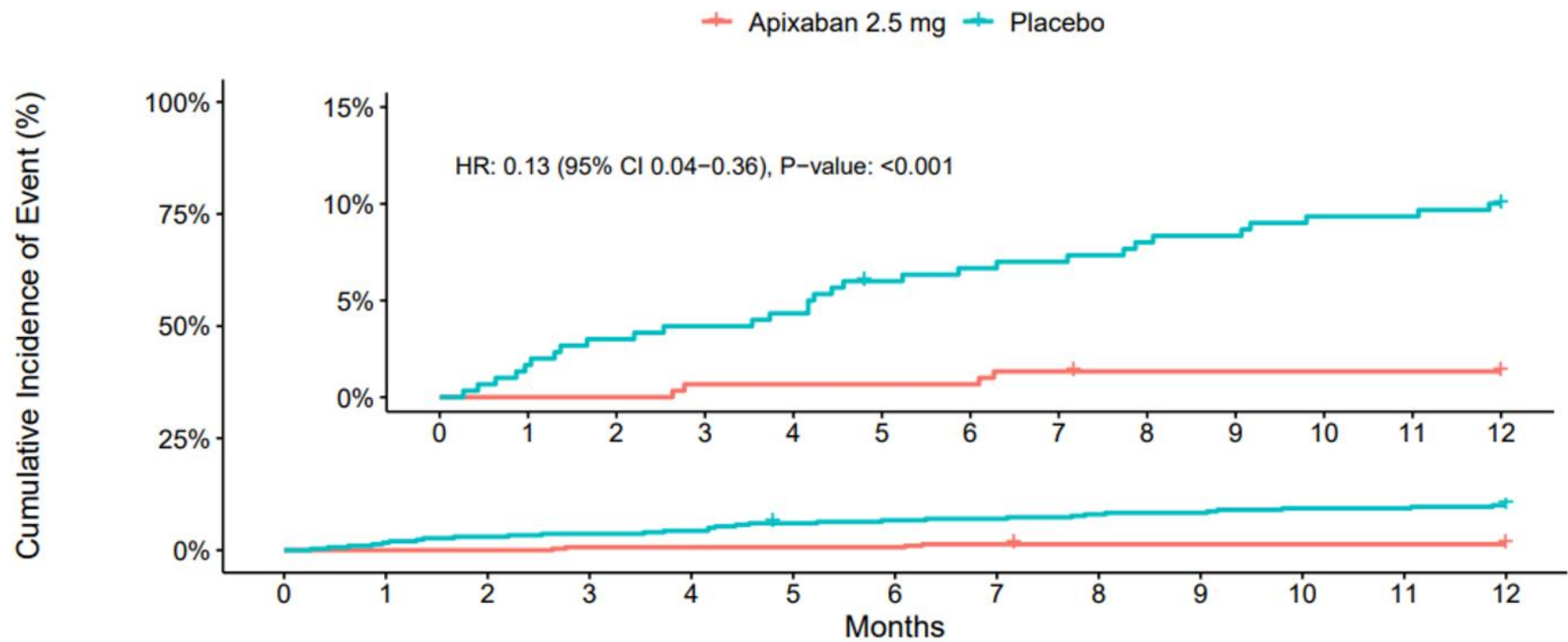
Extended Secondary Prevention for All VTE: EINSTEIN CHOICE



