

Normotensive Shock in Pulmonary Embolism

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Conflicts of Interest

Consulting: Inquis Medical, Jupiter Endovascular

Objectives

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01. GUIDELINES & TERMINOLOGY

Familiarize ourselves with ACC/AHA Guideline terminology

02. ACUTE PE DIAGNOSIS

Recognize normotensive shock in acute PE

03. RISK ASSESSMENT

Recognize risk enhancing features

04. HEMODYNAMIC EVALUATION

Acknowledge the value of invasive hemodynamics in acute PE evaluation

05. INTERVENTIONAL THERAPIES

Review interventional PE therapies

30-Day All Cause Mortality

ICOPER '99

2,454 Patients

12.5%

MORTALITY RATE

Risk Stratification:

- 95.6% Int-risk
- 4.4% High-risk

MGH PERT '18

338 Patients

11.8%

MORTALITY RATE

Risk Stratification:

- 86.0% Int-risk
- 14.0% High-risk

Schultz et al. '19

416 Patients

15.7%

MORTALITY RATE

Risk Stratification:

- 19.0% Low-risk
- 34.0% Int-Low risk
- 35.0% Int-High risk
- 12.0% High-risk

PERT Registry '21

5,048 Patients

10.2%

MORTALITY RATE

Risk Stratification:

- 18.0% Low-risk
- 67.0% Int-risk
- 15.0% High-risk

Long Term Consequences of PE

Meta-analysis including nearly 3,700 PE patients (18-month median follow-up)

18%

**ongoing RV
dysfunction¹**

Persistent right ventricular
strain observed post-event.

11%

**moderate or severe
functional
impairment¹**

Classified as NYHA III-IV
functional status.

5th

percentile

**6-minute walk test
scores¹**

Compared directly against
population norms.

30-Day Outcome

24%

**30-day all-cause
readmission²**

High early post-discharge
burden requiring care
coordination.

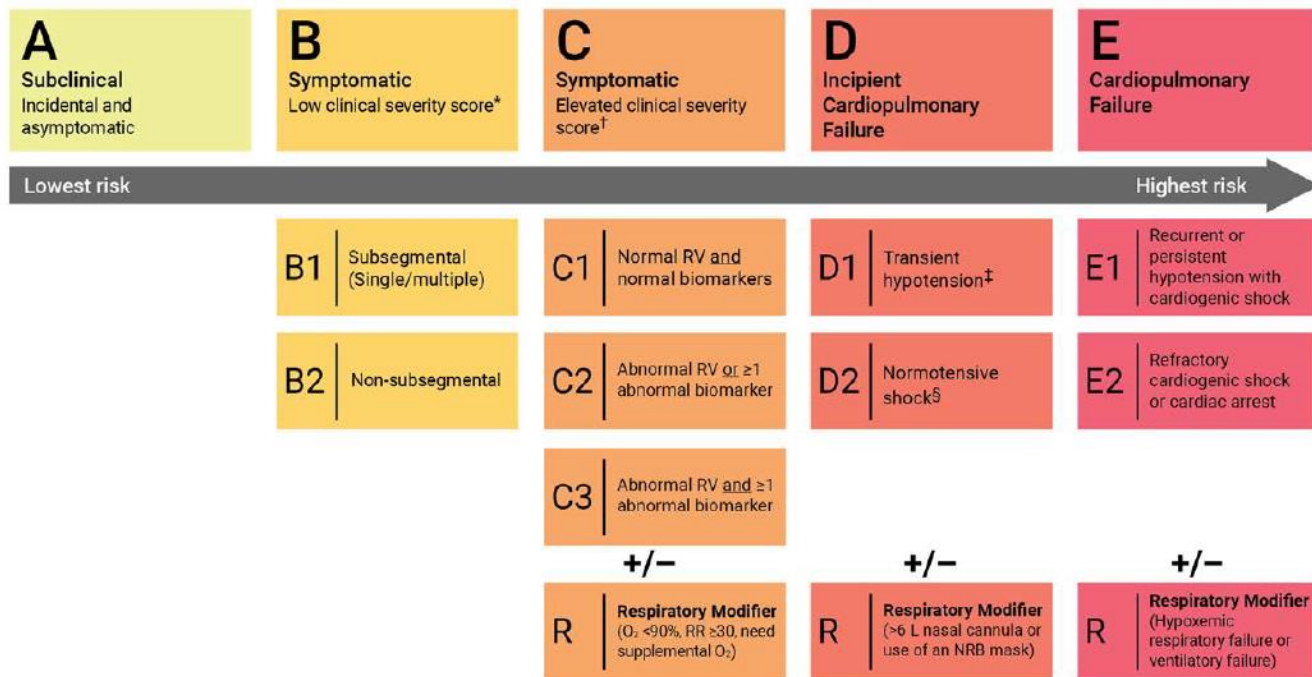
1. Vasc Med. 2017 Feb;22(1):37-43

2. PERT Consortium Registry Data. Interim results on 3,400 Patients presented at PERT Symposium October 2020

European Society of Cardiology

Early mortality risk		Indicators of risk			
		Haemodynamic instability ^a	Clinical parameters of PE severity and/or comorbidity: PESI class III–V or sPESI ≥1	RV dysfunction on TTE or CTPA ^b	Elevated cardiac troponin levels ^c
High		+	(+) ^d	+	(+)
Intermediate	Intermediate–high	-	+ ^e	+	+
	Intermediate–low	-	+ ^e	One (or none) positive	
Low		-	-	-	Assesment optional; if assessed, negative

AHA/ACC Acute PE Clinical Categories



2026 Adults With Acute Pulmonary Embolism
© 2026 by the American Heart Association, Inc., and the American College of Cardiology Foundation.

Category D: Incipient Cardiopulmonary Failure

D1: Transient Hypotension

Systolic blood pressure < 90 mmHg, OR decrease > 40 mmHg from baseline, OR responding to fluids (1L)

Your slide is ready.

D2: Normotensive Shock

Requires ANY of the following clinical indicators:

Lactate > 2

MAP < 60

AKI > 0.3

Increased SCAI Stage / CPES Score = 6

UOP < 0.5 mL/kg/hr

CI < 2.2 L/min/m²

Altered Mental Status

Composite Pulmonary Embolism Shock Score (CPES)

Risk of Adverse Outcomes in Patients With Pulmonary Embolism

RV Dysfunction

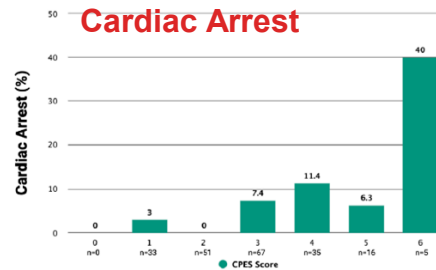
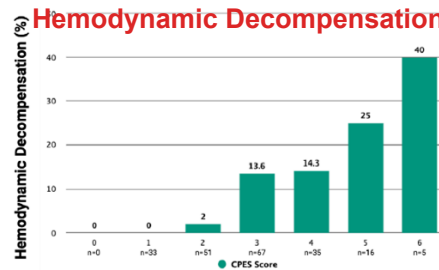
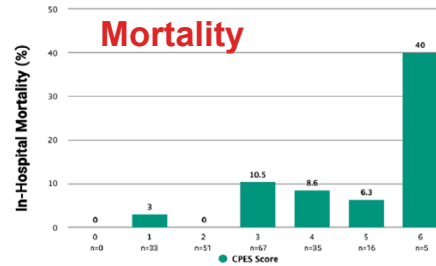
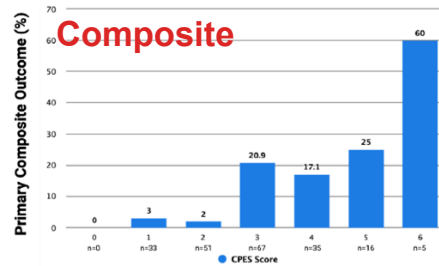
Abnormal Troponin

