



APPROACH TO A PATIENT WITH ACUTE AND CHRONIC PULMONARY EMBOLISM

**Richard Staab Symposium
April 11, 2026**

John Kingrey, MD
Director, Advanced Lung Dz and Pulmonary Hypertension
Integris Health, OKC



Disclosures

Consultant

Janssen Pharmaceuticals
Bayer Pharmaceuticals
United Therapeutics
Merck

Research

Janssen
United Therapeutics
Gossamer Bio

**None are relevant or
conflicting with today's
presentation**



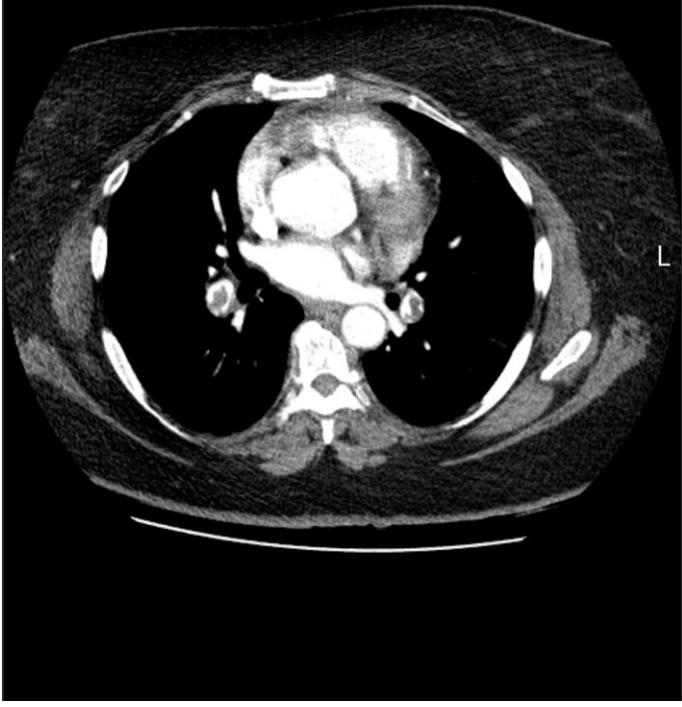
LEARNING OBJECTIVES

- PE risk Stratification
- PE treatments and controversies
- Post PE follow up
- CTEPH recognition and management principles

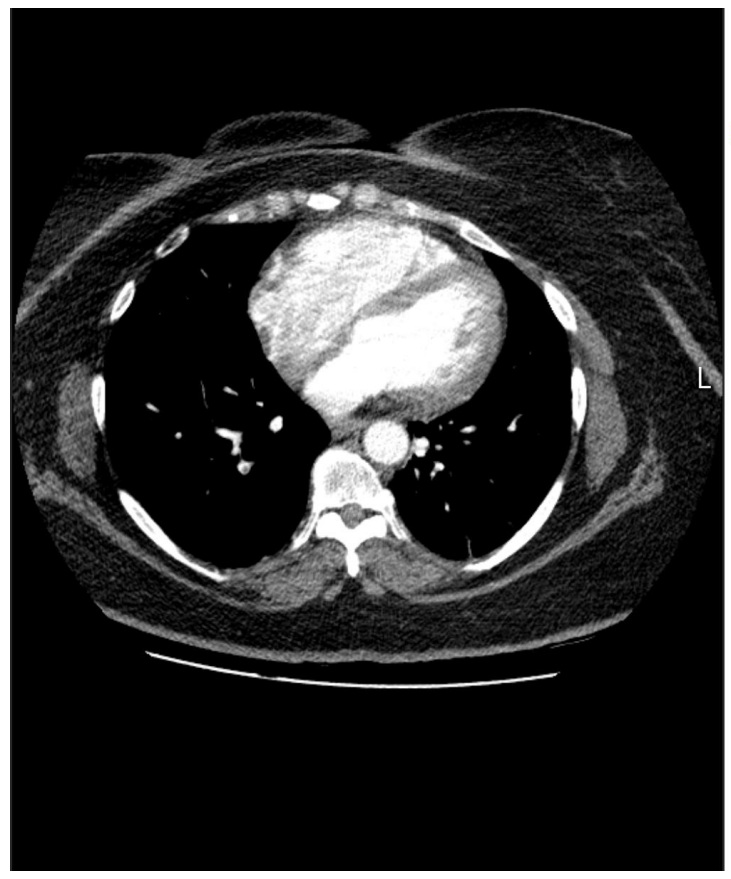


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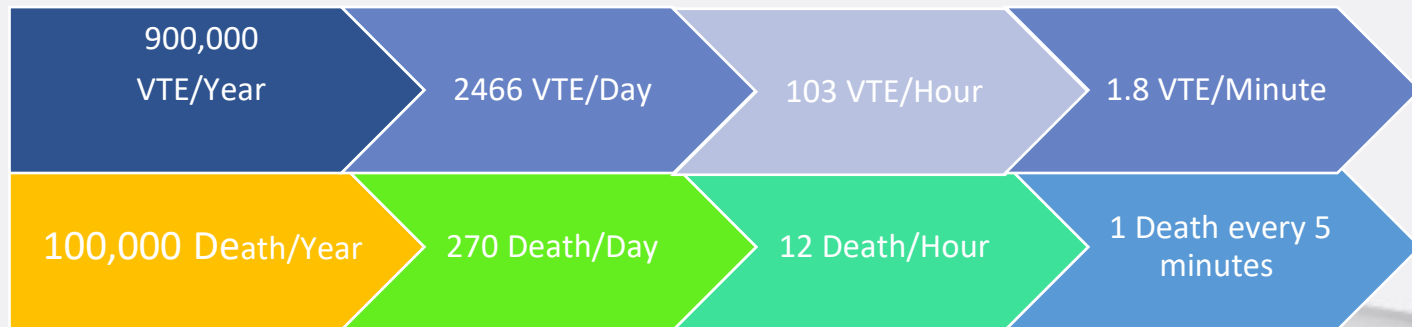


- Annotations
- W/L
- Full quality
- 3D
- MPR
- Print



- Full
- MPR
- F

VTE Matters!!!



End of an Hour: we will have roughly 103 VTE and 12 Death



Prediction Models: US + Europe: >1 Death/Minute



PE CLASSIFICATION

Table 8 Classification of pulmonary embolism severity and the risk of early (in-hospital or 30 day) death



Early mortality risk		Indicators of risk			
		Haemodynamic instability ^a	Clinical parameters of PE severity and/or comorbidity: PESI class III–V or sPESI \geq 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

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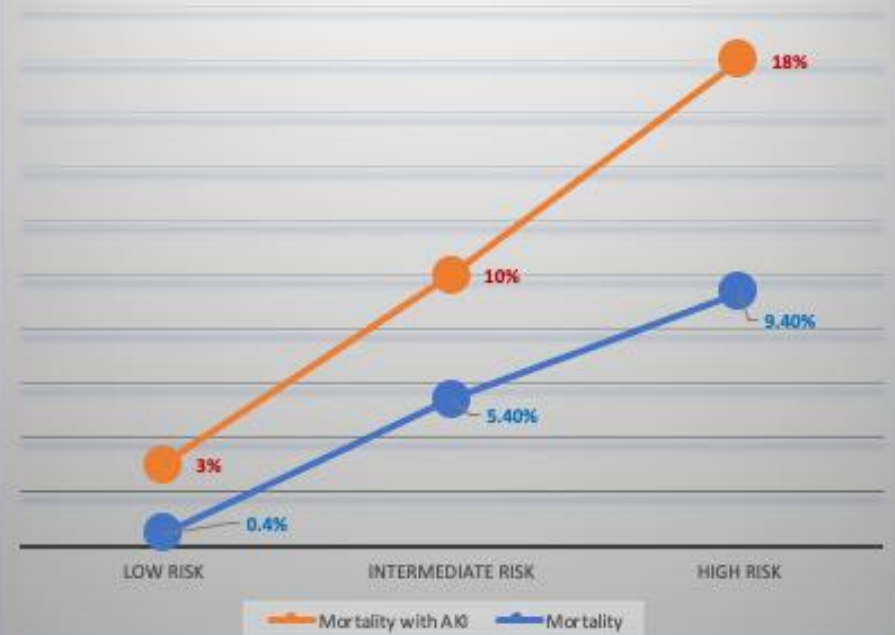
PE distribution and mortality

PE Distribution

N= 3216, Data from PERT centers



PE related Mortality



ADDITIONAL RISK STRATIFICATION

- Lactate > 2 mmol/L
- AKI (eGFR of ≤ 60 mL/min/1.7
- Hyponatremia (<135 mmol/L)
- Degree of Hypoxia?
- Neutrophilic Lymphocytic ratio (>7)

[Pulmonary and Cardiovascular Original Research]

CHEST

Heart Rate and Mortality in Patients With Acute Symptomatic Pulmonary Embolism

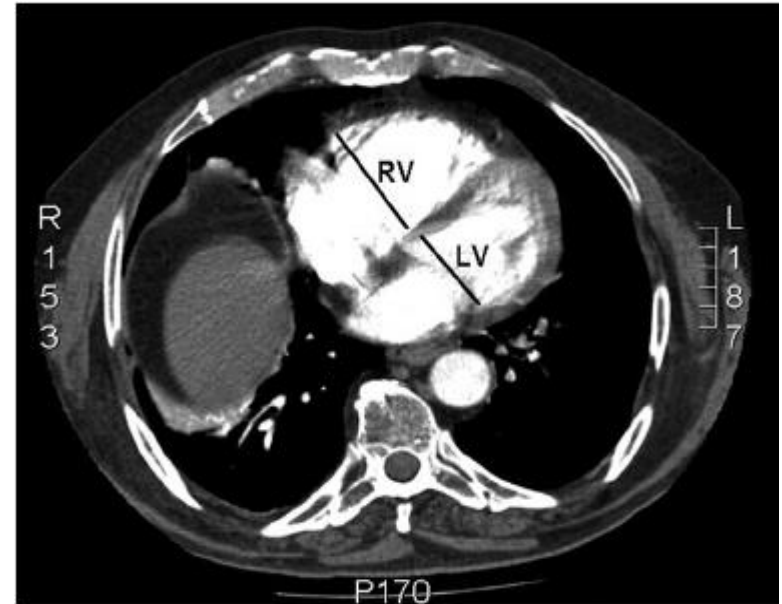
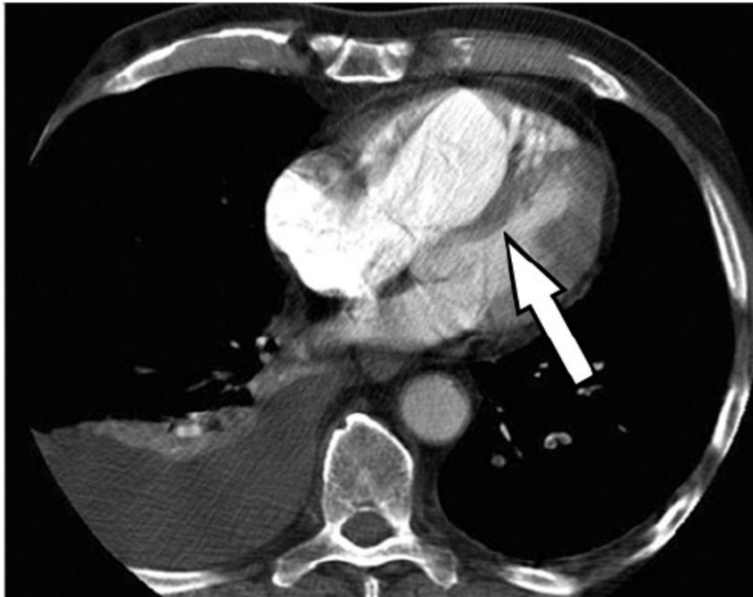
Ana Jaureguizar, MD; David Jiménez, MD, PhD; Behnood Bikdeli, MD; Pedro Ruiz-Artacho; Alfonso Muriel, PhD; Victor Tapson, MD; Raquel López-Reyes, MD, PhD; Beatriz Valero, MD; Gilli Kenet, MD; Manuel Monreal, MD, PhD; and the Registro Informatizado de la Enfermedad TromboEmbólica Investigators*