HI-PRO Trial: 600 High-Risk Patients with Provoked VTE



HI-PRO Primary Efficacy Outcome: Symptomatic Recurrent VTE

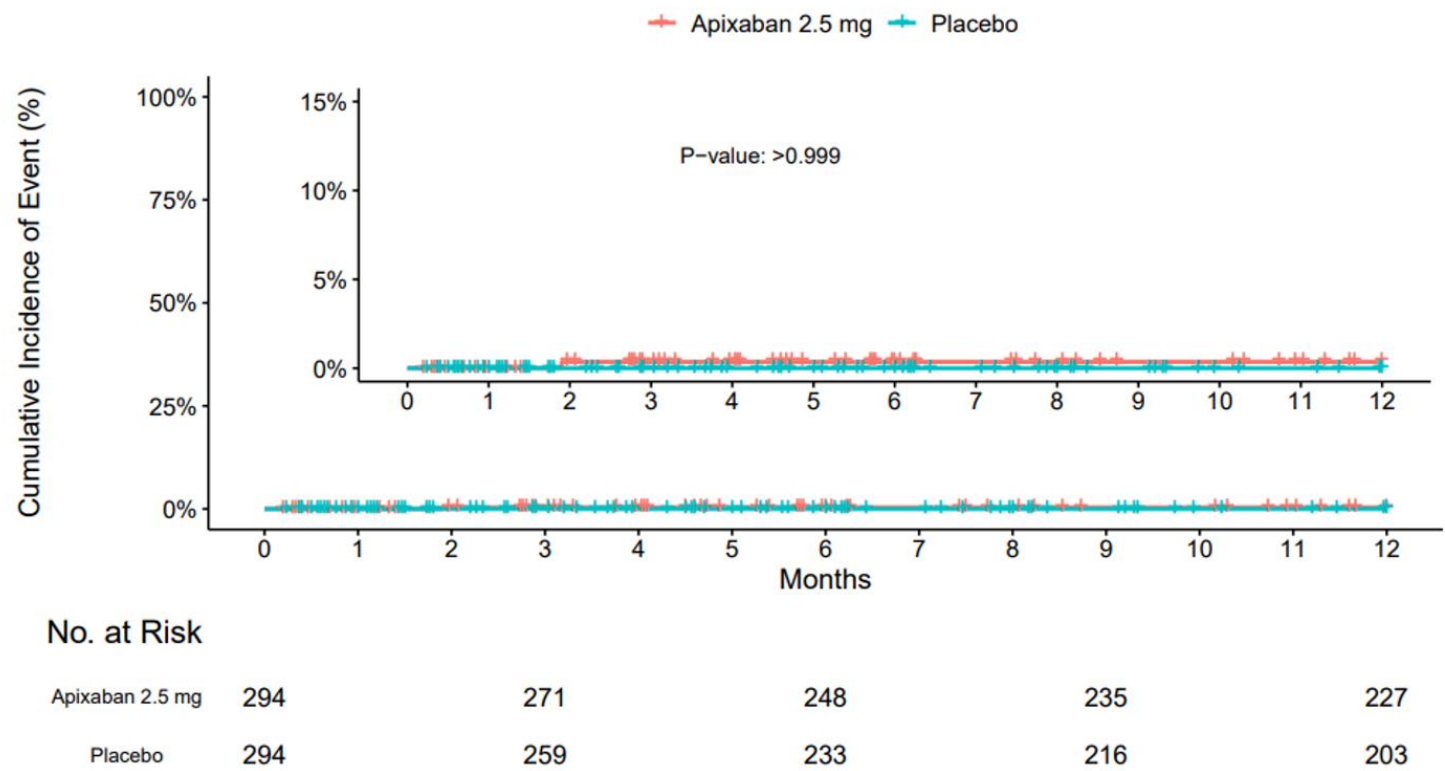


