



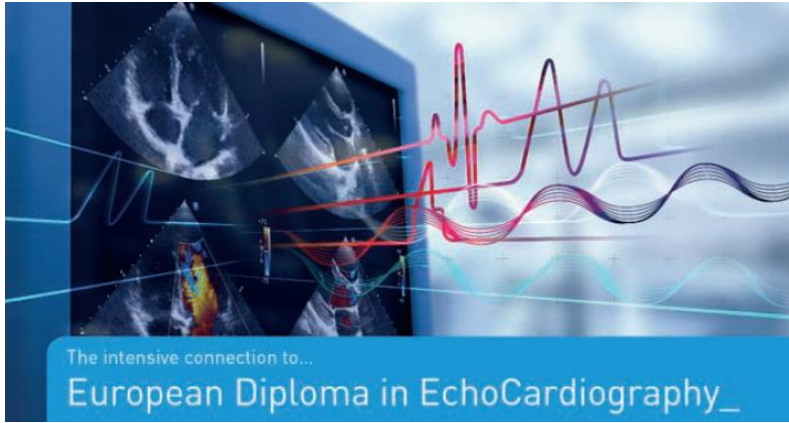
Pulmonary Embolism Response Teams

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Conflict of interest

- Research grants: AZV 18-06-00417 (Prospective randomized double-blind study of efficacy and safety of 1c class antiarrhythmic agent (propafenone) for supraventricular arrhythmias in septic shock), Gilead Sciences (Immune boosting in severe Covid19)
- Research support: ESICM Stoutenbeek Award (Dutch Society of Critical Care)
- Inventor and patent holder: Lactocitrate[®], EU patent (EP2609915B1), Canadian patent (No.2799624)
- Speaker Fees: FMC, GML-Biomedica, Gilead Sciences, BBraun, AOP Orphan
- Grant to organize educational meetings: None
- Advisory board: None