HR > 110 On presentation

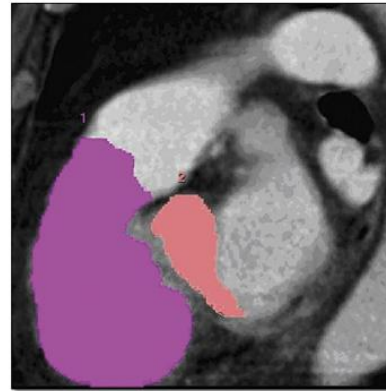
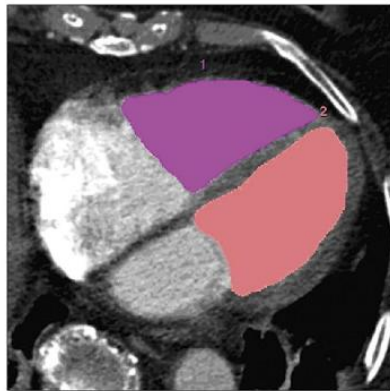
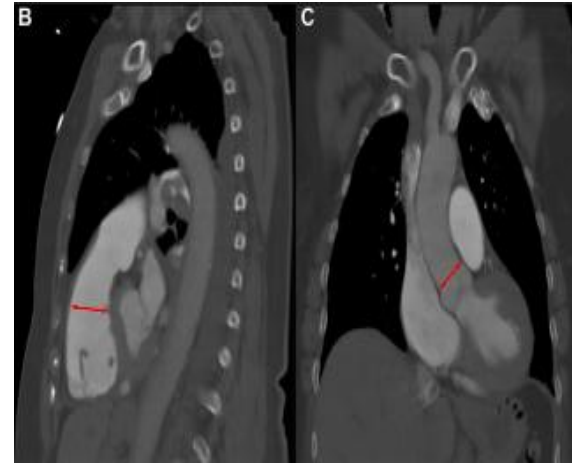
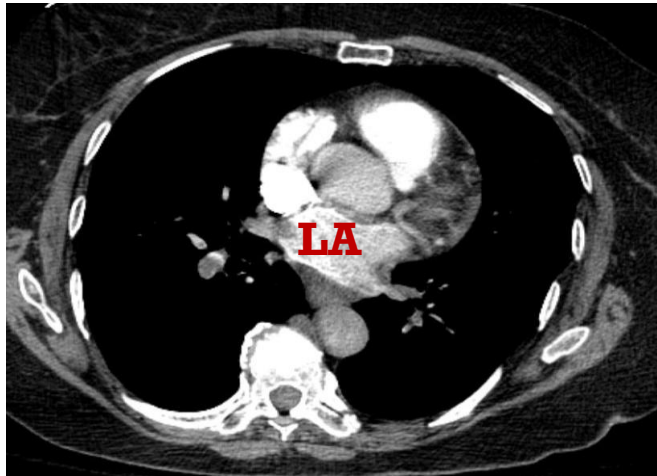
J Crit Care 2015;30:1151.e17.
Thromb Haemost 2019;119:140-148
Ann Emerg Med 2013;61:330-338.
Int J Cardiol 2017;227:251-256
Siddiqui F et al. . Am J Hematol. 2024 May 30.



RISK STRATIFICATION TOOLS (IMAGING)



RISK STRATIFICATION TOOLS (IMAGING)



- 1 J Thromb Thrombolysis. 2019
- 2 Vasc Med. 2019 Nov 10.
- 3 Clin Appl Thromb Hemost. 2019
- 4 Thromb Thrombolysis. 2019 Dec 14
- 5 Rami et al. ATS 2020 (e-poster)

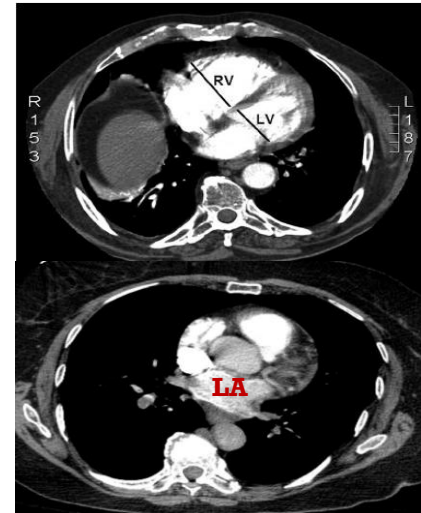


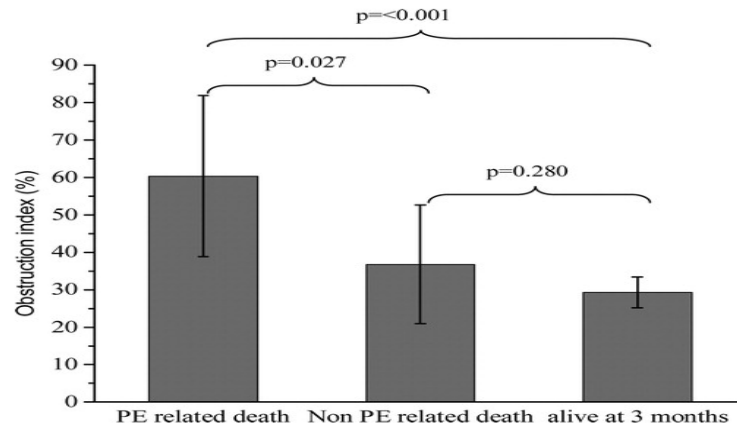
WE CAN USE CTPE BEYOND RV:LV



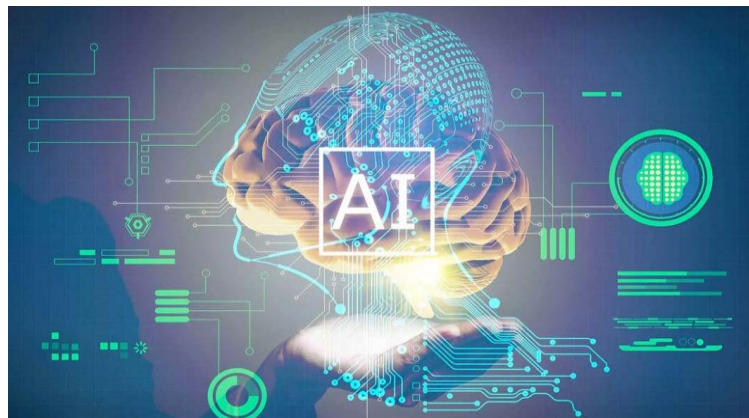
Table 2 CTA findings indicative of signs of RVD

CTA signs of RVD (references)	Abnormal
RV/LV diameter ratio ⁴¹	>1
RV/LV volume ratio ⁴⁵	>1.2
RA/LA volume ratio ⁴⁶	>1.2
LA volume ⁴⁶	<62 mL
PA diameter ³⁹	>29 mm
PA: aortic ratio ⁵⁶	>1.0
PA obstructive index ^{57,59,60}	Score dependent
Intraventricular septal deviation ^{47,48}	Present
IVC contrast reflux ^{49,50}	Present



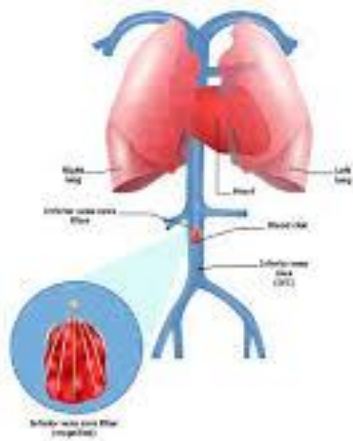


**PAOI (Pulmonary Artery Obstruction Index) >40%
= increase in PE related mortality.**



1. van der Meer, R. (2005). *Radiology*, 235(3), 798-803.
- 2 Bankier, A. A., (1997). *J Thorac Imaging*, 12(2), 150-158.





DVT + PE is different than PE or DVT Alone

Diagnosing DVT during PE treatment may reduce PE-related mortality, recurrent VTE, and prompt timely prevention of post-thrombotic syndrome (PTS).