No. at Risk

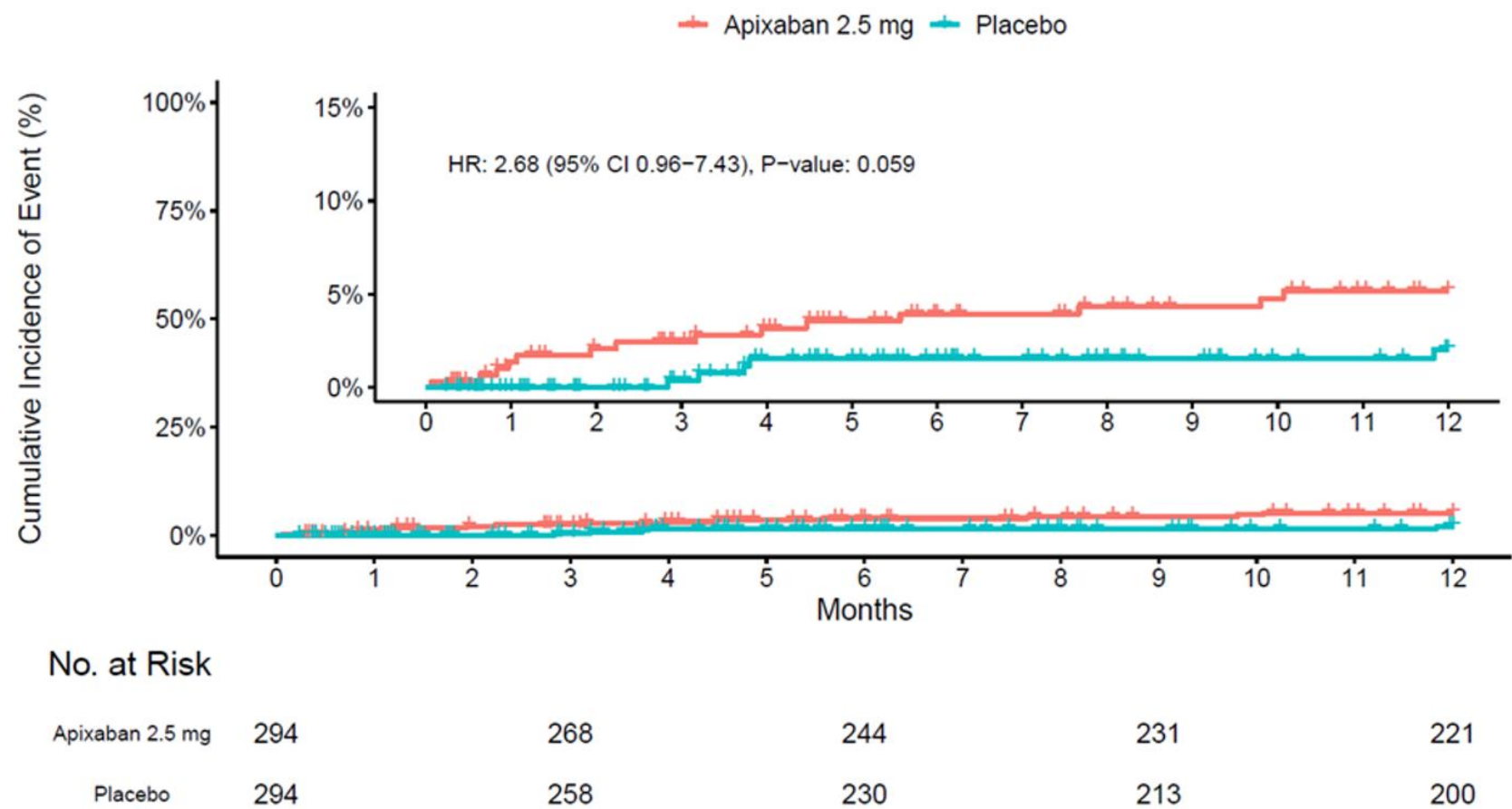
Apixaban 2.5 mg	300	298	298	295	295
Placebo	300	289	279	274	269