Abnormal NT-proBNP

Saddle or 1 Main PA Thrombus

DVT

Tachycardia



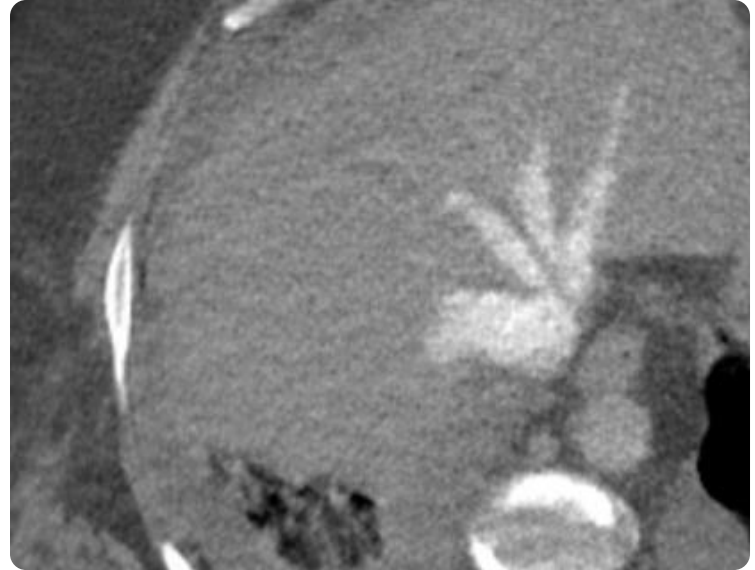
Risk Enhancing Features

Syncope

Hepatic Contrast

Sustained Tachycardia

Narrow Pulse Pressure



Inferior Vena Cava Contrast Reflux Grade is Associated with a Reduced Cardiac Index in Acute Pulmonary Embolism

Contrast Reflux Comparison

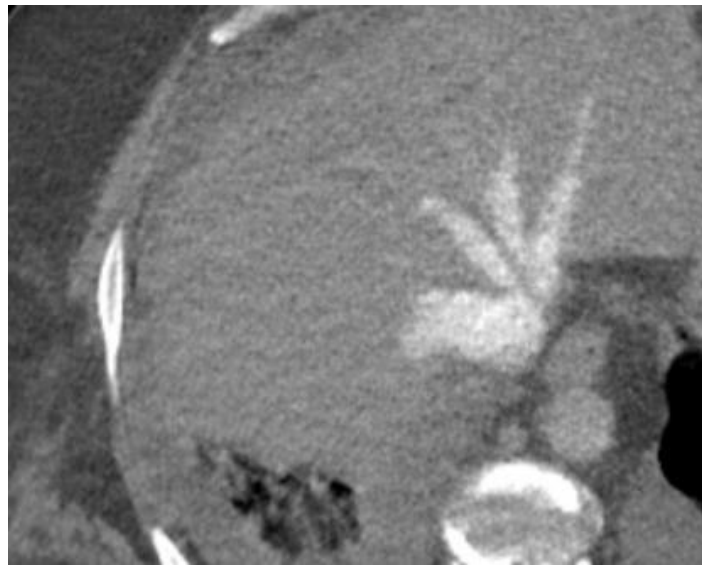
Hepatic veins vs. minimal or limited to IVC

Cardiac Index Difference

1.8 vs **2.6**

Positive Predictive Value (Cardiac Index < 2.2)

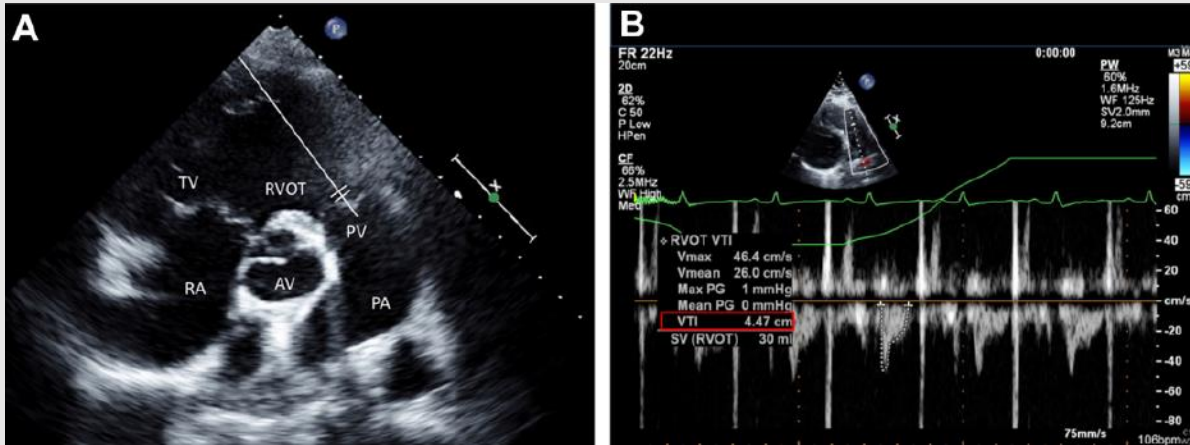
~ 97%



RVOT VTI Predicts Low Cardiac Index in Intermediate Risk Pulmonary Embolism

RVOT VTI < 9.5 cm associated with increased mortality
(13.6% vs 1.3%).

46% had CI < 2.2 despite normotension



Low LVOT VTI is Associated with Poor Outcomes

MORTALITY RISK

6x

Increased Risk

In-hospital death or cardiac arrest
associated with LVOT VTI < 15 cm

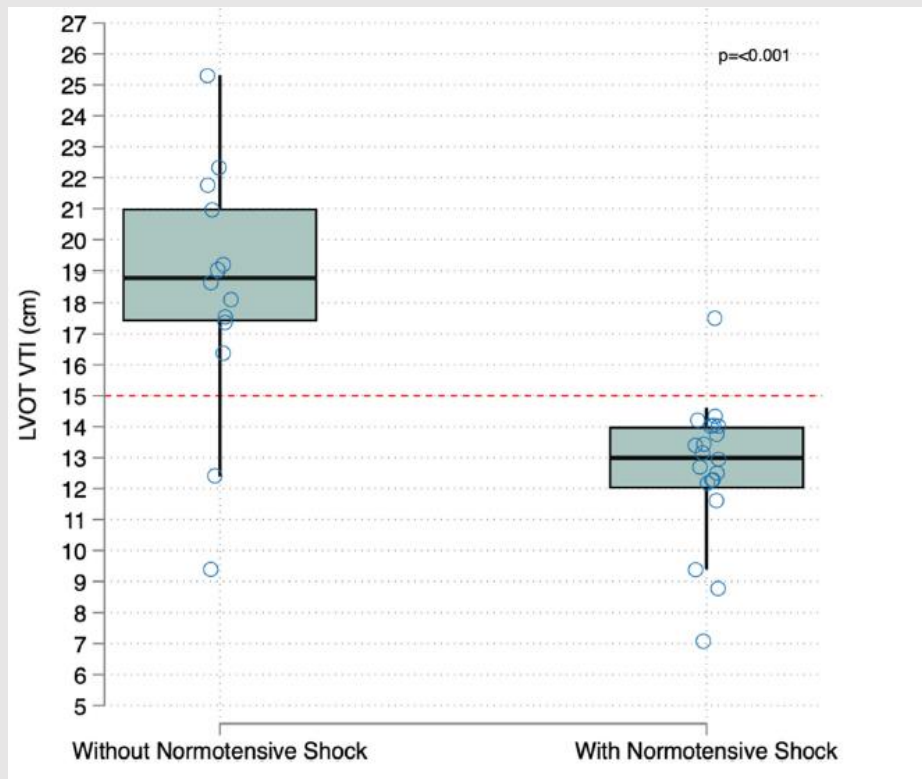
PATIENT PREVALENCE

58%

High Prevalence

Of intermediate-high risk patients present
with LVOT VTI < 15 cm

Low left ventricular outflow tract velocity time integral predicts normotensive shock in patients with acute pulmonary embolism