50-65%

Of patients with PE also have proximal DVT¹⁻³ and nearly half are asymptomatic



>4X

Increased risk of PE-related 90-day mortality in PE patients with proximal DVT⁴



>4X

Increased risk of recurrent VTE in PE patients with proximal DVT⁴

1. Becattini, et al. Chest. 2016 Jan.
2. Hirmerova, et al. Clin Appl ThrombHemost. 2018 Nov.
3. Nishiwaki, et al. 2019 Nov.
4. Jiménez, et al. Am J RespirCrit Care Med. 2010 May



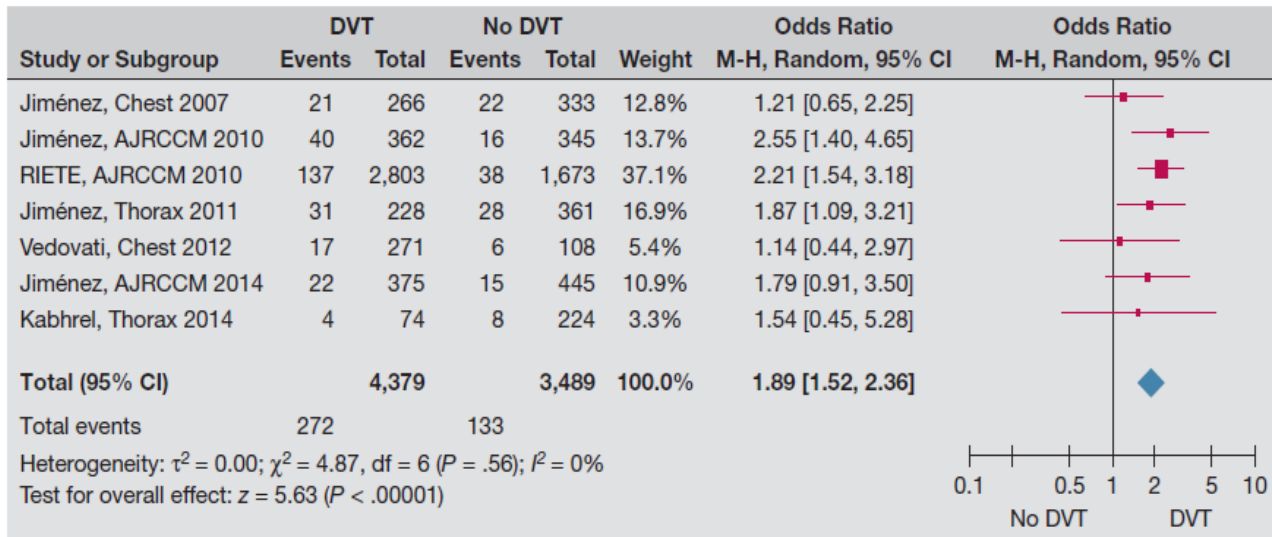
Risk Stratification of Patients With Acute Symptomatic Pulmonary Embolism Based on Presence or Absence of Lower Extremity DVT

Systematic Review and Meta-analysis



Cecilia Becattini, PhD; Alexander T. Cohen, PhD; Giancarlo Agnelli, MD; Luke Howard, PhD; Borja Castejón, MD; Javier Trujillo-Santos, PhD; Manuel Monreal, PhD; Arnaud Perrier, PhD; Roger D. Yusen, MD; and David Jiménez, PhD

A



**DVT + PE
Matters**

4 times increase risk of PE related 90 day mortality
4 times increased risk of recurrent VTE

1. Becattini, et al. Risk Stratification of Patients With Acute Symptomatic Pulmonary Embolism Based on Presence or Absence of Lower Extremity DVT: Systematic Review and Meta-analysis. Chest. 2016 Jan.
2. Hirmerova, et al. The Prevalence of Concomitant Deep Vein Thrombosis, Symptomatic or Asymptomatic, Proximal or Distal, in Patients With Symptomatic Pulmonary Embolism. Clin Appl ThrombHemost. 2018 Nov.
3. Nishiwaki, et al. Impact of Concomitant Deep Vein Thrombosis on Clinical Outcomes in Patients With Acute Pulmonary Embolism. American Heart Association. 2019 Nov.
4. Jiménez, et al. Prognostic significance of deep vein thrombosis in patients presenting with acute symptomatic pulmonary embolism. Am J Respir Crit Care Med. 2010 May



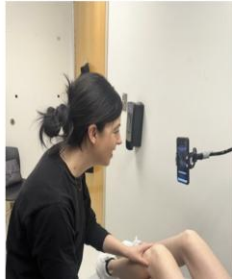
Home > About Temple Health > Newsroom > Temple Health Joins U.S. Study of Artificial Inte...

Temple Health Joins U.S. Study of Artificial Intelligence Diagnostic System for Detection of Deep Vein Thrombosis

View All News

February 13, 2024

Temple Health is partnering with ThinkSono, a UK-based AI company, to study a new artificial intelligence (AI)-powered ultrasound technology that enables more rapid and portable diagnosis of deep vein thrombosis (DVT).



DVT, a condition in which blood clots develop in veins, can lead to potentially fatal complications like the spread of blood clots to the heart and lungs (known as pulmonary embolism) as well as debilitating long-term swelling and pain of the legs (called post-thrombotic syndrome). According to

NEWSWIRE Products Pricing Customer Stories Resources Newsroom

ThinkSono Partners With NYU Langone Health to Conduct Study of Ultrasound AI Guidance Software for DVT Detection

Press Release - Nov 3, 2023

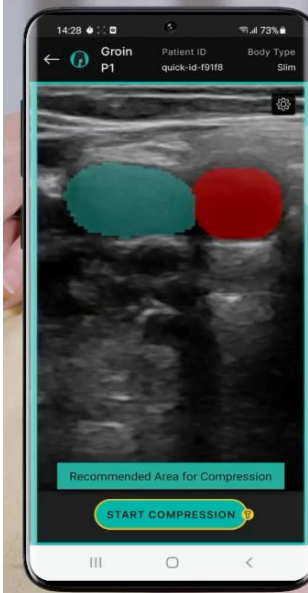


LONDON, England, November 3, 2023 (NewsWire.com) - [ThinkSono Ltd](#) ("ThinkSono"), a leading ultrasound AI company, has partnered with [NYU Langone Health](#) as a trial site to launch the first U.S.-based clinical trial of [ThinkSono Guidance](#) - a new artificial intelligence (AI)-powered ultrasound software that enables more rapid and portable diagnosis of deep vein thrombosis (DVT).



DVT: A leading cause of preventable hospital death

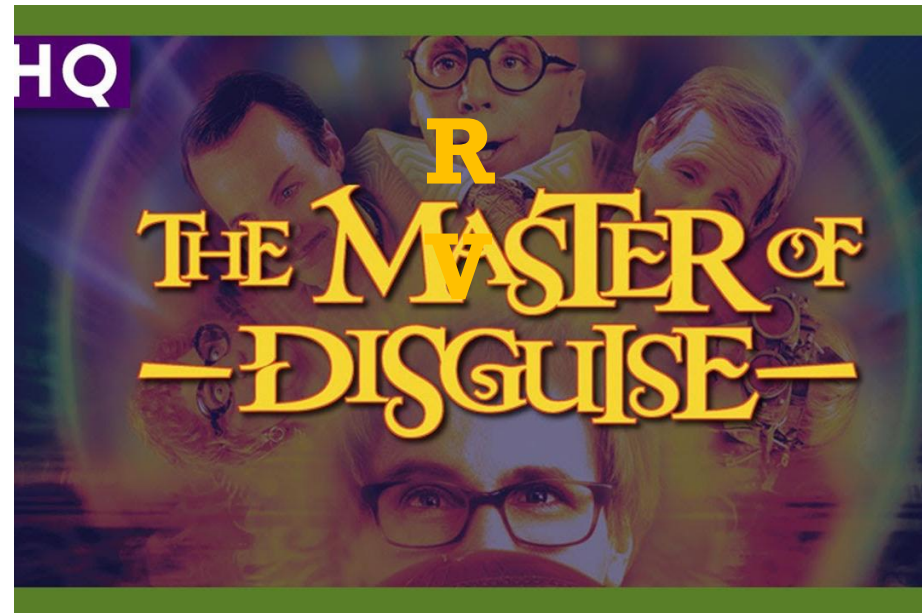
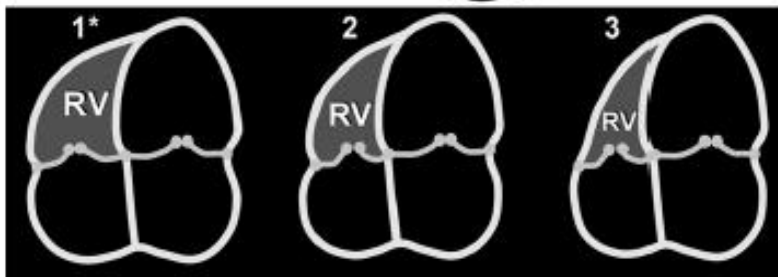
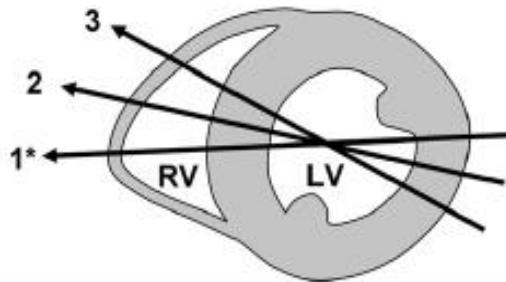
DVT, a condition in which blood clots develop in veins, affects up to 300,000 Americans every year and is common in hospitalized patients. DVT can lead to potentially fatal complications like the spread of blood clots to the heart and lungs (known as pulmonary embolism, PE) as well as debilitating long-term swelling and pain of the legs (called post-thrombotic syndrome). DVT is also a significant driver of healthcare costs, costing the U.S. healthcare system up to \$10 billion each year. NYU Langone's vascular surgeons are experts in the treatment of these conditions, with extensive experience in conducting clinical trials.



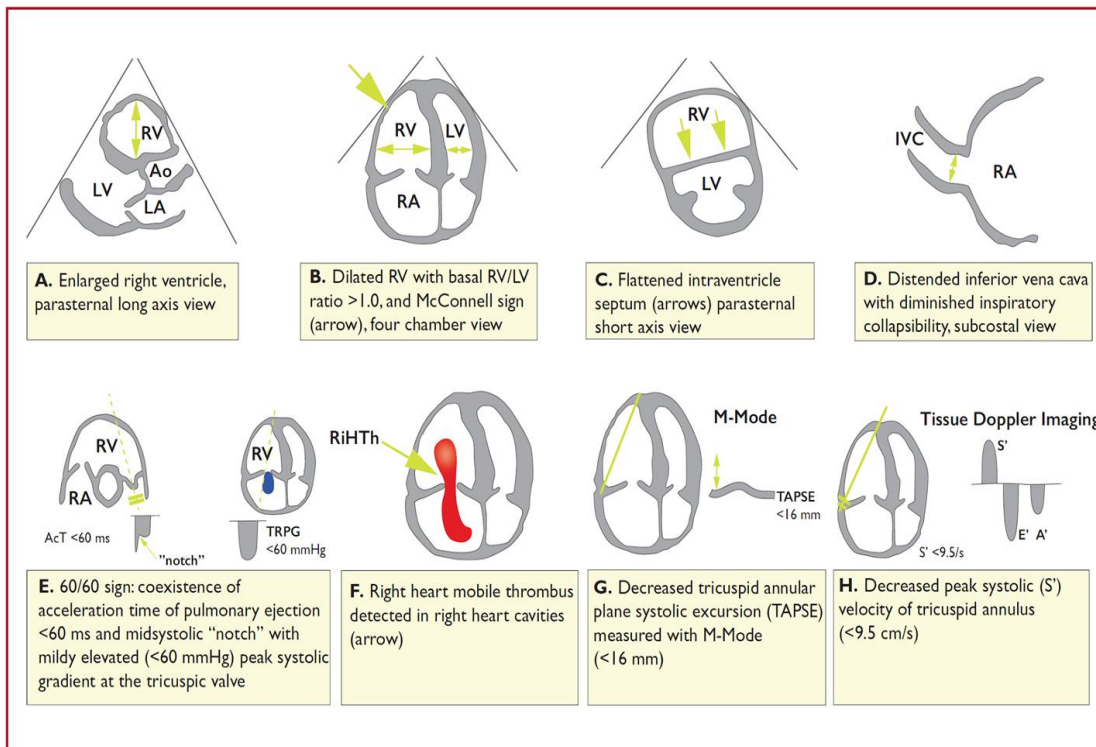
- **THINKSONO:** Automatic AI based DVT detection: On going Study at Temple Health and NYU Langone Health
- Up to a 100 suspected DVT patients will be recruited at each site. (>45 patients recruited at Temple So far)
- Scan done by any nurse or doctor (no ultrasound training required) + remote review by qualified clinician.
- Will compare ThinkSono scan + review vs standard of care duplex ultrasound (image quality, sensitivity, specificity).
- Upon success will apply for FDA clearance.