Right Heart Failure

n = 39, 610



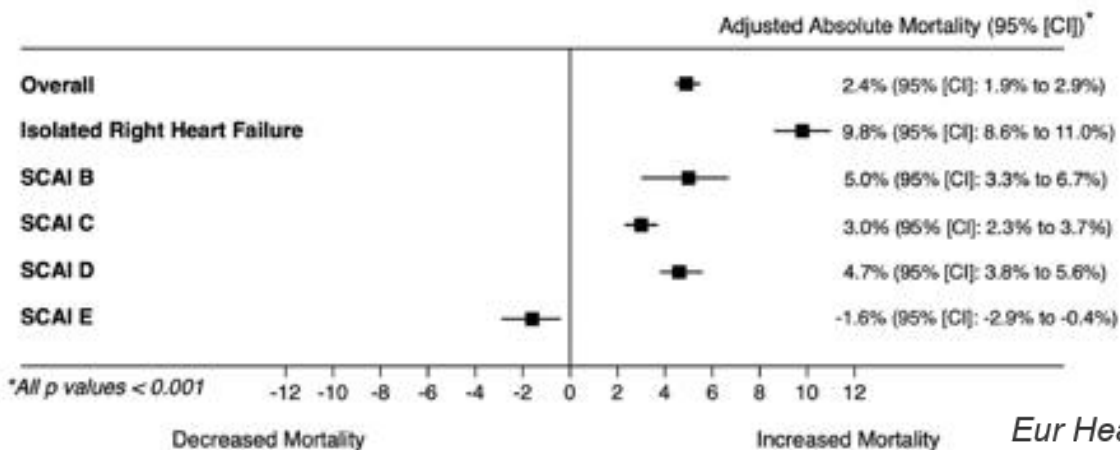
No Right Heart Failure

n = 309, 309



Mean age	60.5
Female (%)	36.9%
AMI (%)	8.7%
OHCA (%)	5.8%

Mean age	65.5
Female (%)	36.5%
AMI (%)	20.7%
OHCA (%)	5.8%



Decision: echocardiography in cardiogenic shock

AHA/ACC Acute PE Clinical Categories

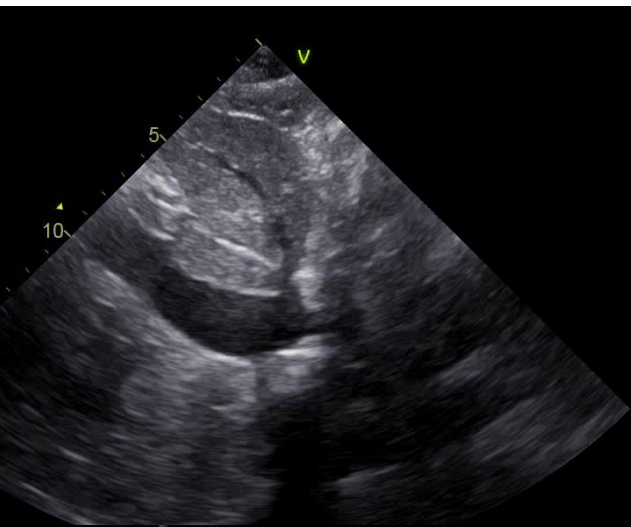
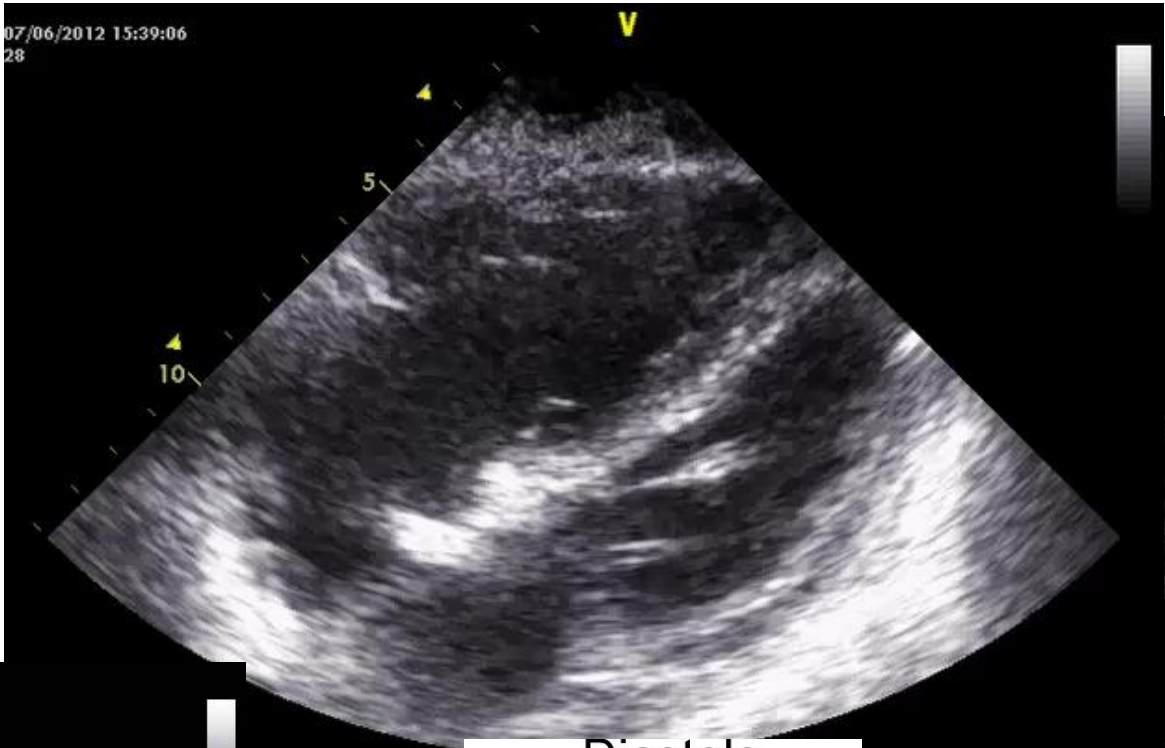
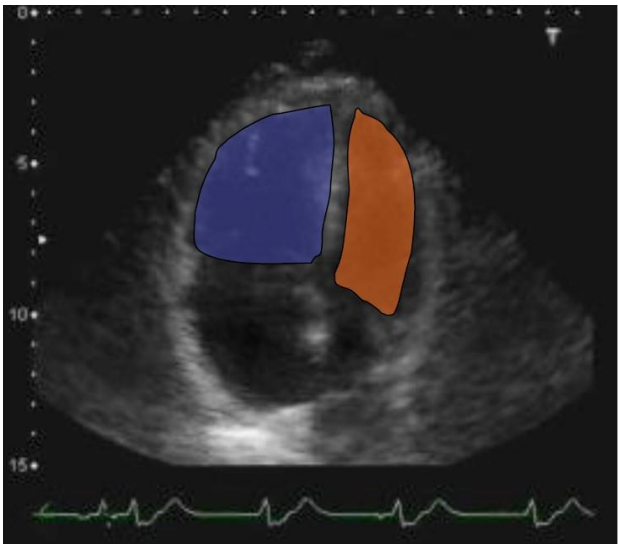
A Subclinical Incidental and asymptomatic	B Symptomatic Low clinical severity score*	C Symptomatic Elevated clinical severity score†	D Incipient Cardiopulmonary Failure	E Cardiopulmonary Failure
Lowest risk → Highest risk				
	B1 Subsegmental (Single/multiple)	C1 Normal RV and normal biomarkers	D1 Transient hypotension‡	E1 Recurrent or persistent hypotension with cardiogenic shock
	B2 Non-subsegmental	C2 Abnormal RV or ≥1 abnormal biomarker	D2 Normotensive shock§	E2 Refractory cardiogenic shock or cardiac arrest
		C3 Abnormal RV and ≥1 abnormal biomarker		
		+/-	+/-	+/-
	R Respiratory Modifier (O ₂ <90%, RR ≥30, need supplemental O ₂)	R Respiratory Modifier (>6 L nasal cannula or use of an NRB mask)	R Respiratory Modifier (Hypoxemic respiratory failure or ventilatory failure)	