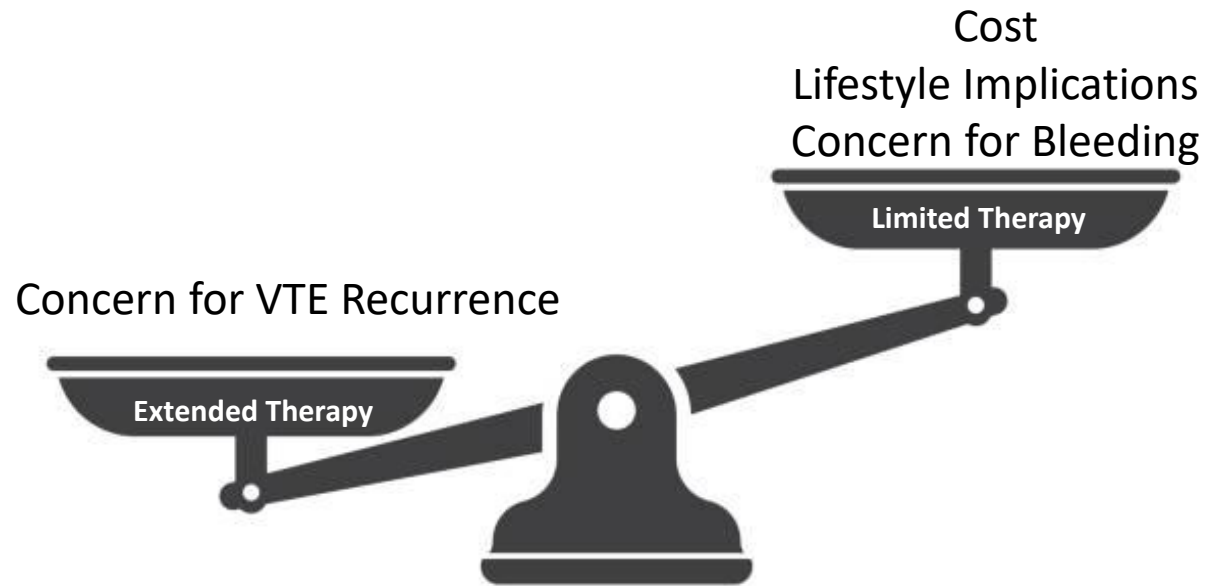
HI-PRO Principal Safety Outcome: Major Bleeding



HI-PRO Principal Safety Outcome: Clinically Relevant Non-Major Bleeding



Shared Decision-Making: Patient Preferences and Attitudes Toward Bleeding and VTE Recurrence



Bleeding Risk Must Be Part of the Equation

The VTE-BLEED Score

Introduction
The VTE-BLEED score was developed to identify patients on anticoagulation for VTED and who