RV ASSESSMENT: NEED MORE THAN ONE VIEWS



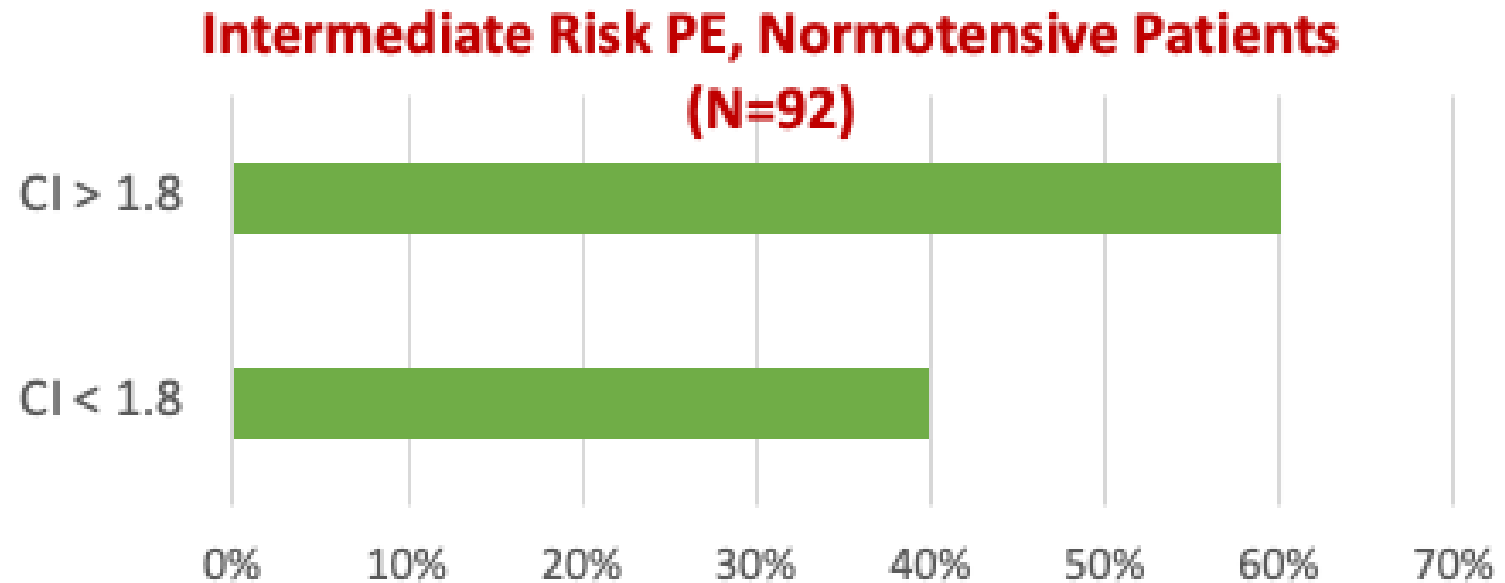
ECHO based risk stratification



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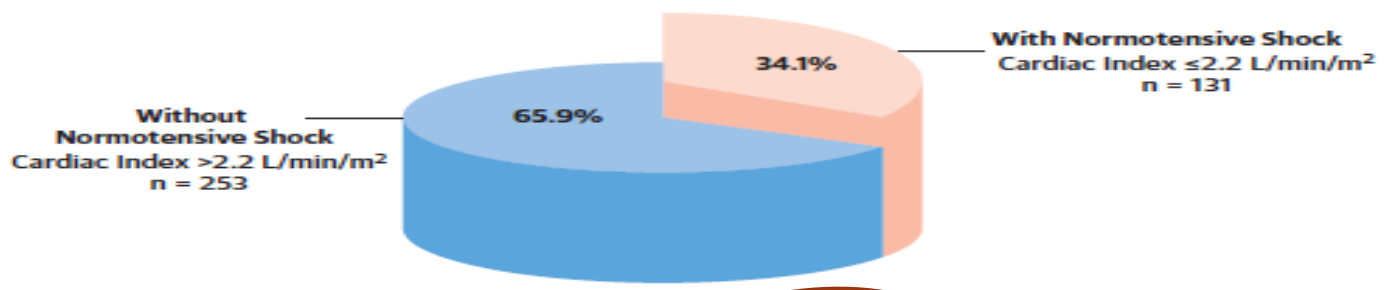
Sub Clinical Shock State?



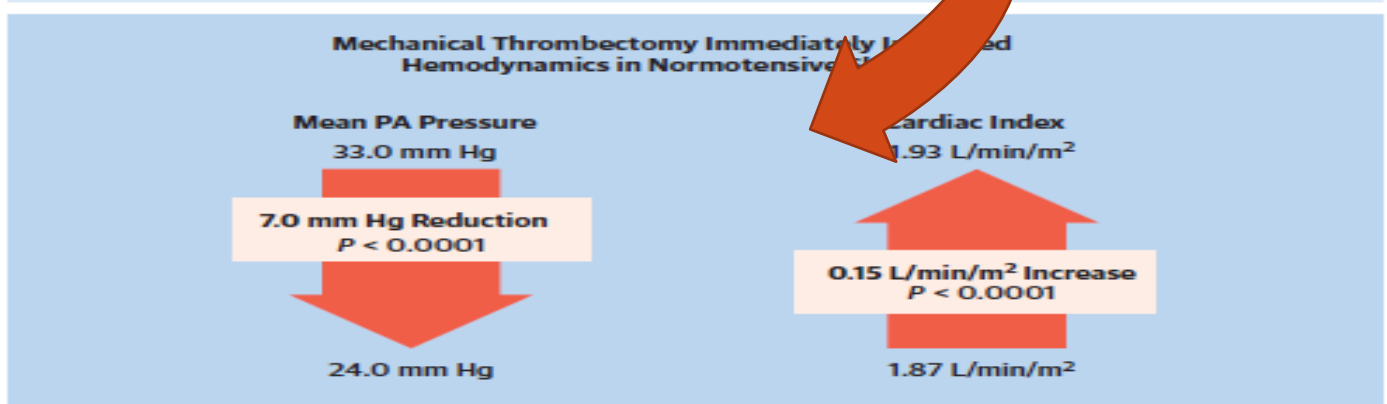
Predictors of Normotensive Shock in Intermediate-Risk PE Patients- FLASH Registry

CENTRAL ILLUSTRATION Normotensive Shock in Intermediate-Risk Pulmonary Embolism Patients Is Predicted by a Composite Shock Score and Is Immediately Improved After Mechanical Thrombectomy

Normotensive Shock in Patients With Intermediate-Risk Pulmonary Embolism From the FLASH Registry



Composite
Elevated Troponin + Elevated BNP + Moderate/Severely Reduced RV function + Saddle PE + Concomitant DVT + Tachycardia
Risk Factor Associated With Normotensive Shock
(OR: 5.84; 95% CI: 2.00-17.04)



Bangalore S, et al. J Am Coll Cardiol Interv. 2023;16(8):958-972.

ADDITIONAL STRATIFICATION: BLEEDING RISK SCORES

Table 4. Major Bleeding Risk–Predicting Scores in Pulmonary Embolism Treatment

Score	Percent Predicted
RIETE score for major bleeding (51) (VKA-related bleeding score)	
Low risk (0 points)	0.3%
Intermediate risk (1–4 points)	2.6%
High risk (>4%)	7.3%
PE-CH score for ICH (55) (systemic thrombolysis–related bleeding risk score)	
0	1.2%
1	2.9%
2	3.4%
>5	17.8%

BACS Score: **B**leeding (3 points), **A**ge >75 years (1 point), active **C**ancer (1 point), and **S**yncope (1 point) Predicting Major Bleeding in patients receiving tPA



BLEEDING RISK FOR TPA AND ANTICOAGULATION: IMPORTANT IN DECISION MAKING LOW INTERMEDIATE RISK.

Table 4 Bleeding risk scores

Bleeding risk scores (references)	Factors
Thrombolysis-related bleeding ✓	
PE-CH ¹¹⁰	Preexisting vascular disease (1 point) Elderly (1 point) Prior CVA (5 points) Prior Heart attack (1 point)
BACS ¹¹¹	Bleeding (3 points) Age >75 (1 point) Cancer (1 point) Syncope (1 point)
Anticoagulation-related bleeding ✓	
OBRI ¹¹²	Age >65 (1 point) History of CVA (1 point) History of GIB (1 point) Recent MI, Hct < 30%, Cr > 1.5 or diabetes mellitus (1 point)
HAS-BLED ¹¹⁴	Hypertension (1 point) Abnormal renal/liver function (1 or 2 point) Stroke (1 point) Bleeding (1 point) Labile INR (1 point) Elderly (age > 65) (1 point) Drug or alcohol use (1 or 2 point)
RIETE ¹¹⁷	Recent major bleeding (2 points) Creatinine >1.2 mg/dL (1.5 points) Anemia (1.5 points) Cancer history (1 point) Clinically overt PE (1 point) Age >65 (1 point)
VTE-BLEED ¹¹⁹	Active cancer (2 points) Male with uncontrolled arterial hypertension (1 point) Anemia (1.5 points) History of bleeding (1.5 points) Age ≥60 y (1.5 points) Renal dysfunction (1.5 points)