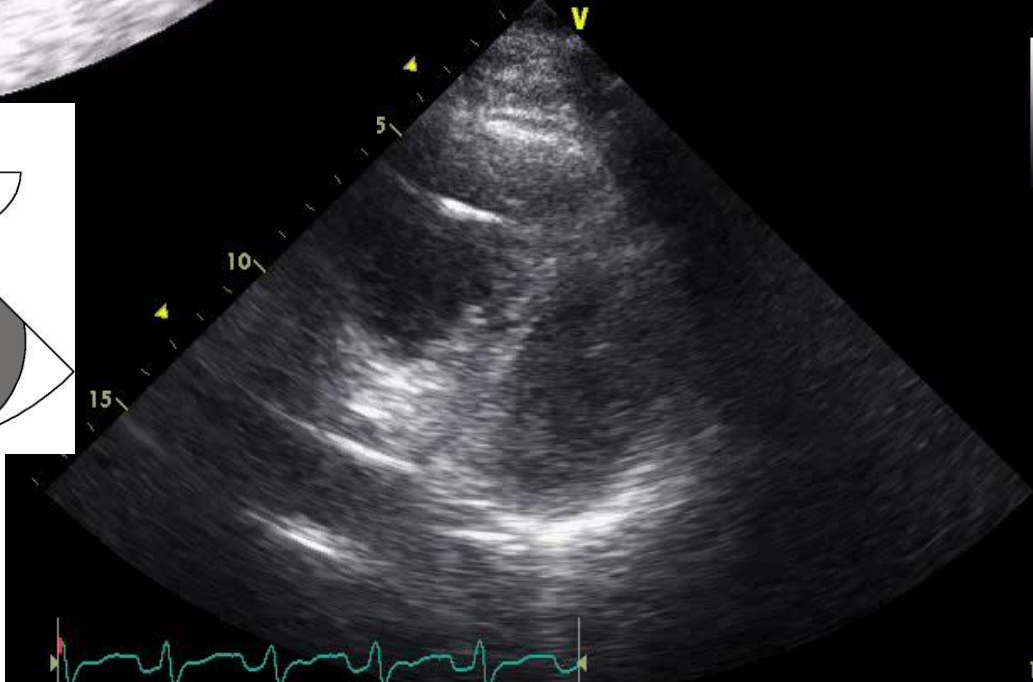
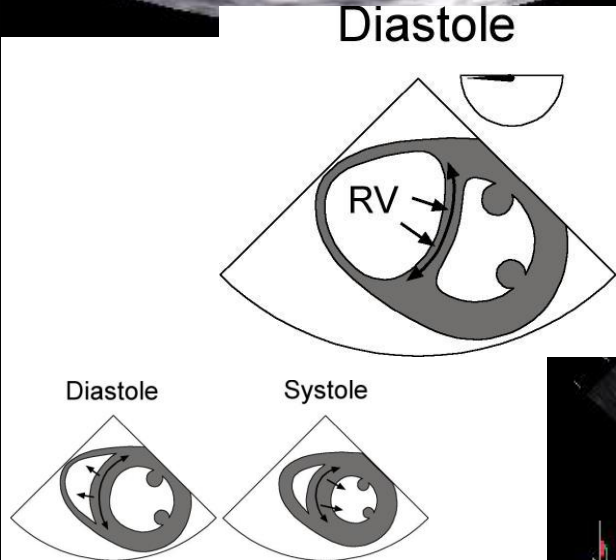
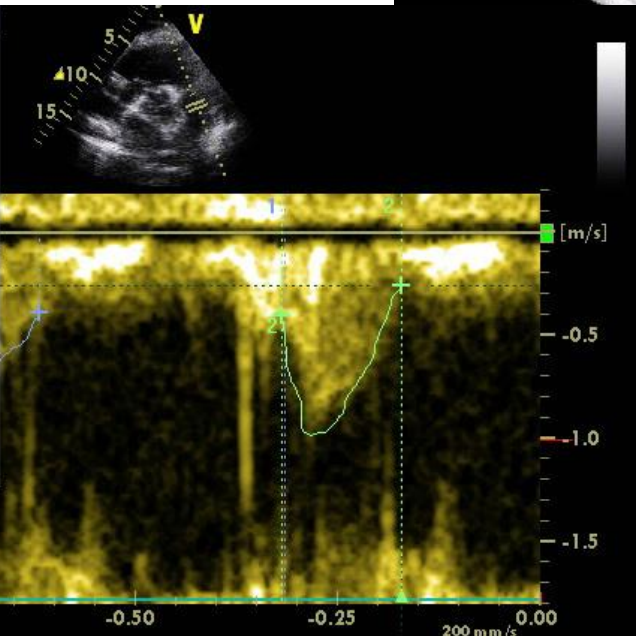
2026 Adults With Acute Pulmonary Embolism

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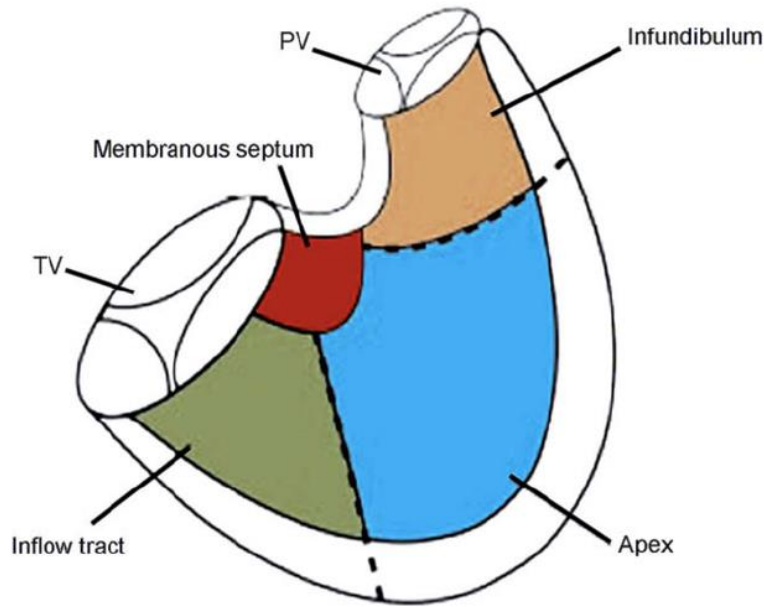
CS: Male 62 years (PE)