TAPSE / PASP Ratio

TAPSE/ PASP > 0.34
RV Coupling

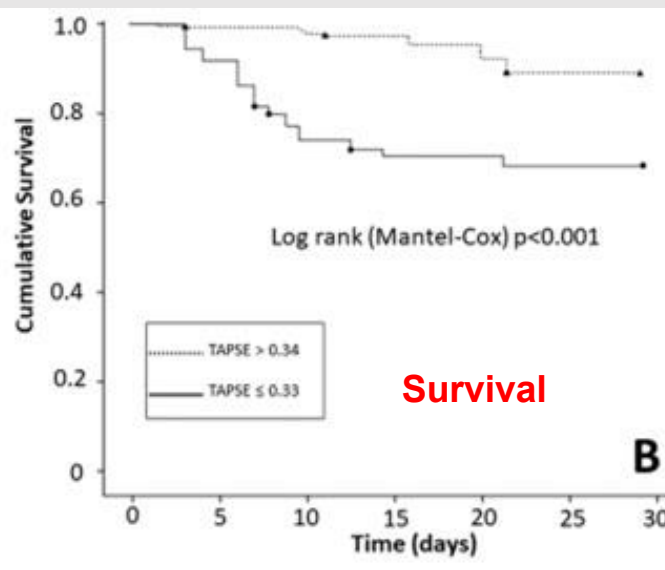
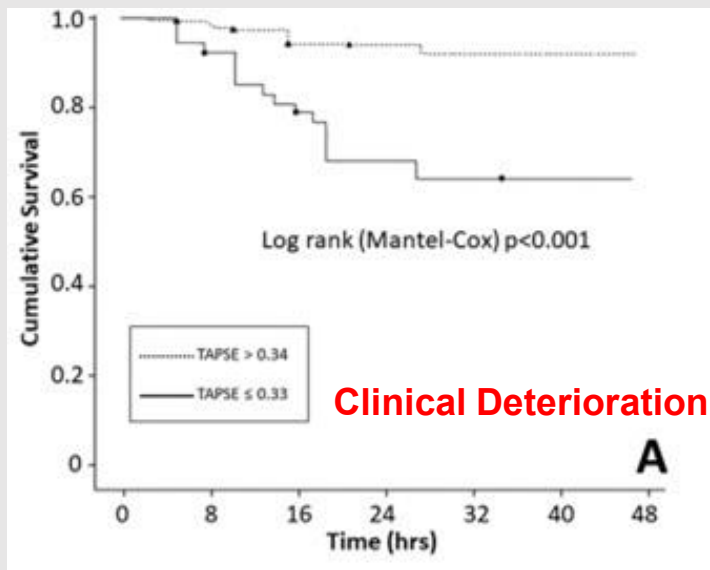


TAPSE/ PASP ≤ 0.34
RV Uncoupling



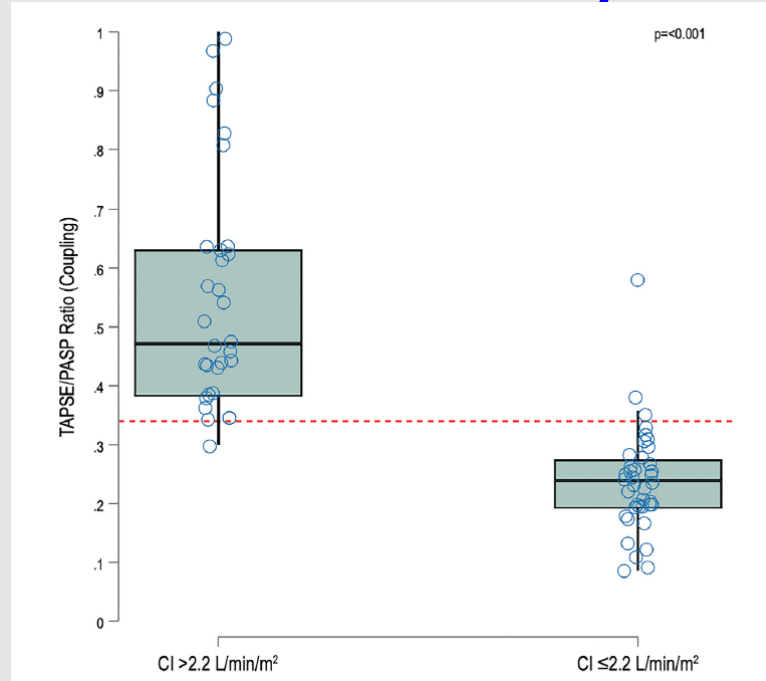
A) coupling
ed into the
to

Prognostic Role of TAPSE to Systolic Pulmonary Artery Pressure Ratio for the Identification of Early Clinical Deterioration in Intermediate High Risk Pulmonary Embolism Patients

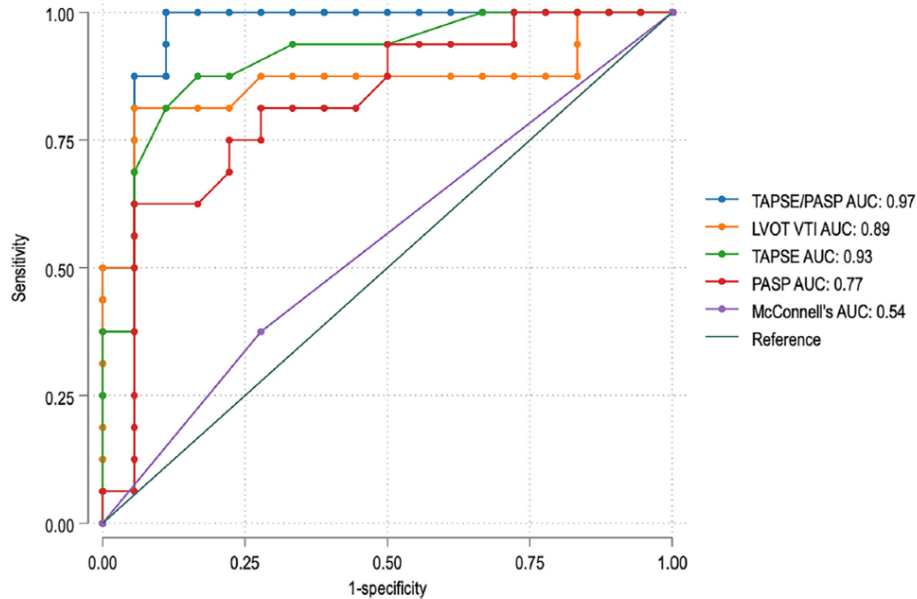


N = 422

Right Ventricular-Pulmonary Arterial Uncoupling as a Predictor of Invasive Hemodynamics and Normotensive Shock in Acute Pulmonary Embolism



Receiver Operator Curves for Prediction of Shock



PREDICTIVE ACCURACY (AUC SUMMARY)

TAPSE / PASP Ratio — 0.97 AUC

Highest overall predictive performance

TAPSE Alone — 0.93 AUC

LVOT VTI — 0.89 AUC

PASP
0.77 AUC

McConnell's
0.54 AUC

Treatment Options

Thrombus Reduction

Catheter Based Therapies

medication

Pharmacologic

tune

Mechanico-pharmacologic

medical_services

Percutaneous Thrombectomy

Moving from an era of changes in RV/LV ratio to in PE specific outcomes

Catheter Directed Thrombolysis

Low dose infusion of tPA over 6-12 hours

EKOS - uses ultrasound to “thin” out clots to allow for increased drug receptor sites.

ISTH Major Bleed: 1.6%
Mortality: 1%

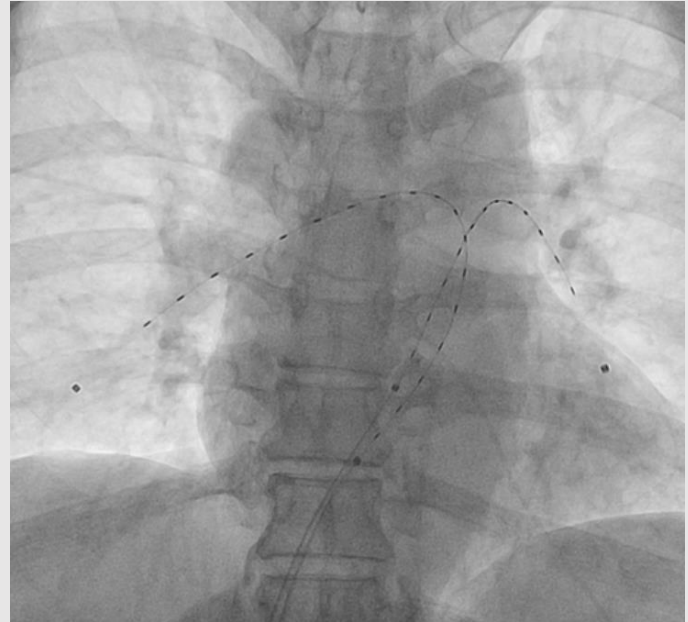
Ultima Trial (Circulation. 2014 Jan 28;129(4):479-86.)