Common Themes and real-world patients

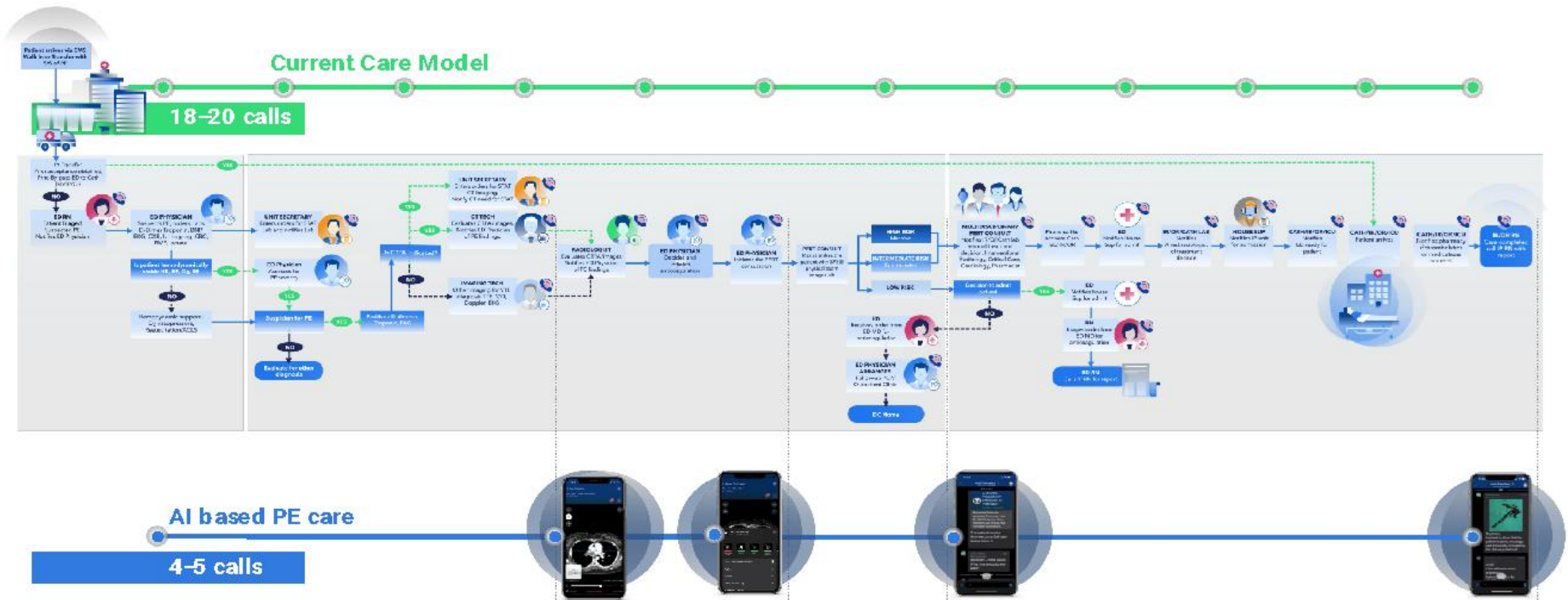


CVA
Old Age
Cancer
Syncope
Hx of Bleeds
Anemia
Abn Cr/GFR
HTN
Coagulopathy
DM

Artificial Intelligence in PE care

Door to Plan Execution

Imaging to Decision, Imaging to Ordering Anti-coagulants



WHY DID I HAVE THE BLOOD CLOT?

PROVOKE![®]
THE REVOLUTION OF IDEAS

Terminology such as “provoked” *versus* “unprovoked” PE/VTE is no longer supported by the Guidelines, as it is potentially misleading and not helpful for decision-making regarding the duration of anticoagulation.

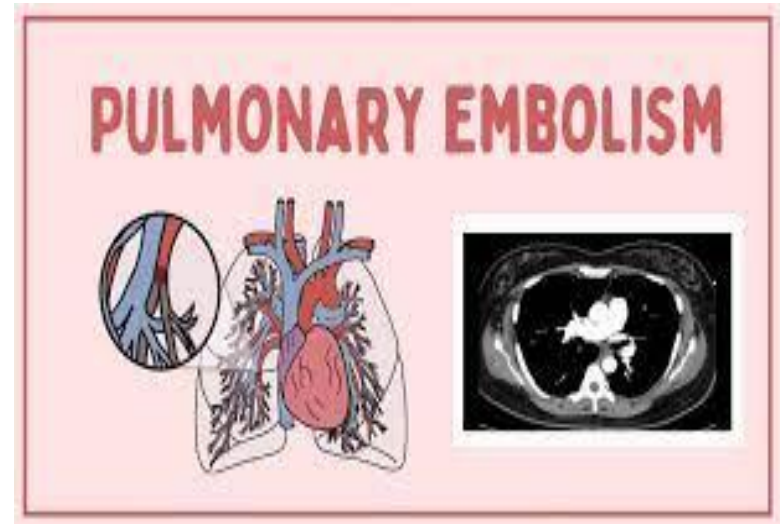
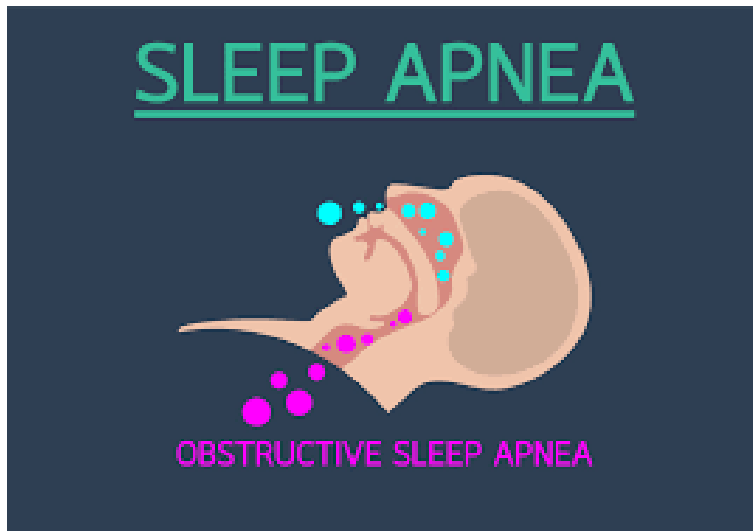


TRAVEL HX: PROVOKED?

- Not only confined to air travel.
- Travel + individual risk factors responsible for VTE.
- >4 hours: one in 4656
- >8 hours: 0.5% *
- Severe symptomatic PE is rare unless flights >12 hours: 5 per million



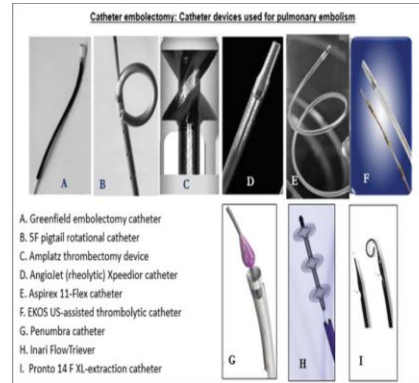
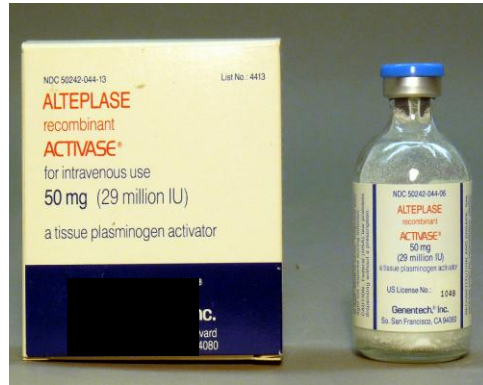
GOOD OR BAD COMBINATION



OSA is not associated with increased mortality in PE

Seckin ZI et al. J Clin Sleep Med. 2020 Jul 15;16(7):1029-1036
Alonso-Fernandez et al. Chest. 2016;150(6):1291-1301
Giorgi-Pierfranceschi M et al. Chest. 2021 Mar;159(3):1310
Ghiasi F et al. J Res Med Sci. 2015 Jul;20(7):662-7.





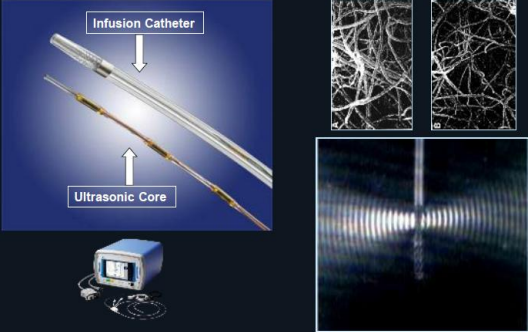
TREATMENT OPTIONS FOR PE



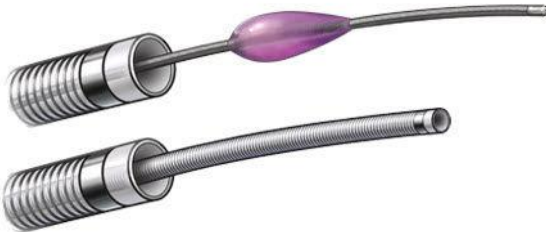
INTERMEDIATE RISK INTERVENTION



The Simple (2): Ultrasound-Accelerated Thrombolysis (EKOS)



The diagram illustrates the EKOS system components. On the left, an 'Infusion Catheter' is shown inserted into an 'Ultrasonic Core'. Below the core is a control unit with a digital display. On the right, three images show: a cross-section of a thrombus (clot), a longitudinal view of the thrombus, and a close-up of the ultrasonic core's tip.