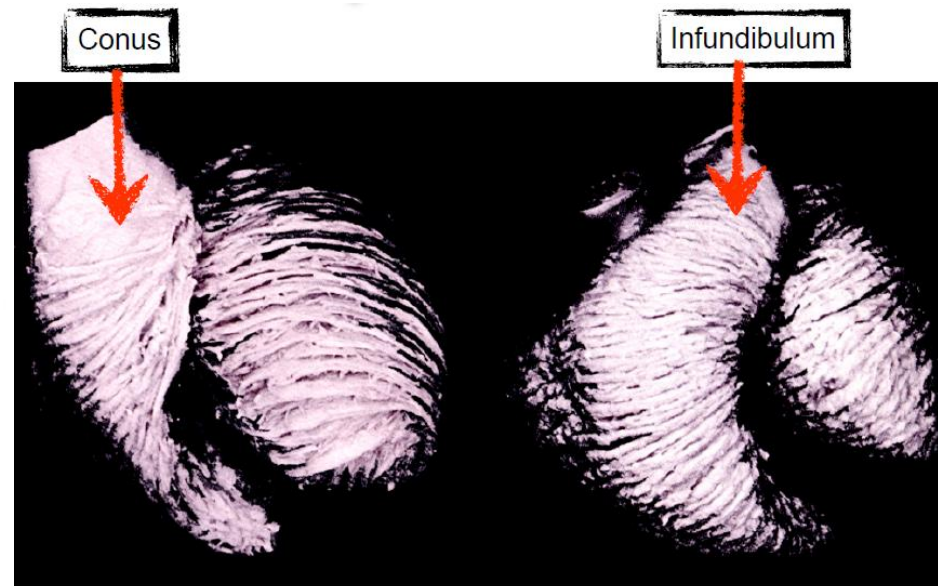
2	LVOT Vmax	0.98 m/s
	LVOT Vmean	0.72 m/s
	LVOT maxPG	3.87 mmHg
	LVOT meanPG	2.25 mmHg
	LVOT VTI	10.6 cm
	LVOT Env.Ti	148 ms
	HR	406 BPM
1	LVOT Vmax	0.89 m/s
	LVOT Vmean	0.67 m/s
	LVOT maxPG	3.16 mmHg
	LVOT meanPG	1.89 mmHg
	LVOT VTI	8.2 cm
	LVOT Env.Ti	122 ms
	HR	141 BPM



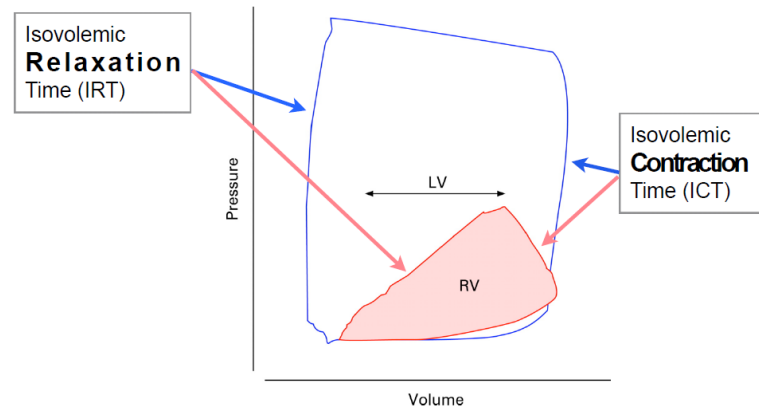
RV physiology



J Am Soc Echocardiogr 2009;22:776-792



Heart 2008;94:1510-1515



Heart 2008;94:1510-1515

- Thin-walled ventricle
- Wraps around LV
- Peristaltic contraction with fractional shortening including of the RVOT (infundibulum)
- 25% of contraction generated by LV

- Lower myocard. mass perfused 2/3 RCA, 1/3 LCA
- RV perfused in both systolic and diastolic phases (unlike LV)
- Reduced isovolemic phases (x LV)
- Tei RV up to 0.25-0.28
- Sensitive to afterload: 30-50% reserve in PA circulation
- Acute PE vs acute-on-chronic
 - Underneath signs of CCP

ORIGINAL ARTICLE

Right ventricular dysfunction on echocardiography to predict mortality in acute pulmonary embolism: an individual patient data meta-analysis