were at increased risk of bleeding. The original study was based on a post-hoc analysis of patients enrolled in various trials evaluating Dabigatran [a direct Thrombin inhibitor] versus standard treatment with Warfarin and subsequent studies have evaluated patients on Rivaroxaban [a direct Factor Xa inhibitor].

The algorithm is summarised below:

The VTE Bleed Score:

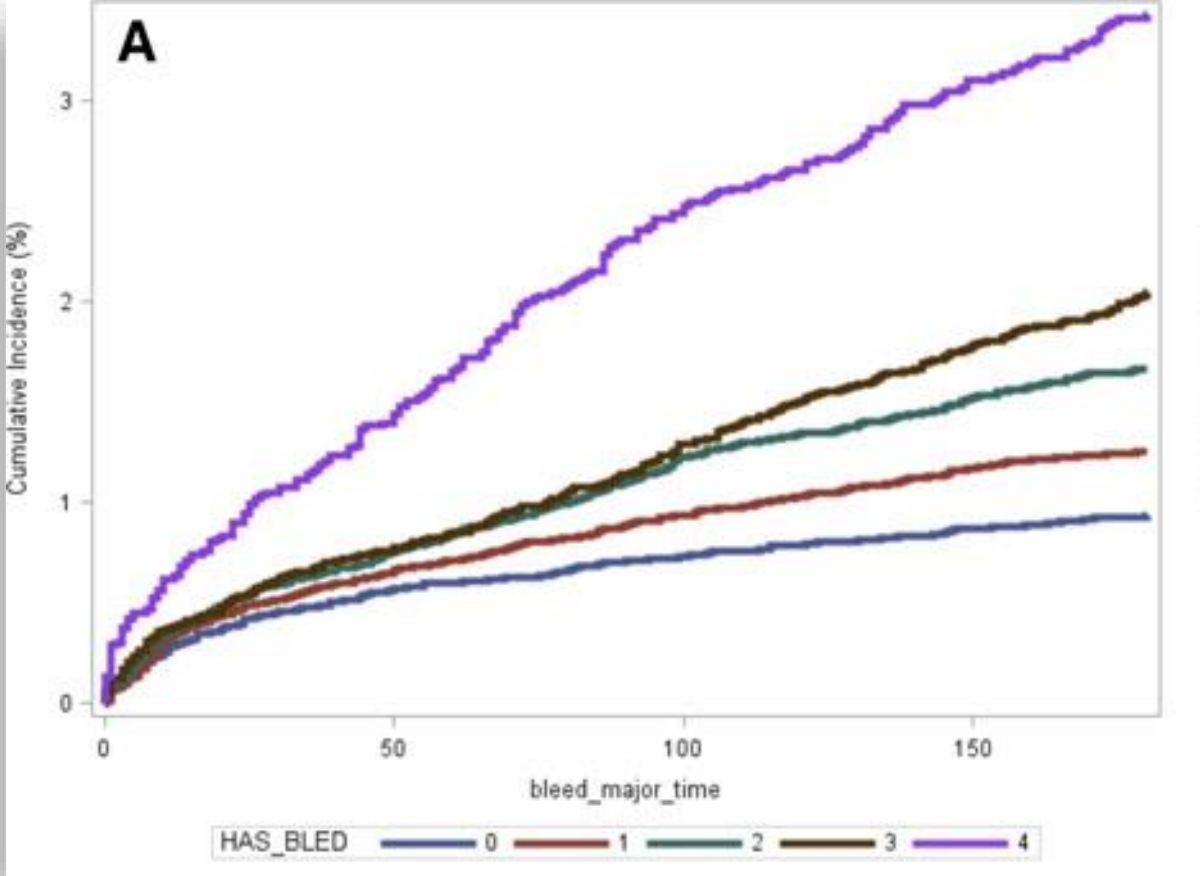
Select Criteria:

Active Cancer	
<input type="radio"/> Yes	2 Points
Male Patient with Uncontrolled Hypertension [Systolic BP \geq 140mm Hg]	
<input type="radio"/> Yes	1 Point
Anaemia [Hb <130g/L Men. Hb <120g/L Women]	
<input type="radio"/> Yes	1.5 Points
History of Bleeding [Major or non-major clinically relevant bleeding]	
<input type="radio"/> Yes	1.5 Points
Renal Dysfunction [CrCl 30-60ml/min]	
<input type="radio"/> Yes	1.5 Points
Age \geq60 yrs	
<input type="radio"/> Yes	1.5 Points

Score
[Max score 9]

VTE-BLEED Score

<2	Low bleeding risk
\geq 2	High bleeding risk

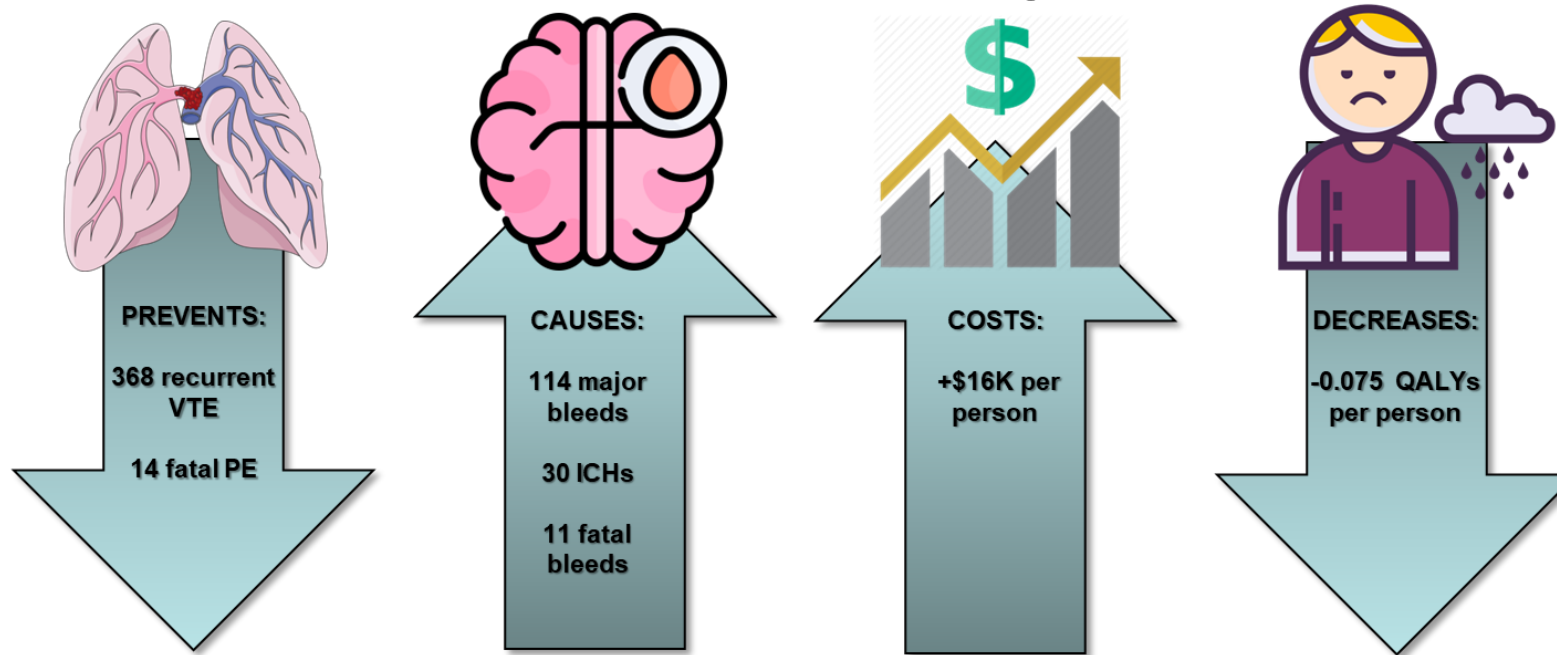


Klok FA, et al. Br J Haematol. 2018; 183: 457
Brown JD, et al. JAHA. 2018; 7: e007901