The Seattle II Study (J Am Coll Cardiol Interv. 2015 Aug, 8 (10) 1382–1392)

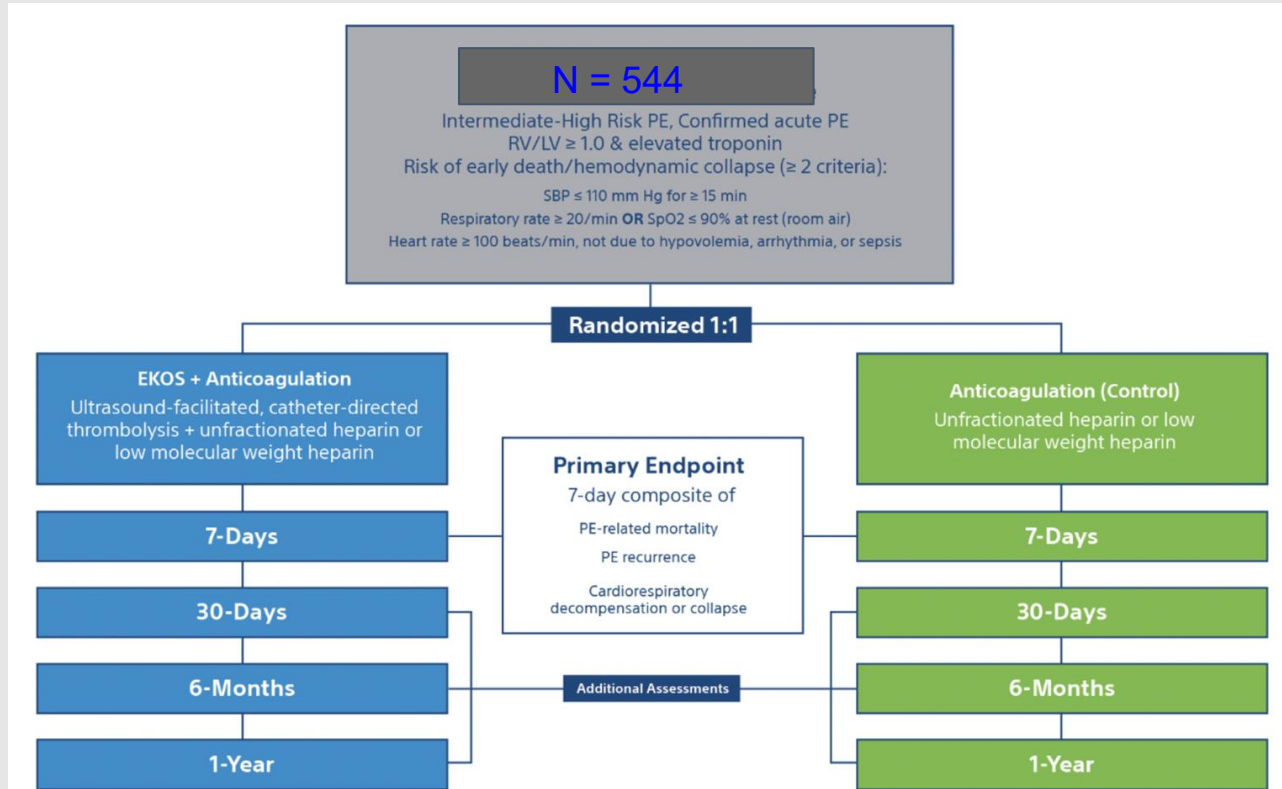
Knockout PE (Circ Cardiovasc Interv. 2024 Mar;17(3):e013448.)

Optalyse PE Trial (J Am Coll Cardiol Interv. 2018 Jul, 11 (14) 1401–1410)

Sunset PE Trial (J Am Coll Cardiol Interv. 2021 Jun, 14 (12) 1364–1373)



HI PEITHO Trial



HI - PEITHO

Table 2. Clinical Efficacy Outcomes (Intention-to-Treat Population).*

Outcome	Intervention (N=273)		Control (N=271)		Relative Risk (95% CI) [†]
	<i>no. of patients</i>	<i>% (95% CI)[‡]</i>	<i>no. of patients</i>	<i>% (95% CI)[‡]</i>	
Any primary-outcome event	11	4.0 (2.3–7.1)	28	10.3 (7.2–14.5)	0.39 (0.20–0.77) [‡]
Components of the primary outcome					
Pulmonary embolism–related death	3	1.1 (0.4–3.2)	1	0.4 (0.1–2.1)	3.0 (0.3–28.5)
Cardiorespiratory decompensation or collapse	10	3.7 (2.0–6.6)	28	10.3 (7.2–14.5)	0.4 (0.2–0.7)
Recurrence of pulmonary embolism	1	0.4 (0.1–2.0)	1	0.4 (0.1–2.1)	1.0 (0.1–15.8)

No EKOS? No Problem

Prague 26

N = 558

Intermediate High Risk PE

1 mg per catheter bolus + 1 mg per catheter x 9 hours

Table 3. Outcomes (Intention-to-Treat Population).^{‡*}

Outcome	Thrombolysis (N=280)		Standard Care (N=278)		Relative Risk (95% CI)
	no. of patients	% of patients (95% CI)†	no. of patients	% of patients (95% CI)†	
Primary outcome					
Death from any cause, recurrence of pulmonary embolism, or cardiorespiratory decompensation or collapse	2	0.7 (0.0–2.7)	19	6.8 (4.4–10.5)	0.10 (0.02–0.44)‡
Secondary outcomes					
Death from any cause	0	0 (0.0–1.6)	4	1.4 (0.4–3.8)	0
Recurrence of pulmonary embolism	2	0.7 (0.0–2.7)	1	0.4 (0.0–2.2)	1.99 (0.18–21.77)
Cardiorespiratory decompensation or collapse	2	0.7 (0.0–2.7)	15	5.4 (3.2–8.8)	0.13 (0.03–0.57)

Large Bore Mechanical Thrombectomy

Penumbra: Lightning Indigo - 16F, Computer Assisted Vacuum Technology
Extract PE Trial (J Am Coll Cardiol Interv. 2021 Feb; 14 (3) 319–329)
STORM PE Trial