- Metaanalysis of 9233 patients until 2023

RVD parameter	Incidence rates, WMI		Estimated risk		I ² (%) ^a for short-term all-cause death/ PE-related death
	Short-term all-cause death % (95% CI)	PE-related death % (95% CI)	Short-term all-cause death OR (95% CI/PI)	PE-related death OR (95% CI/PI)	
All-comers					
TAPSE < 16 mm vs ≥16 mm	10.6 (3.3-17.9) vs 5.8 (3.9-7.5)	5.8 (0.9-10.6) vs 1.9 (0.4-3.4)	1.78 (1.46-2.16/1.33-2.45)	2.22 (1.58-3.17/1.58-3.17)	0/0
RV-to-LV > 1.0 vs ≤1.0	9.1 (5.8-12.5) vs 5.9 (2.9-9.9)	5.6 (3.5-7.7) vs 1.3 (0.07-3.5)	1.59 (1.33-1.92/1.25-1.92)	2.59 (1.88-3.57/1.90-3.89)	0/0
RV hypokinesis (RV free wall or McConnell's sign), present vs absent	12.1 (6.6-17.6) vs 6.8 (3.7-9.9)	7.1 (2.9-11.3) vs 2.9 (0.2-6.2)	1.79 (1.45-2.21/1.51, 2.54)	2.42 (1.82-3.21/1.81, 3.75)	0/0
Paradoxical septum motion, present vs absent	10.9 (2.5-24.5) vs 6.9 (3.9-9.8)	8.0 (5.2-10.9) vs 4.3 (3.4-5.1)	1.44 (1.10-1.87/0.35-8.66)	2.09 (1.38-3.17/0.09-39.33)	25/59
RV diameter > 30 mm vs ≤30 mm	7.6 (0.1-15.0) vs 6.5 (4.4-8.6)	4.9 (2.5-12.3) vs 3.5 (2.5-9.58)	1.29 (1.05-1.59/0.54-2.62)	1.42 (1.00-2.02/0.17-16.24)	33/57
Estimated PAP ≤ 30 vs >30 mm Hg	8.0 (4.2-11.8) vs 5.7 (3.5-7.7)	4.3 (0.1-8.6) vs 2.4 (0.1-4.9)	1.52 (1.20-1.91/0.86-1.85)	1.79 (1.20-2.50/1.30-6.71)	0/0

RV: Importance of RV coupling with PA pressures and PVR

- RV Ees /Ea 1.5-2 (x LV 0.9-1), RV-PA coupling: TAPSE/PAPs >0.63- 0.47 mm/mmHg
- RV-PA uncoupling: TAPSE/PAPs ≤0.4 mm/mmHg
- Must interpret RV-RA in context of pulmonary circulation and inflow:
 - PA pressures - afterload
 - IVC/SVC - preload
 - Increments of VA-ECMO flow

D'Alto et al. Crit Care (2020) 24:670
https://doi.org/10.1186/s13054-020-03385-5

Critical Care

RESEARCH

Open Access

Right ventricular-arterial uncoupling independently predicts survival in COVID-19 ARDS

Michele D'Alto^{1*}, Alberto M. Marra^{2†}, Sergio Severino³, Andrea Salzano⁴, Emanuel

JACC: CARDIOVASCULAR IMAGING
© 2021 BY THE AMERICAN COLLEGE OF CARDIOLOGY FOUNDATION
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ORIGINAL RESEARCH

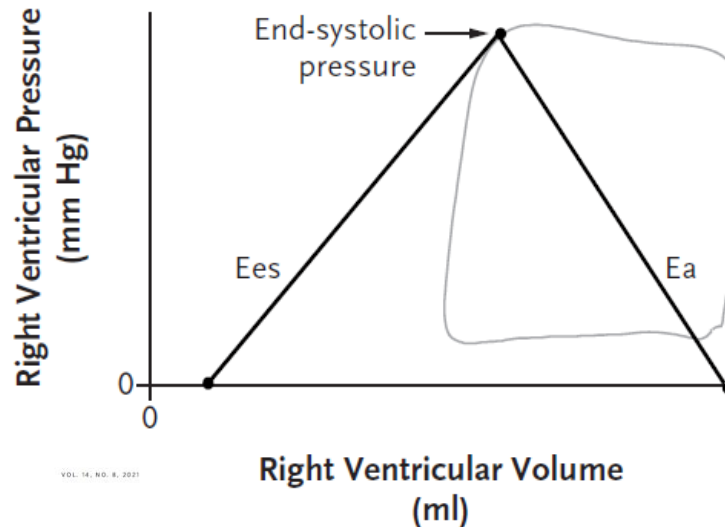
Prognostic Implication of RV Coupling to Pulmonary Circulation for Successful Weaning From Extracorporeal Membrane Oxygenation



ESC HEART FAILURE
ESC Heart Failure (2023)
Published online in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/ehf2.14289

Prognostic implication of a novel right ventricular injury score in septic patients

Hongmin Zhang^{1*}, Dingding Zhang², Xiaoting Wang^{1*}, Ye Liu³, Hui Lian⁴, Qing Zhang¹, Hua Zhao¹,