INTERMEDIATE RISK PE AND TPA

- PEITHO trial (N=1006 patient)

Major Bleeding (ISTH)

Fatal

Symptomatic bleed in critical organ

Hgb fall >2 g/dL

Transfusion >2 units blood

Compared to A/C:
Less
hemodynamic
decompensation
and/or reduce
mortality (**2.6** Vs
5.6%) within 7
days



ICH **2%** Vs 0.2%

ISTH Major Bleeding

11.5% Vs 2.4%

ISTH Minor Bleeding

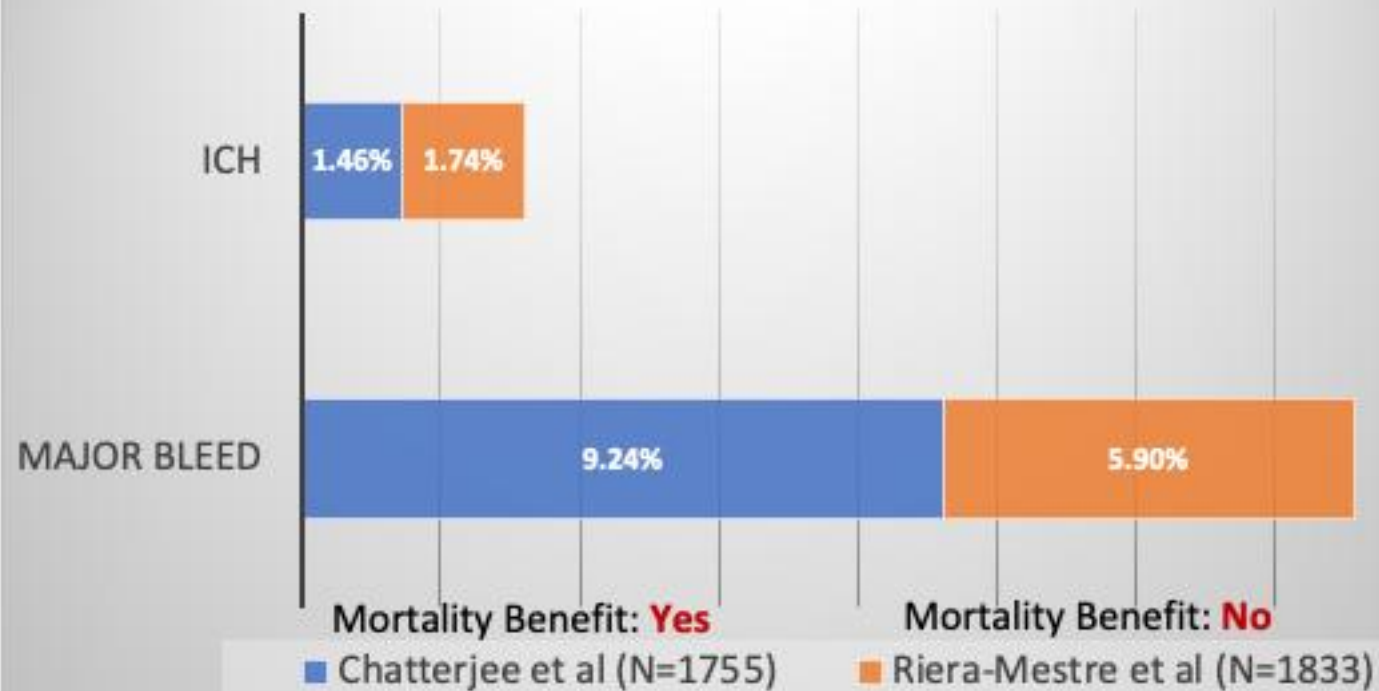
32.6% Vs 8.6%

A/C= ANTICOAGULATION

ISTH= Int'l Soc Thromb and Haemostasis



Systemic Review: tPA and Intermediate risk PE



SYSTEMIC THROMBOLYSIS IN HIGH-RISK PE

- **Only RCT of systemic lysis in Massive PE!**
- **N=8**
- **4 treated with UFH died**
- **4 treated with streptokinase survived**
- **100% survival in lysis (p=0.02)**

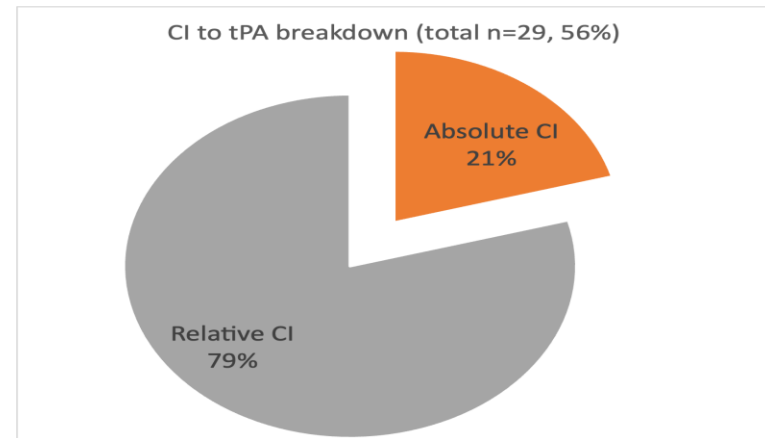
*Streptokinase and Heparin versus Heparin Alone
in Massive Pulmonary Embolism: A Randomized
Controlled Trial*

*Carlos Jerjes-Sanchez,¹ Alicia
Ramírez-Rivera,² María de Lourdes
García,¹ Roberto Arriaga-Nava,¹
Salvador Valencia,¹ Alfonso Rosado-Buzzo,¹
Juan A. Pierzo,⁴ and Emma Rosas³*

*¹Emergency Care Department, ²Respiratory Department,
³Echocardiography Department, and ⁴Nuclear Medicine
Department, Hospital de Cardiología, National Medical Center,
Mexico City, Mexico*



WATCHFUL WAITING/STABILITY CAN BE REVISITED



> [J Vasc Surg Venous Lymphat Disord.](#) 2022 Jun 15;S2213-333X(22)00255-4.
doi: 10.1016/j.jvs.2022.04.014. Online ahead of print.

Contemporary practice patterns and outcomes of systemic thrombolysis in acute pulmonary embolism

Shameek Gayen¹, Alyson Katz², Fusun Dikengil³, Benjamin Kwok⁴, Matthew Zheng³, Ronald Goldenberg⁴, Catherine Jamin⁵, Eugene Yuriditsky⁴, Riyaz Bashir⁶, Vladimir Lakhter⁶, Joseph Panaro⁷, Gary Cohen⁷, Kerry Mohrien⁸, Parth Rali³, Shari B Brosnahan⁷