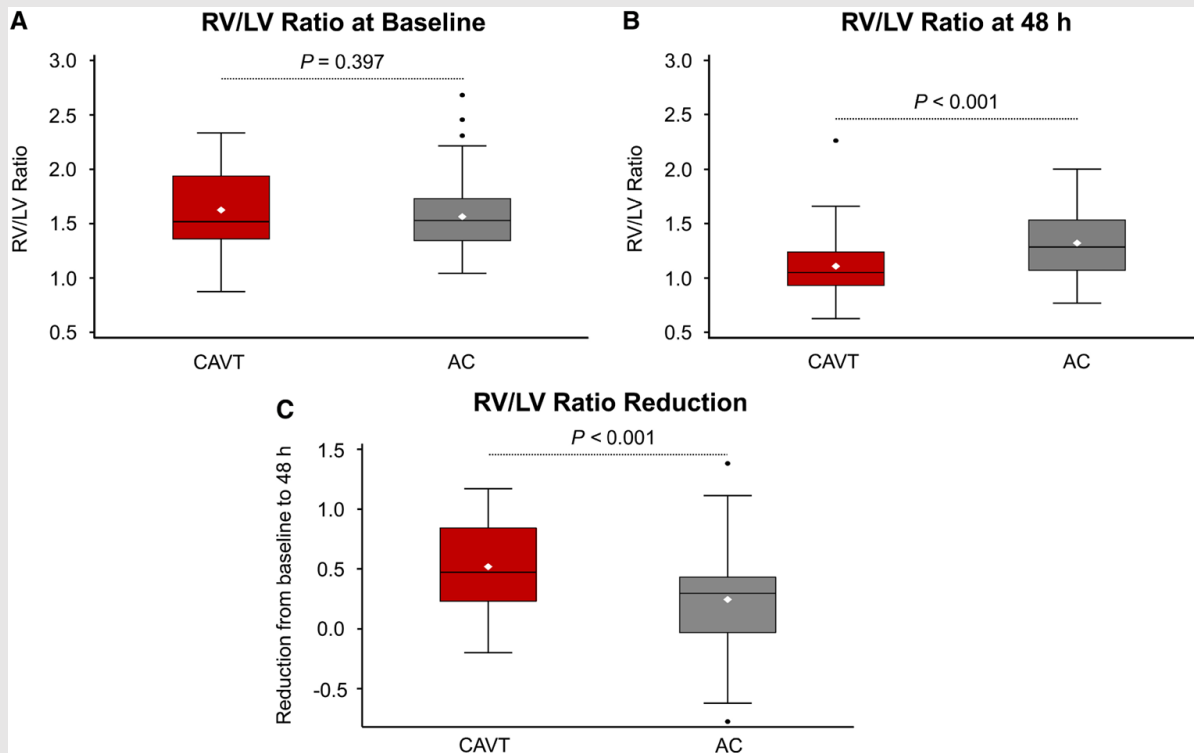
Inari: Up to 24F. Mechanical thrombectomy. Nitinol discs for thrombus engagement. Ability to re-infuse blood
FLARE Study (J Am Coll Cardiol Interv. 2019 May; 12 (9) 859–869)
FLASH Registry (EuroIntervention. 2023 Feb 20;18(14):1201-1212.)
FLAME Study (Circ Cardiovasc Interv 2023;16:e013406)
PEERLESS II

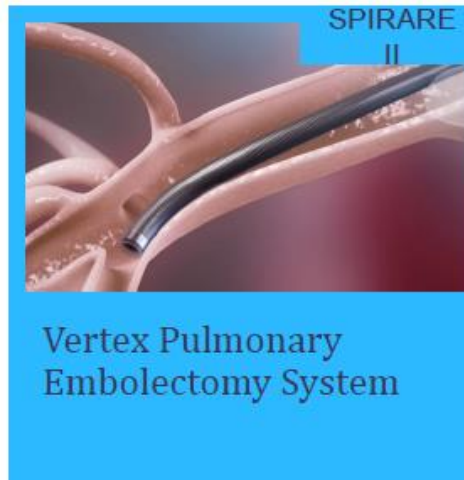
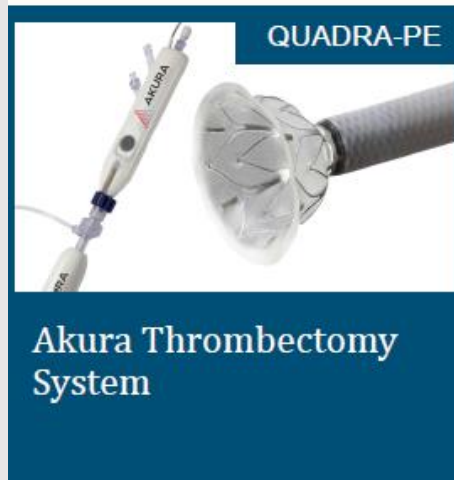
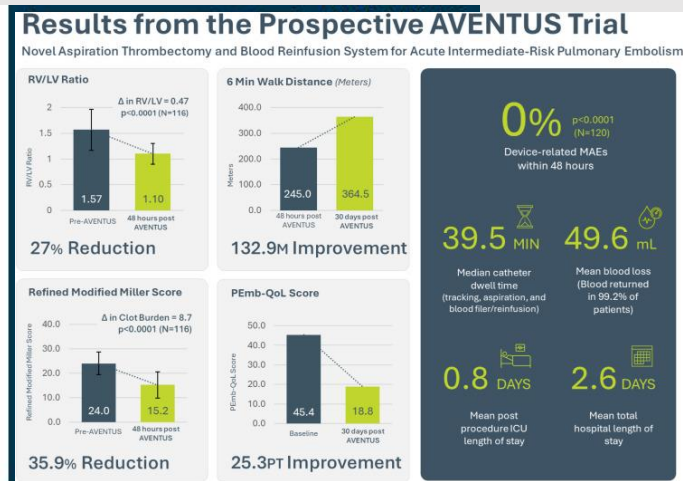
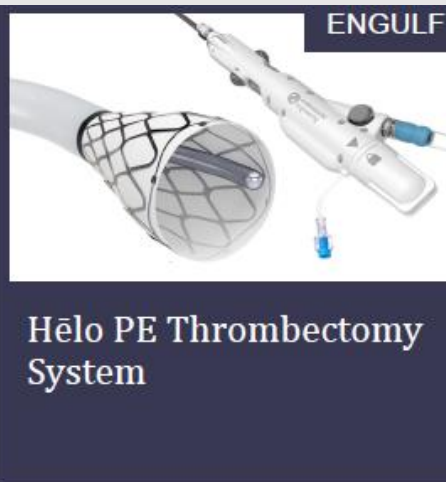
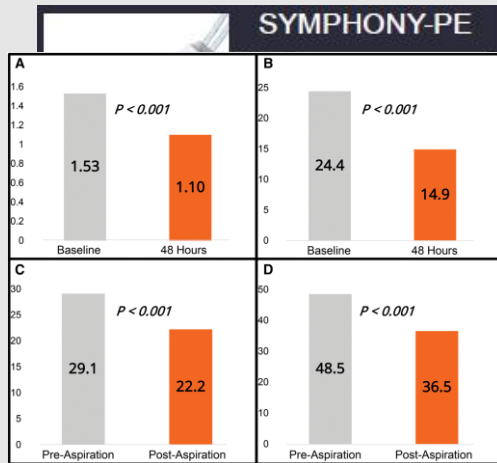
Angiovac: AlphaVac - 18F mechanical thrombectomy
APEX AV (JSCAI 4. 2025. 102463)



STORM PE

Prospective RCT: AC (53) vs LBMT (47) alone





SAFETY AND EFFICACY OF MODERN PERCUTANEOUS MECHANICAL THROMBECTOMY DEVICES IN ACUTE PULMONARY EMBOLISM: A SYSTEMATIC REVIEW AND META-ANALYSIS OF INVESTIGATIONAL DEVICE EXEMPTION TRIALS AND PROSPECTIVE MULTI-CENTER REGISTRIES

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¹ University of Connecticut School of Medicine, Farmington, CT

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6 studies
N = 1571

MPAP: ↓ 5.3 mm Hg

RV/LV: ↓ 0.39

30d Mortality: 0.6%

BACKGROUND

- Acute pulmonary embolism is the third leading cause of cardiovascular death in the United States
- Catheter-based interventions have emerged as important modalities for treatment of selected patients with intermediate or high-risk acute PE
- Alongside catheter-directed thrombolysis, a variety of large bore mechanical thrombectomy devices have emerged as adjuncts to anticoagulation.

METHODS

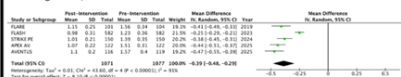
- A systematic literature search spanning PubMed/Medline, Embase, CENTRAL, and ClinicalTrials.gov databases (from inception to 14 May 2025) was conducted to retrieve investigational device exemption trials and large prospective multicenter registries or randomized controlled trials evaluating large bore (12F and above) thrombectomy devices for the management of acute PE.
- Mean differences and proportions were pooled using random effects model.
- Statistical analyses were performed using RevMan version 5.4.1 and OpenMeta[Analyst] version 10.12.