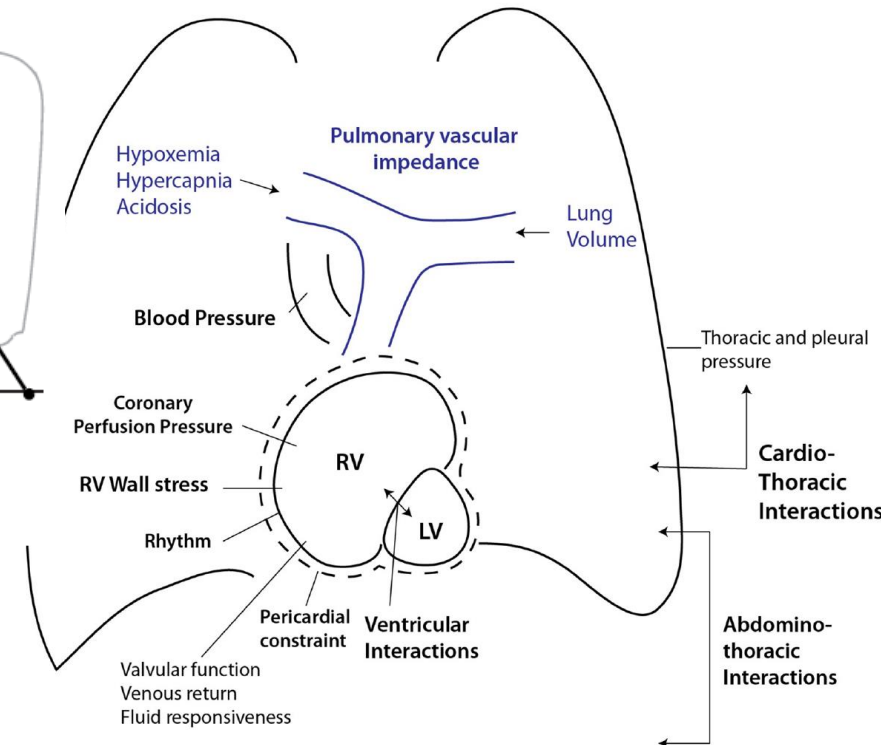
N Engl J Med 2023;388:1111-25.
DOI: 10.1056/NEJMra2207410



European Heart Journal: Acute Cardiovascular Care (2024) 13, 817–825
https://doi.org/10.1093/ehjacc/zae120

ORIGINAL SCIENTIFIC PAPER
Thromboembolic Diseases

Right ventricular-pulmonary artery coupling for prognostication in acute pulmonary embolism



Intensive Care Med (2018) 44:774–790
https://doi.org/10.1007/s00134-018-5172-2

Key role of echocardiography

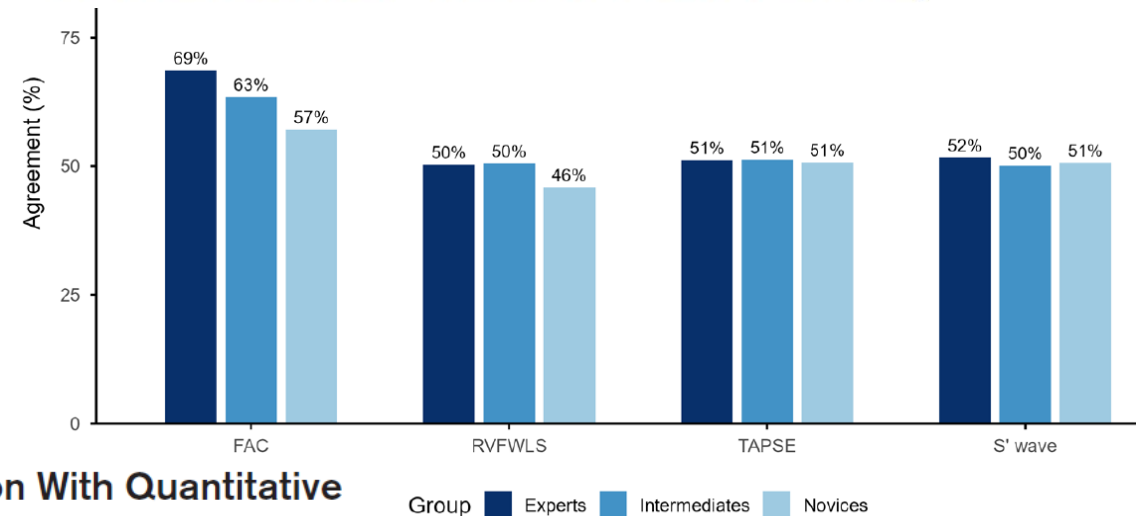
- Complexity of RV assessment: integrate multiple parameters of inflow, contractility and outflow
- Lack of experience in assessment can lead to
 - RV failure and CS – typically after rapid volume expansion on aggressive IPPV
 - Uncertainty and therapeutic overkill with arrhythmogenic inotropes – do they know to turn exclusively to RV? 😊
- Low agreement particularly for
 - Fractional area change of the RV free wall
 - Paradoxical septal motion

Critical Care Medicine

XXX 2026 • Volume 54 • Number 00 • Pages XX–XX

CLINICAL INVESTIGATION

Visual Right Ventricular Assessment in ICU: A Multicenter International Study



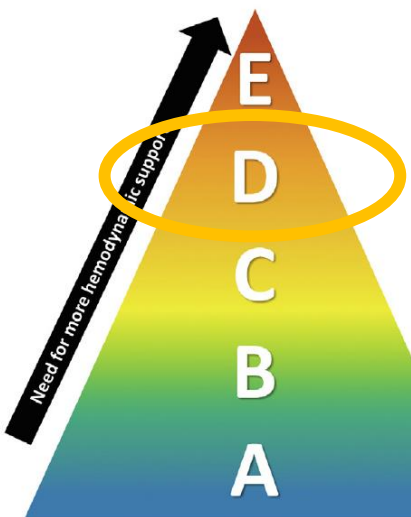
Concordance Between Visual Right Ventricular Size and Septal Motion With Quantitative Right Ventricular Metrics