Text

FULL TEXT LINKS

[ELSEVIER](#)
FULL-TEXT ARTICLE

ACTIONS

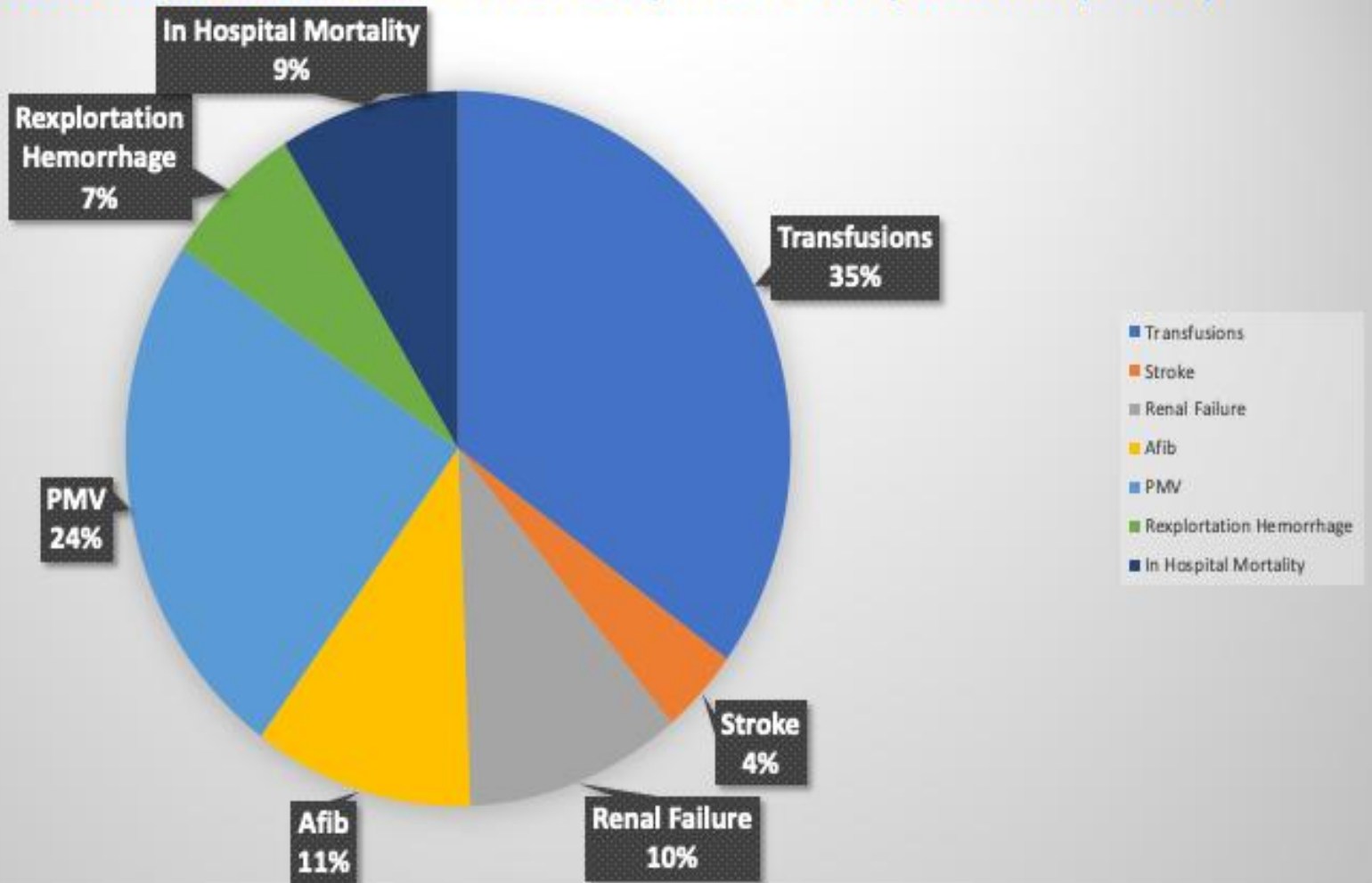
« Cite

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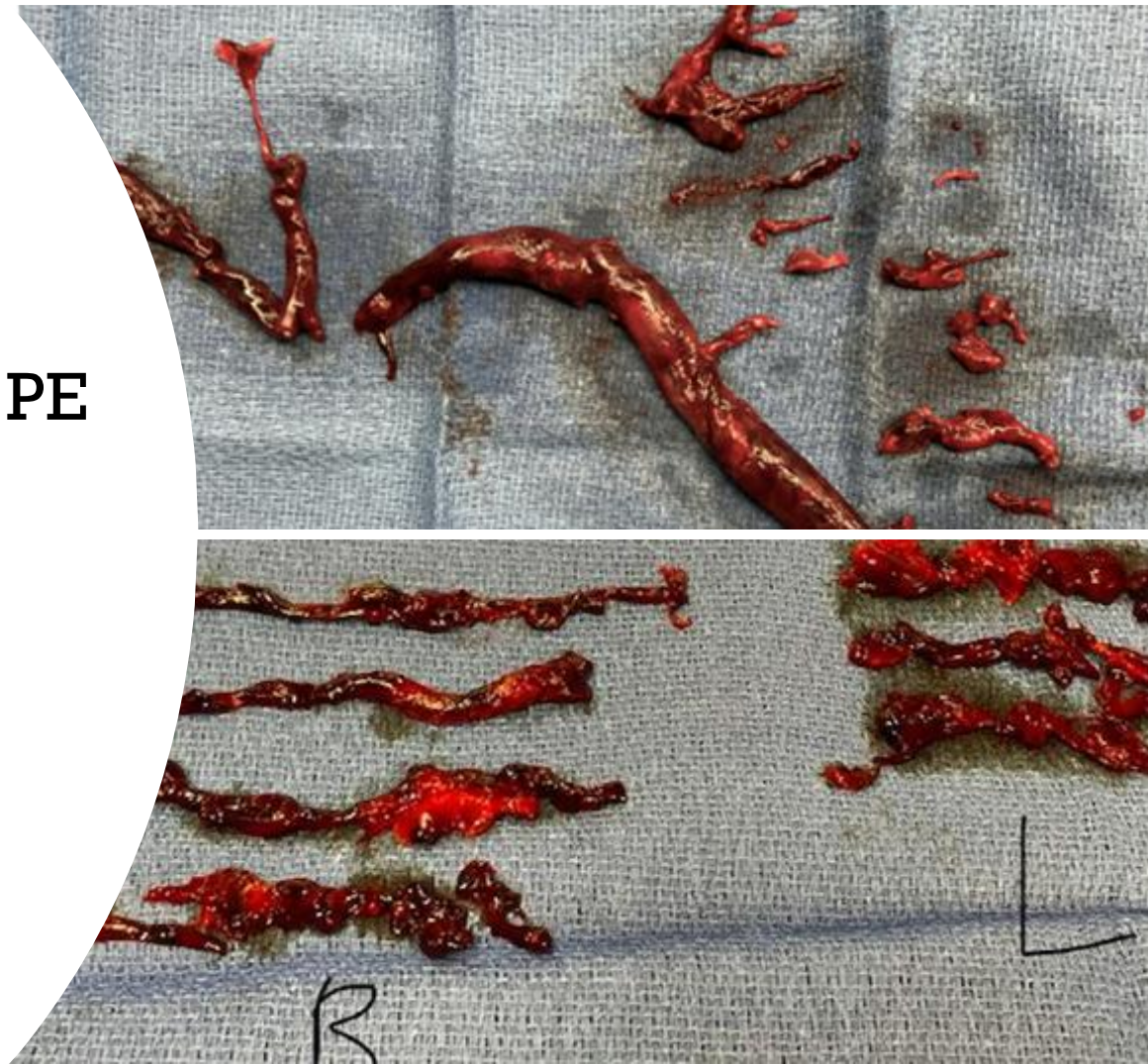


STS Database: Submassive PE Post Operative Complications (N=176)



**REAL CASES:
INTERMEDIATE RISK PE**

**SURGICAL OR
PERCUTANEOUS ?**





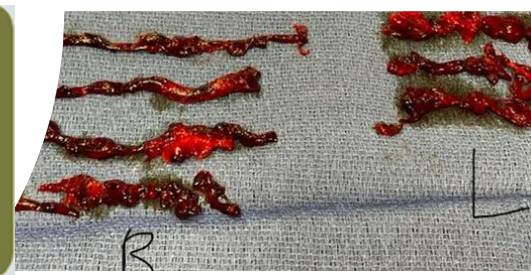
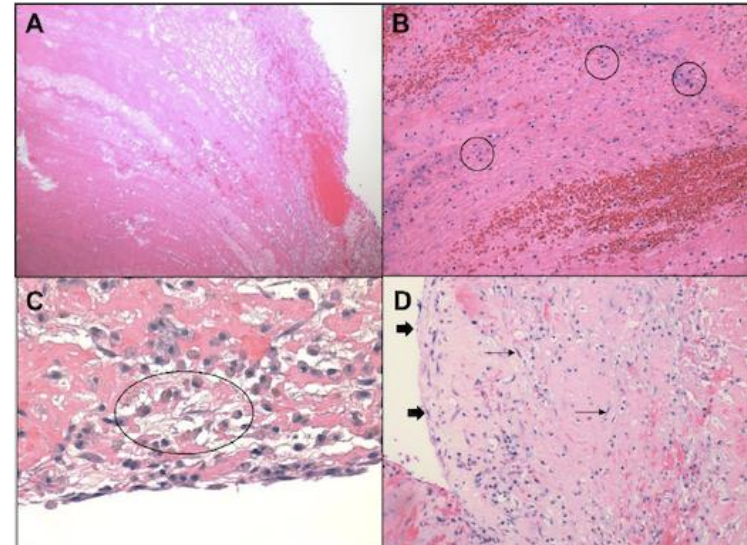
CLOTS MORPHOLOGY

ARTICLE IN PRESS

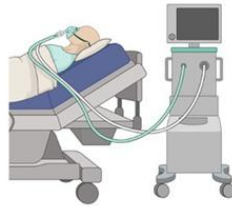
Microscopic Examination of Clots from Percutaneous Mechanical Embolectomies in Pulmonary Embolism

Vruksha Upadhyay, MD^{a,*}, Shameek Gayen, MD^b, Amandeep Aneja, MD^c,
 Maruti Kumaran, MD^d, Riyaz Bashir, MD^e, Vladimir Lakhter, DO^f,
 Joseph Panaro, MD^g, Gary Cohen, MD^h, Eduardo Bossone, MDⁱ,
 Gerard Crine, MD^j, Parth Rali, MD^k

Patient	Symptom Onset, d	Clot Age on CTPA	Clot Age via Histology, d	DVT Location	Initial Oxygen Requirement
1	3	Acute	2-7	3	50 L/min
2	1	Acute	0-3	0	100% Fio ₂ via ventilator
3	7	Acute	2-7	3	3 L/min
4	1	Acute	5-14	3	2 L/min
5	7	Acute	5-14	3	3 L/min
6	7	Acute	>14	3	40% Fio ₂ via ventilator
7	6	Acute	>14	3	0 L/min
8	5	Acute	2-7	3	100% Fio ₂ via CPAP
9	1	Acute	>14	0	5 L/min
10	1	Acute	5-14	4	2 L/min
11	1	Acute	2-7	4	15 L/min
12	7	Acute	5-14	3	4 L/min
13	2	Acute	0-3	3	10 L/min



Oxygen therapy and ventilation



- Start with conventional devices
- Consider HFNC if required
- Avoid intubation if possible; if necessary, use etomidate or ketamine in induction
- Aim for low or zero PEEP, low tidal volume, and end-inspiratory plateau pressure <30 cmH₂O

Mechanical circulatory support

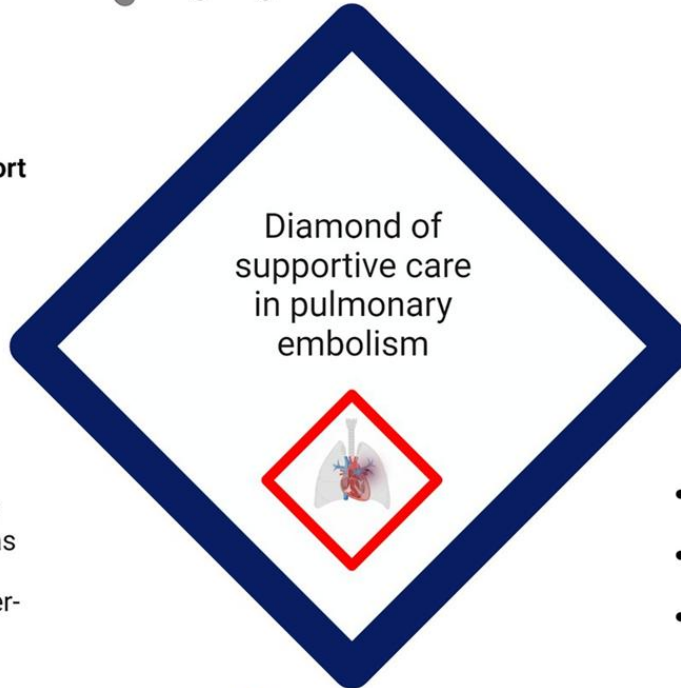


- Consider VA-ECMO in patients with high-risk PE, and circulatory collapse or cardiac arrest. Also as a bridge to other therapies (e.g., surgical embolectomy or catheter-directed thrombolysis)
- May consider RVAD

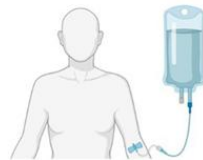
Pharmacological support with vasopressors, inotropes, and vasodilators



- Consider early pharmacological support in PE patients with hypotension
- First-line: NE; titrate to keep MAP >65 mmHg
- Consider dobutamine if NE insufficient



Fluid therapy and diuretics

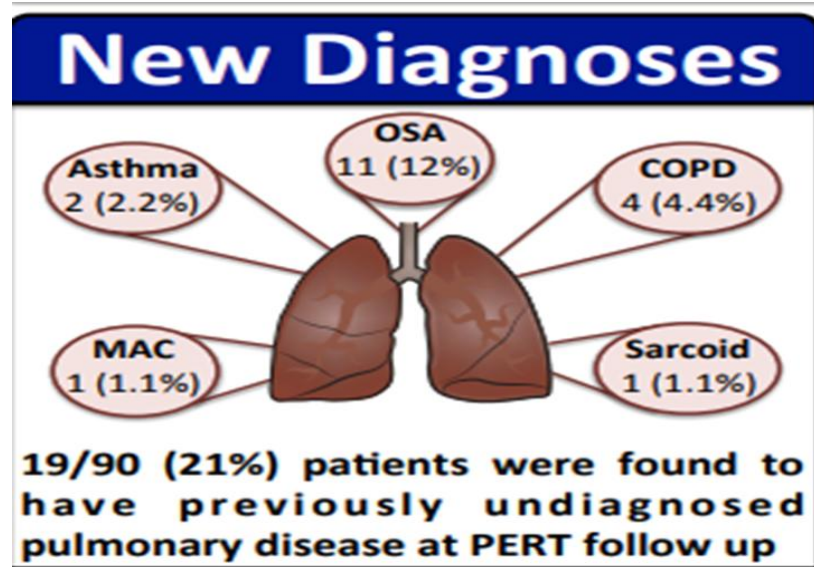
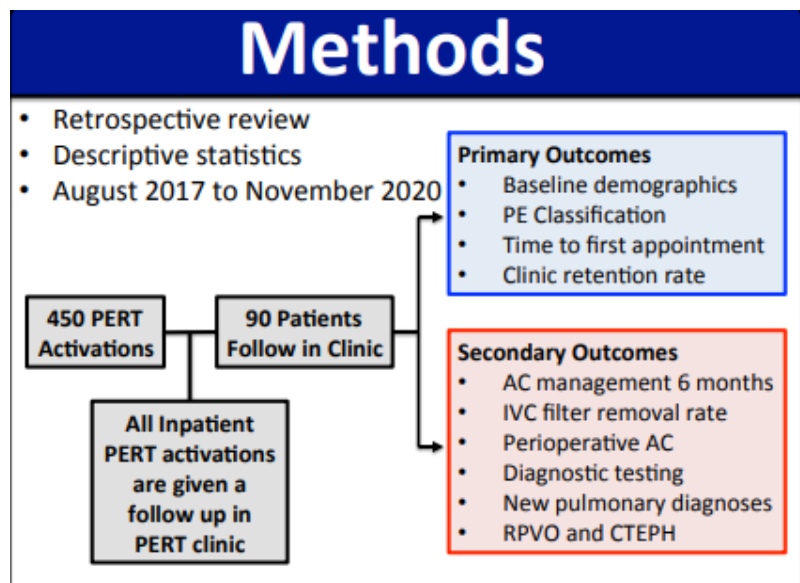