RESULTS

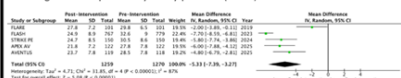
- 6 studies (FlowTriever: FLARE, FLASH and PEERLESS; Alphavac F188; APEX AV, Indigo; STRIKE-PE Interim Analysis; Aventus; AVENTUS) with a total of 1,571 patients were included
- Pooled estimate reported change
- RV/LV ratio by -0.39 (95% CI: -0.48, -0.29, I²=91%)
- Mean pulmonary artery pressure by -5.33 mmHg (95% CI: -7.39, -3.27, I²=87%)
- Modified miller score by -5.33 (95% CI -8.92, -1.74, I²=98%)

FIGURES

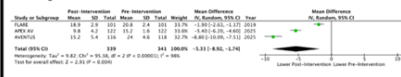
A. Change in RV/LV ratio



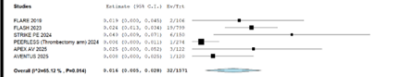
B. Change in Mean pulmonary artery pressure (MPAP)



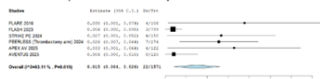
C. Change in Modified Miller Score



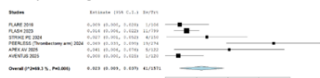
D. Adjunctive therapy use



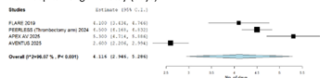
E. Device or procedure related major adverse events



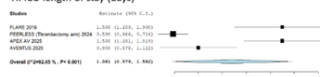
F. Major bleeding



G. Hospital length of stay (days)



H. ICU length of stay (days)



I. 30-day mortality

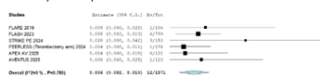


Fig A-I: Forest plots demonstrating safety and efficacy outcomes for large bore mechanical thrombectomy devices: A) Change in RV/LV ratio, B) Change in mean pulmonary artery pressure C) Change in Modified Miller Score, D) Adjunctive therapy use (systemic thrombolysis, catheter directed thrombolysis or different mechanical thrombectomy device), E) Device or procedure related major adverse events, F) Major bleeding, G) Hospital length of stay (days), H) ICU length of stay (days), I) 30-day mortality.

RESULTS (CONT'D)

- Pooled estimate for hospital and ICU length of stay were 4.11 days (95% CI: 2.95, 5.29, I²=96%) and 1.08 days (95% CI 0.58, 1.58, I²=93%), respectively
- Pooled estimate for adjunctive therapy usage was 1.6% (95% CI 0.005, 0.028, I²= 65%)
- Pooled estimate for device or procedure related major adverse events, major bleeding, and 30-day mortality were 1.5% (95% CI 0.004, 0.026, I²=63%), 2.3% (95% CI 0.009, 0.037, I²=69%) and 0.6% (95% CI 0.002, 0.010, I²=0%) respectively

CONCLUSION

- Large bore mechanical thrombectomy devices provide safe and efficacious treatment options in the management of acute PE.
- Further research is needed to identify reasons contributing to high heterogeneity in outcomes between studies comparing different thrombectomy devices

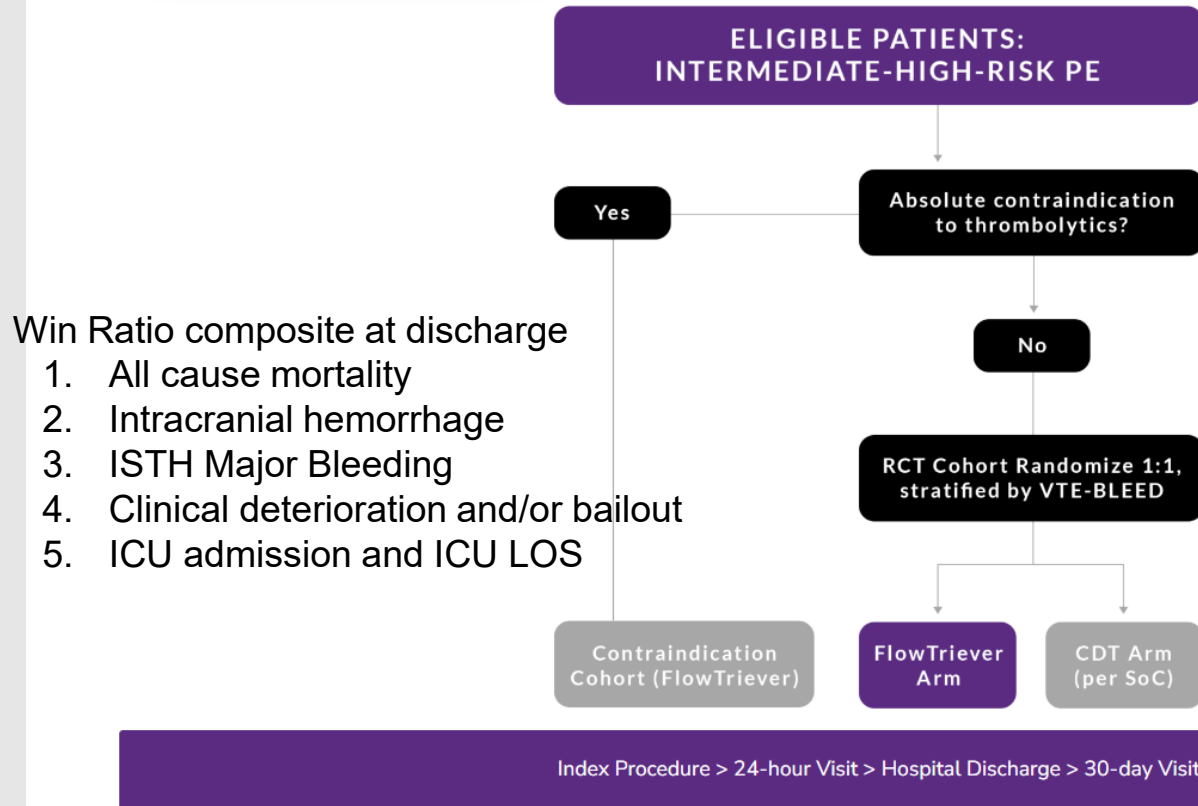
REFERENCES

1. Gattameloni G, Meyer S, Boscetti L, et al. 2023 ESC Guidelines for the diagnosis and management of acute pulmonary embolism. *European Heart Journal*. 2023;44(18):e1811.
2. Stein PD, Alpert JS, Hyatt R, et al. Large-bore mechanical thrombectomy versus catheter-directed thrombolysis in the management of intermediate- and high-risk acute pulmonary embolism: a randomized controlled trial. *Circulation*. 2023;147(10):1055-1065.
3. Janssen PC, Dinkel J, de Boer A, et al. Catheter-directed and systemic thrombolysis for acute pulmonary embolism: a randomized controlled trial. *Journal of the American Medical Association*. 2023;329(10):911-921.
4. Janssen PC, Dinkel J, de Boer A, et al. Systemic and catheter-directed thrombolysis in patients with acute pulmonary embolism: a randomized controlled trial. *Journal of the American Medical Association*. 2023;329(10):911-921.
5. Janssen PC, Dinkel J, de Boer A, et al. Systemic and catheter-directed thrombolysis in patients with acute pulmonary embolism: a randomized controlled trial. *Journal of the American Medical Association*. 2023;329(10):911-921.
6. Janssen PC, Dinkel J, de Boer A, et al. Systemic and catheter-directed thrombolysis in patients with acute pulmonary embolism: a randomized controlled trial. *Journal of the American Medical Association*. 2023;329(10):911-921.
7. Janssen PC, Dinkel J, de Boer A, et al. Systemic and catheter-directed thrombolysis in patients with acute pulmonary embolism: a randomized controlled trial. *Journal of the American Medical Association*. 2023;329(10):911-921.
8. Janssen PC, Dinkel J, de Boer A, et al. Systemic and catheter-directed thrombolysis in patients with acute pulmonary embolism: a randomized controlled trial. *Journal of the American Medical Association*. 2023;329(10):911-921.
9. Janssen PC, Dinkel J, de Boer A, et al. Systemic and catheter-directed thrombolysis in patients with acute pulmonary embolism: a randomized controlled trial. *Journal of the American Medical Association*. 2023;329(10):911-921.
10. Janssen PC, Dinkel J, de Boer A, et al. Systemic and catheter-directed thrombolysis in patients with acute pulmonary embolism: a randomized controlled trial. *Journal of the American Medical Association*. 2023;329(10):911-921.