Parameters	Global (n = 73)	Experts (n = 17)	Intermediates (n = 36)	Novices (n = 20)
RV dilatation				
RV basal diameter > 42 mm	0.43 (0.41–0.45)	0.43 (0.39–0.47)	0.45 (0.41–0.48)	0.42 (0.39–0.45)
RV/LV surface ratio > 0.6	0.47 (0.45–0.49)	0.47 (0.43–0.51)	0.47 (0.44–0.51)	0.46 (0.43–0.50)
RV/LV basal diameter ratio > 1	0.25 (0.23–0.27)	0.25 (0.21–0.28)	0.24 (0.21–0.27)	0.26 (0.23–0.29)
Paradoxical septal motion	0.28 (0.25–0.3)	0.26 (0.22–0.3)	0.31 (0.27–0.34)	0.26 (0.22–0.29)

73 raters (5 countries) of three levels vs 115 echo loops

PE-CS: hypotension or volume corrected SV/CI ?

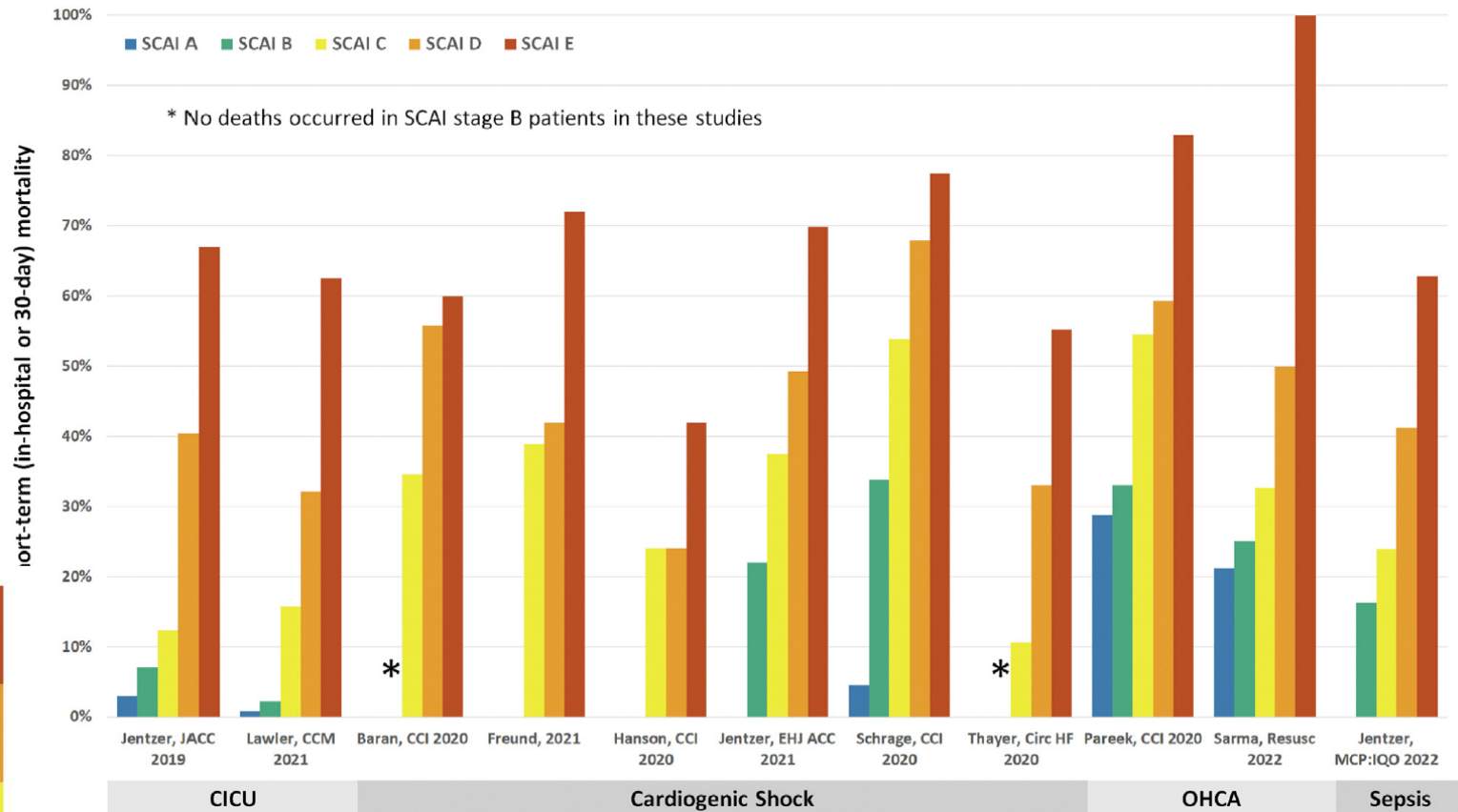
- Stage of shock ?
- Duration „in shock“ ?
- Impact on reperfusion injury
- Are „hypotension, clammy extremities and lactate“ enough for diagnosis ?
- Or, rather, TTE/TEE with volume corrected SV/CO/CI ?