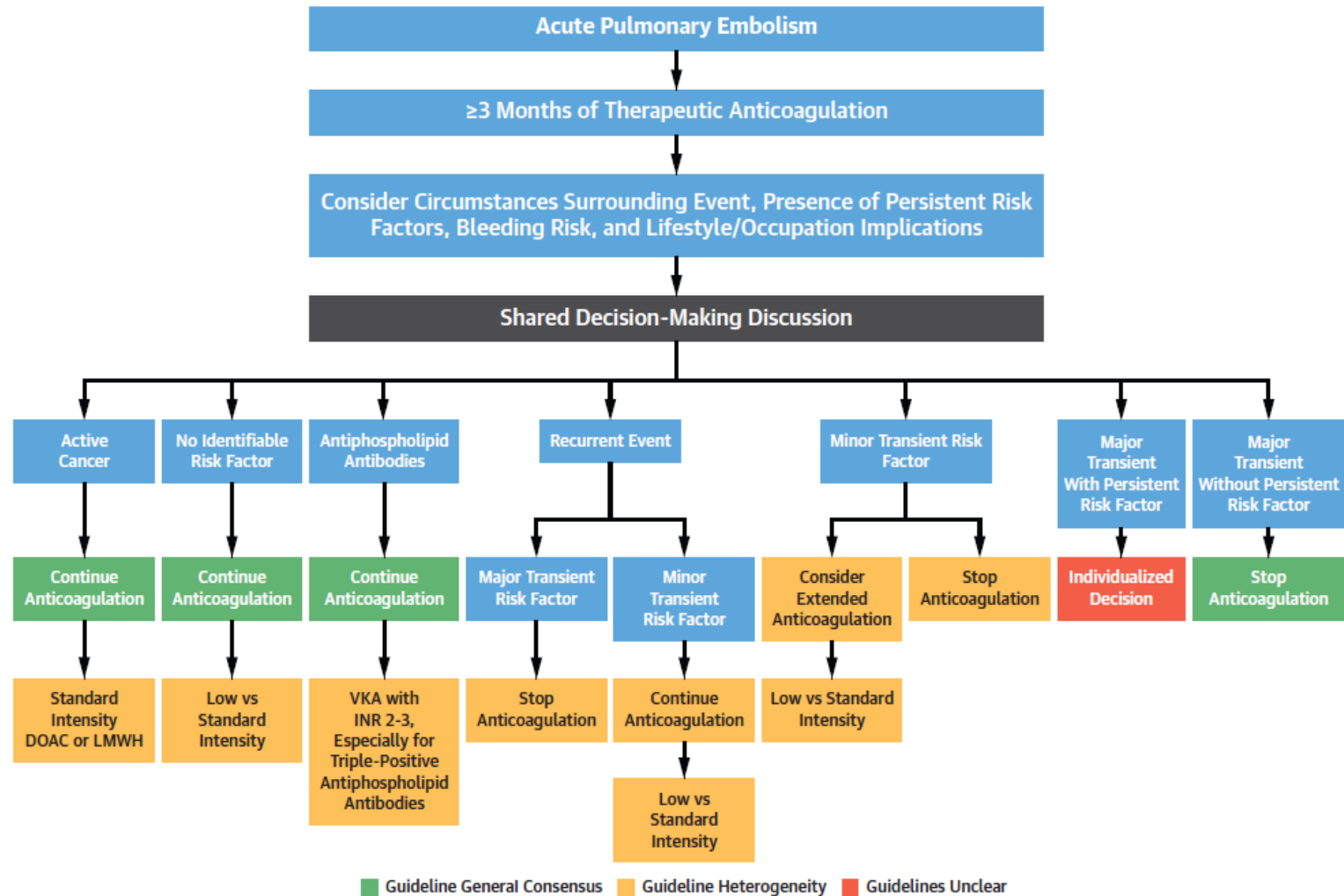


A Cautionary Note on Indefinite Anticoagulation: A Canadian Cost-Effectiveness Study




























In a hypothetical cohort of 1000 patients with a first unprovoked VTE, indefinite vs. time-limited anticoagulation



Optimal Duration of Anticoagulation: Guideline-Based Care
















































Follow-Up Care for PE

 Suggested  Not addressed  Not recommended	ESC/ERS [2] 	PERT [12] 	CHEST [13] 	AHA [14] 	ASH [15] 	NICE [20] 
Routine re-evaluation of patients at 3-6 months after the index PE event						
TTE and or V/Q scan in patients with persistent otherwise unexplained dyspnea and/or exercise intolerance after 3 months^b				 ^a		
Refer symptomatic patients with PH and/or mismatched perfusion defects at V/Q scan to a referral center for CTEPH						

a. After 6 weeks to evaluate persistent pulmonary hypertension
b. Preference of imaging is generally based on center's expertise and resources availability