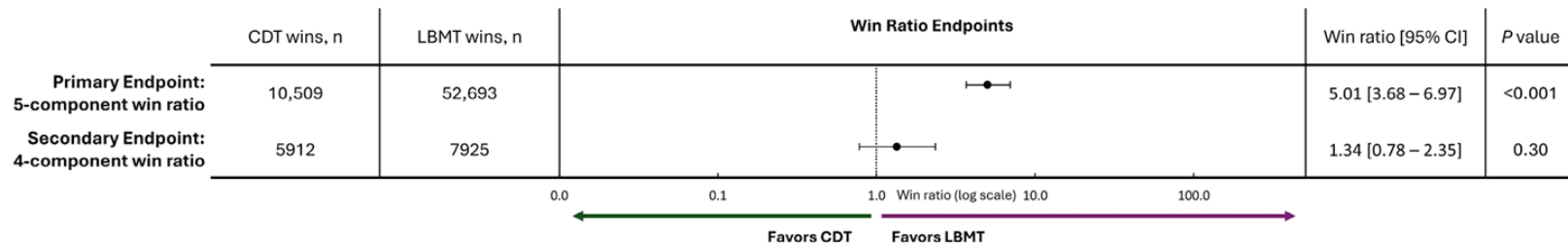
DISCLOSURES

The authors declare that they have no relevant financial interests related to the research in this paper

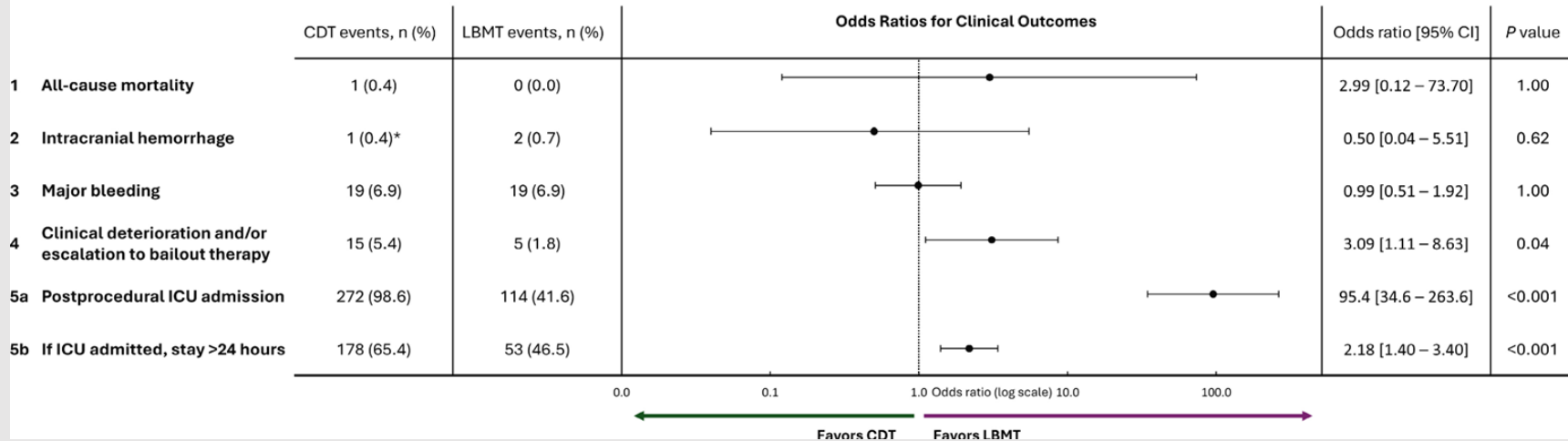
PEERLESS



A



B

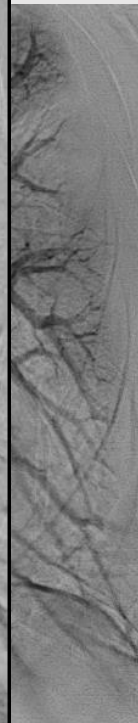
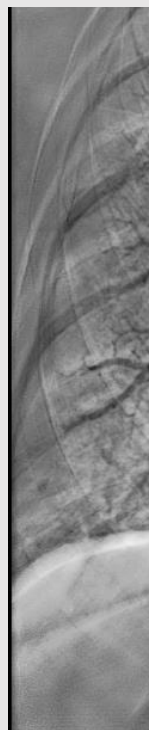


Clinical Trial Pipeline

			
RCT 1:1 ENDOVASC VS ANTICOAG INTERMEDIATE	RCT 1:1 FLOWTRIEVER VS ANTICOAG INTERMEDIATE	RCT 1:1 OF REDUCED DOSE ALTEPLASE VS UFH INTERMEDIATE HIGH	RCT 1:1 of FLOWTRIEVER VS SOC FOR HIGH RISK
500 SUBJECTS 30 NORTH AMERICAN SITES	1200 PATIENTS	650 SUBJECTS	200 SUBJECTS
PV02 AT 90 DAYS NYHA CLASSIFICATION AT ONE YEAR ISTH MAJOR BLEED AT 7 DAYS	ALL-CAUSE MORTALITY BY 30 DAYS CLINICAL DETERIORATION AND/OR BAILOUT BY 30 DAYS ALL-CAUSE HOSPITAL READMISSION BY 30 DAYS DYSYPNEA SCORE AT 48-HOUR VISIT	ALL CAUSE MORTALITY, CLINICAL DETERIORATION, OR RECURRENT PE AT 30 DAYS	ALL-CAUSE MORTALITY CARDIAC ARREST WITH LOSS OF CONSCIOUSNESS REQUIRING CPR BAILOUT TO ALTERNATIVE THERAPEUTIC STRATEGY MAJOR BLEEDING** PERSISTENT NEED FOR ECMO
12 MONTHS	90 DAY FOLLOW UP	24 MONTH FOLLOW UP	90 DAY FOLLOW UP

Thank you for your time and attention

Cases with PE Hemodynamics



Case 1

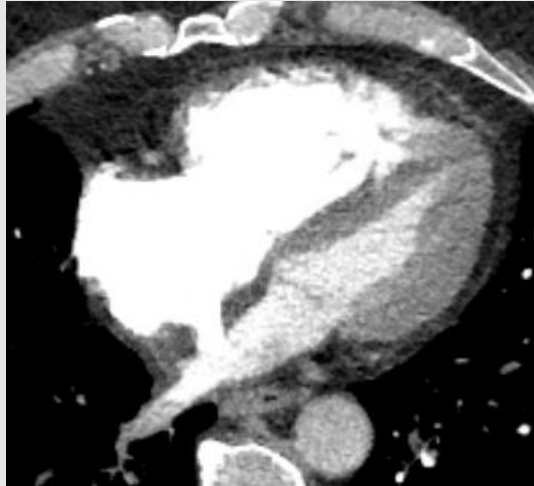
55 M with history of DVT/PE p/w 1.5 day acute onset SOB, presyncope