- Use IV fluids with caution
- Avoid fluid overload
- Monitor CVP and stop IV fluids if elevated
- Consider diuretics

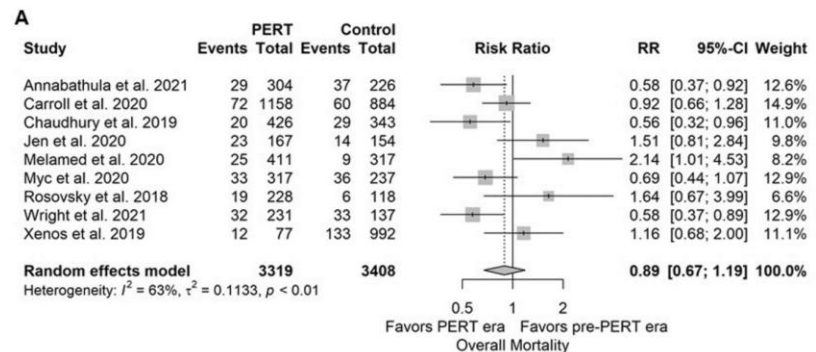
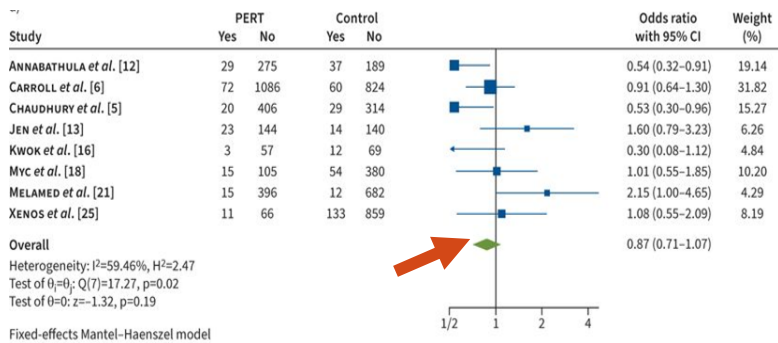


POST PE PATIENTS FOLLOW UP AT TEMPLE UNIVERSITY HOSPITAL

(Courtesy of Parth Rali, MD)



WITH Pulmonary Embolism Response Teams (PERT), WE ARE MOVING THE NEEDLE !!



Fleitas Sosa D *et al.* Eur Rev. 2022 Jul 12;31(165) Respir

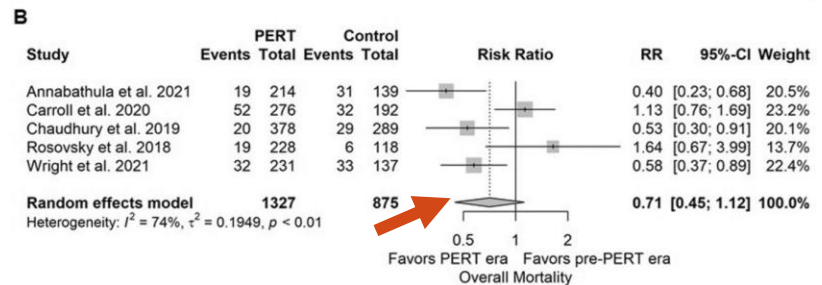


EUROPEAN RESPIRATORY REVIEW
 REVIEW
 D. FLEITAS SOSA ET AL.

Impact of pulmonary embolism response teams on acute pulmonary embolism: a systematic review and meta-analysis

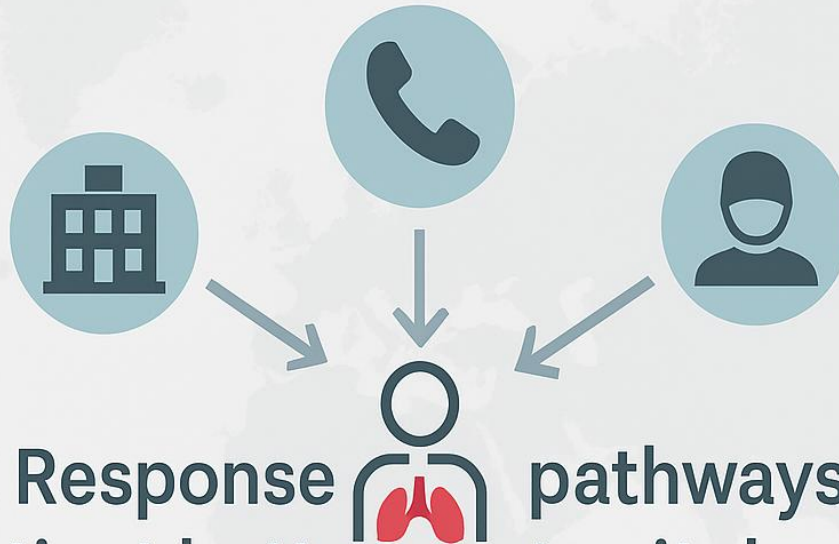
Derlis Fleitas Sosa ^{1,9}, Andrew L. Lehr ^{2,9}, Huaqing Zhao ³, Stephanie Roth ⁴, Vlad Lakhther ⁵, Riyaz Bashir ⁵, Gary Cohen ⁶, Joseph Panaro ⁶, Thomas S. Maldonado ⁷, James Horowitz ⁸, Nancy E. Amoroso ², Gerard J. Criner ¹, Shari B. Brosnahan ² and Parth Rali ¹

¹Dept of Thoracic Medicine and Surgery, Lewis Katz School of Medicine at Temple University, Philadelphia, PA, USA. ²Division of Pulmonary, Critical Care and Sleep Medicine, New York University Langone Health, New York, NY, USA. ³Dept of Clinical Sciences, Temple University School of Medicine, Philadelphia, PA, USA. ⁴Biomedical and Research Services Librarian, Simmy and Harry Ginsburg Library, Temple University, Philadelphia, PA, USA. ⁵Dept of Cardiovascular Diseases, Lewis Katz School of Medicine at Temple University, Philadelphia, PA, USA. ⁶Dept of Radiology, Lewis Katz School of Medicine at Temple University, Philadelphia, PA, USA. ⁷Division of Vascular Surgery, New York University Langone Health, New York, NY, USA. ⁸Division of Cardiology, New York University Langone Health, New York, NY, USA. ⁹Both authors contributed equally.



Hobohm *et al.* Clin Res Cardiol. 2022





All PE Response pathways lead to patient betterment -- it doesn't matter what the structure is

PERT = TEAM, SPEED, OUTCOMES



2020 ESC/ERS GUIDELINES

6.4. Multidisciplinary pulmonary embolism teams

The concept of multidisciplinary rapid-response teams for the management of “severe” (high-risk and selected cases of intermediate-risk) PE emerged in the USA, with increasing acceptance by the medical

647-2019

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ACUTE PULMONARY EMBOLISM | S.V. KONSTANTINIDES ET AL.

community and implementation in hospitals in Europe and worldwide. Set-up of PE response teams (PERTs) is encouraged, as they address the needs of modern systems-based healthcare [301]. A PERT brings together a team of specialists from different disciplines including, for example, cardiology, pulmonology, haematology, vascular medicine, anaesthesiology/intensive care, cardiothoracic surgery, and (interventional) radiology. The team convenes in real time (face-to-face or *via* web conference) to enhance clinical decision-making. This allows the formulation of a treatment plan and facilitates its immediate implementation [301]. The exact composition and operating mode of a PERT are not fixed, depending on the resources and expertise available in each hospital for the management of acute PE.



CTEPH

(Chronic Thromboembolic Pulmonary Hypertension)

Demographics Slide-

CTEPH vs CTED

risk of CTEPH after initial VTE

burden of CTEPH nationally

V/Q vs CTPE for chronic clot



CTEPH

(Chronic Thromboembolic Pulmonary Hypertension)

Evaluation of CTEPH

Echo, Right Heart Cath, V/Q, Pulmonary Angiography



CTEPH

(Chronic Thromboembolic Pulmonary Hypertension)

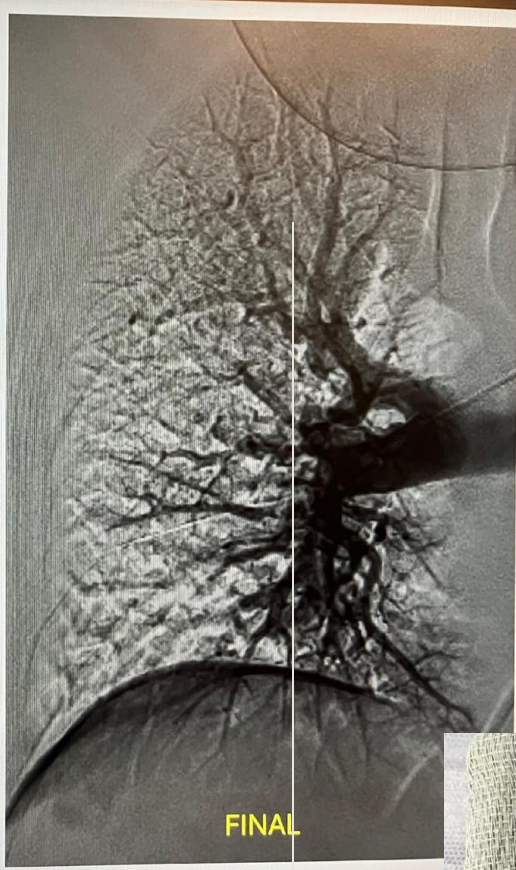
Treatment of CTEPH

Medical- anticoagulation, riociguat, off label use

Balloon Pulmonary Angioplasty

Pulmonary Thromboendarterectomy





Hot off the Press

New ACC/AHA guidelines

Brief summary of new ACC/AHA guidelines



CONCLUSIONS

- PE hemodynamic profile is a moving target. Adapt to treatment options as patient's clinical status changes.
- All comers with Intermediate risk (i.e. Submassive PE) are not indicated for catheter directed intervention.
- Identify goals of re-perfusions and discuss with the patients. Shared decision making is important.
- CTEPH is more common than you think. $V/Q > CT$