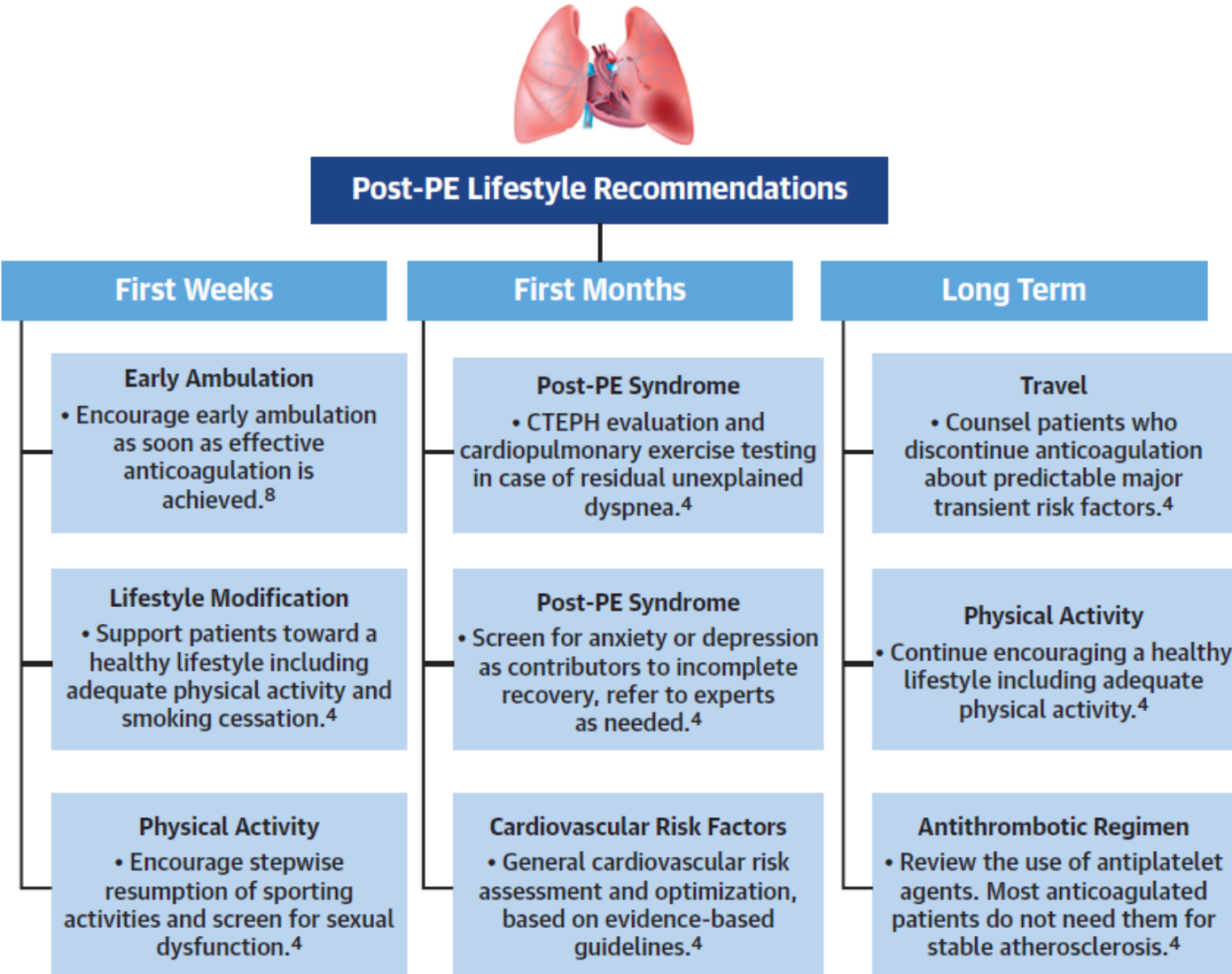
Lifestyle Modification

<div>  Suggested  Not addressed  Not recommended </div>	ESC/ERS [2] 	PERT [12] 	CHEST [13] 	AHA [14] 	ASH [16] 	NICE [20] 
Smoking Cessation	 a					
Diet	 a					
Weight loss strategy for overweight/obesity						
Return to work						
Physical activity/exercise	 a					
Participation in sexual activity						

a. The ESC Guideline text stated "work collaboratively with patients using behavioral frameworks and motivational interviewing, to identify and modify associated risk factors (smoking cessation, diet, physical activity, and exercise).



Lifestyle Modification



KEY TAKE HOME POINTS

1. Risk stratification is critical to identify VTE patients who may benefit from advanced therapy.
2. Selection of advanced therapies depends on assessment of the patient's risk of adverse outcomes and major bleeding.
3. Determining the optimal anticoagulation regimen should consider risk of recurrence, risk of bleeding, and patient preference.



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Zuin M, et al. International Clinical Practice Guideline Recommendations for Acute Pulmonary Embolism: Harmony, Dissonance, and Silence. J Am Coll Cardiol. 2024;84:1561-1577.

Creager MA, et al. 2026 AHA/ACC/ACCP/ACEP/CHEST/SCAI/SHM/SIR/SVM/SVN Guideline for the Evaluation and Management of Acute Pulmonary Embolism in Adults: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. J Am Coll Cardiol. 2026:S0735-1097(25)10161-7.