P: 110 BP: 108/70 POx: 92% on 3L

hsTrop: 121

Nt pro BNP 247

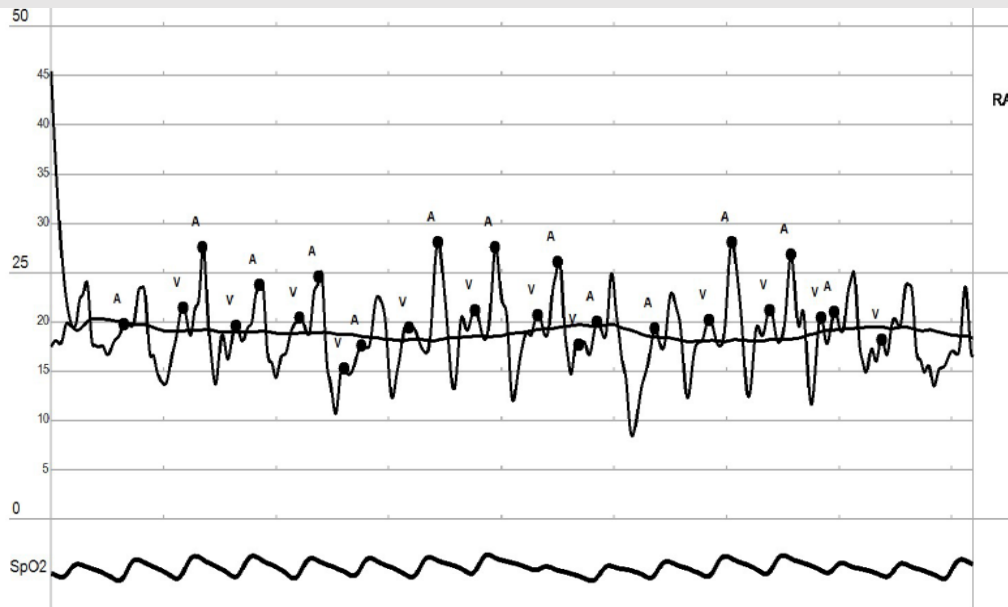
Lactic Acid: 2.3



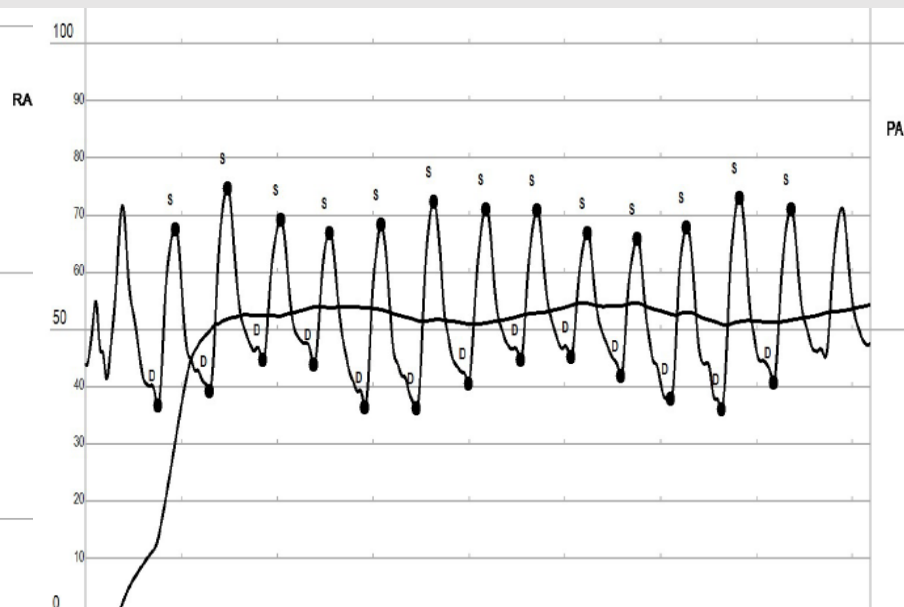
RHC + LBMT

PA Saturation = 50.8%

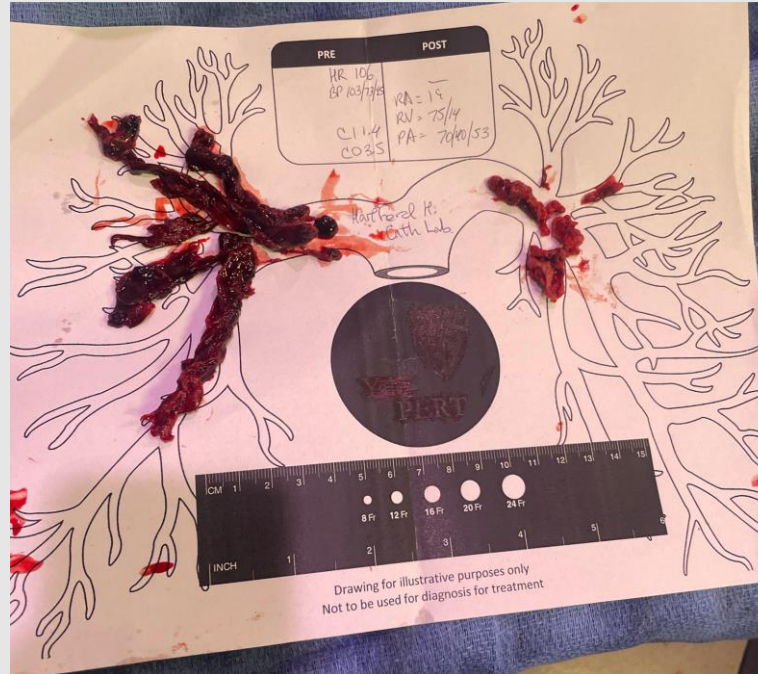
CO = 3.5 L/min ; CI = 1.4 L/min/kg²



HR: 115 bpm Resp: 15 ipm Spo2: 97 % Temp: Off NIBP: 124/81 mmHg



HR from 110 → 80
Discharged home the next day



Case 2

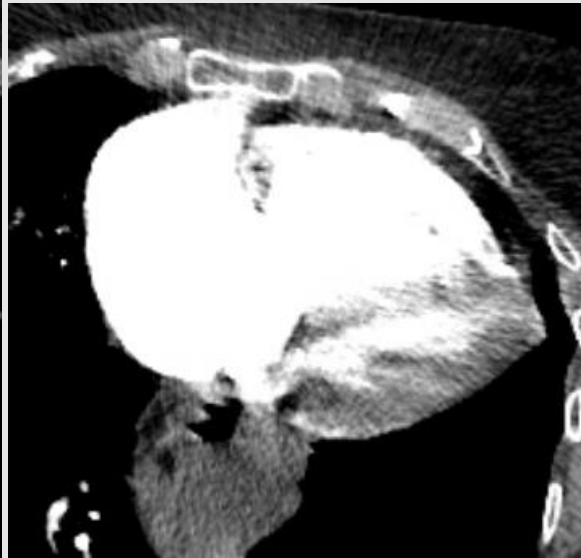
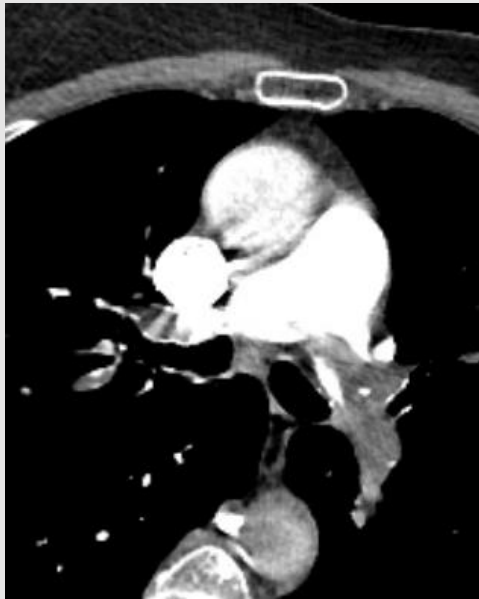
70 F p/w <1 day acute SOB, presyncope

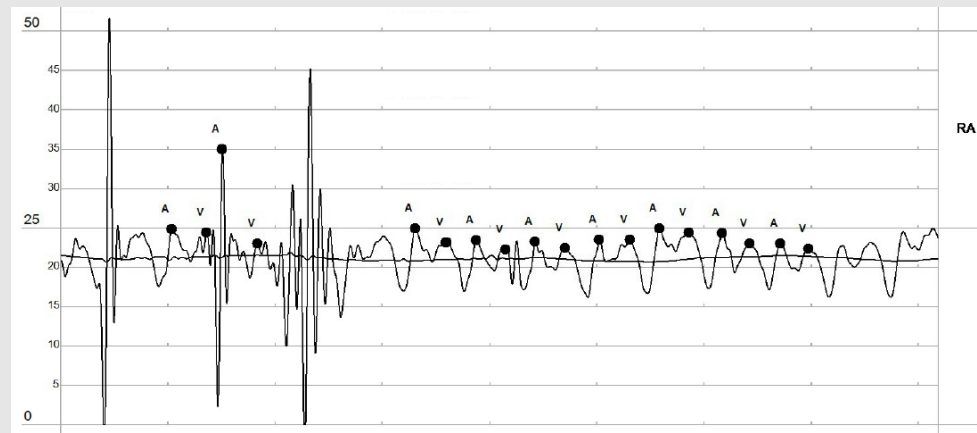
P: 115 BP: 115/71 POx 94% on 4L

HST: 211

NT pro BNP: 1955

Lactic Acid: 4.7





PA Sat 37%
CO: 1.89 L/min
CI: 1.3 L/min/kg²

s/p EKOS

PA sat → 65% the next morning