SCAI Shock stage E: Rescue / salvage therapy
• Treat reversible causes of refractory shock
• Escalate temporary MCS, consider ECMO support
• Management of metabolic complications
SCAI Shock stage D: Treatment of deteriorating shock
• Transfer to shock center, assess LVAD candidacy
• Initiate or escalate temporary MCS
• Doubtful benefit of IABP (inadequate support)
SCAI Shock stage C: Initial management of shock
• Transfer to CICU, consult shock team
• Invasive hemodynamic monitoring
• Initiate vasoactive drugs or temporary MCS
SCAI Shock stage B: Early intervention for pre-shock
• Consider invasive monitoring, check lactate
• Consider initiation of vasoactive drugs
• Possible role for IABP in selected patients
SCAI Shock stage A: Disease-targeted therapy
• Revascularization for acute coronary syndrome
• Guideline-directed medical therapy
• Monitoring for early hemodynamic instability

Jentzer *et al*
Advances in the Staging and Phenotyping of Cardiogenic Shock

JACC: ADVANCES, VOL. 1, NO. 4, 2022
OCTOBER 2022:100120



Stage Emortality $\geq$ 50%

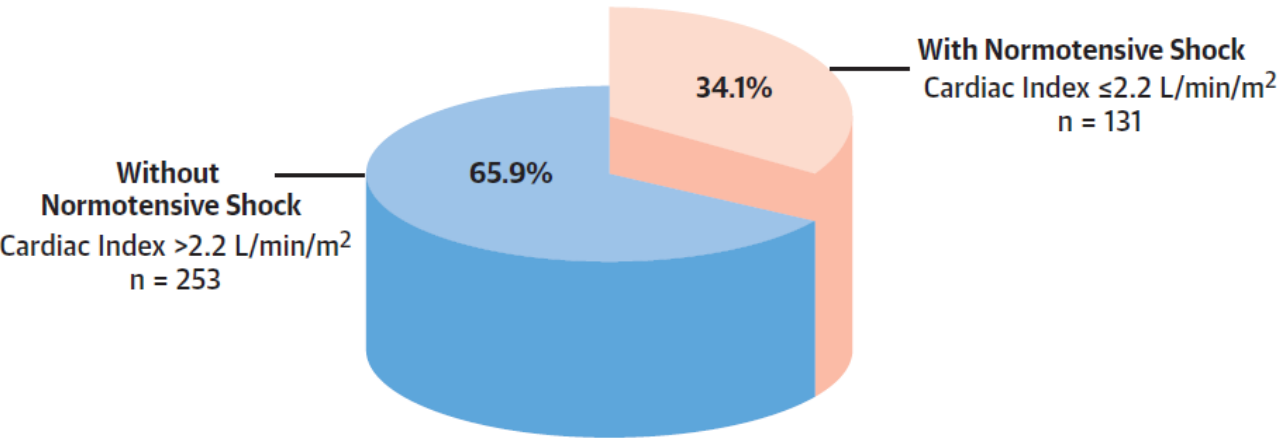
NEW RESEARCH PAPER

PERIPHERAL

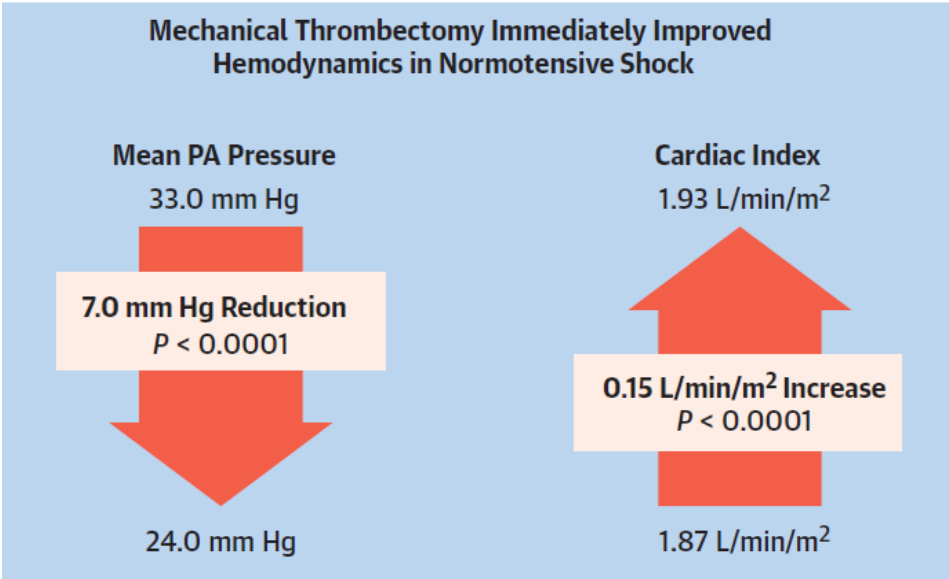
Prevalence and Predictors of
Cardiogenic Shock in Intermediate-Risk
Pulmonary Embolism

Insights From the FLASH Registry

Sripal Bangalore, MD, MHA,^a James M. Horowitz, MD,^b Daren Beam, MD,^c Wissam A. Jaber, MD,^d
Sameer Khandhar, MD,^e Catalin Toma, MD,^f Mitchell D. Weinberg, MD, MBA,^g Bushra Mina, MD^h



- Strongest predictor of PE outcome is hypotension.....but.....
- Intermediate-high-risk PE can have normal BP
- CI≤ 2.2 l/min.m2 and normal BP in 34.1%
- CI normalized in only 30.5% others progress to stage E1-3 (SCAI D-E)



CLINICAL PRACTICE GUIDELINES

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

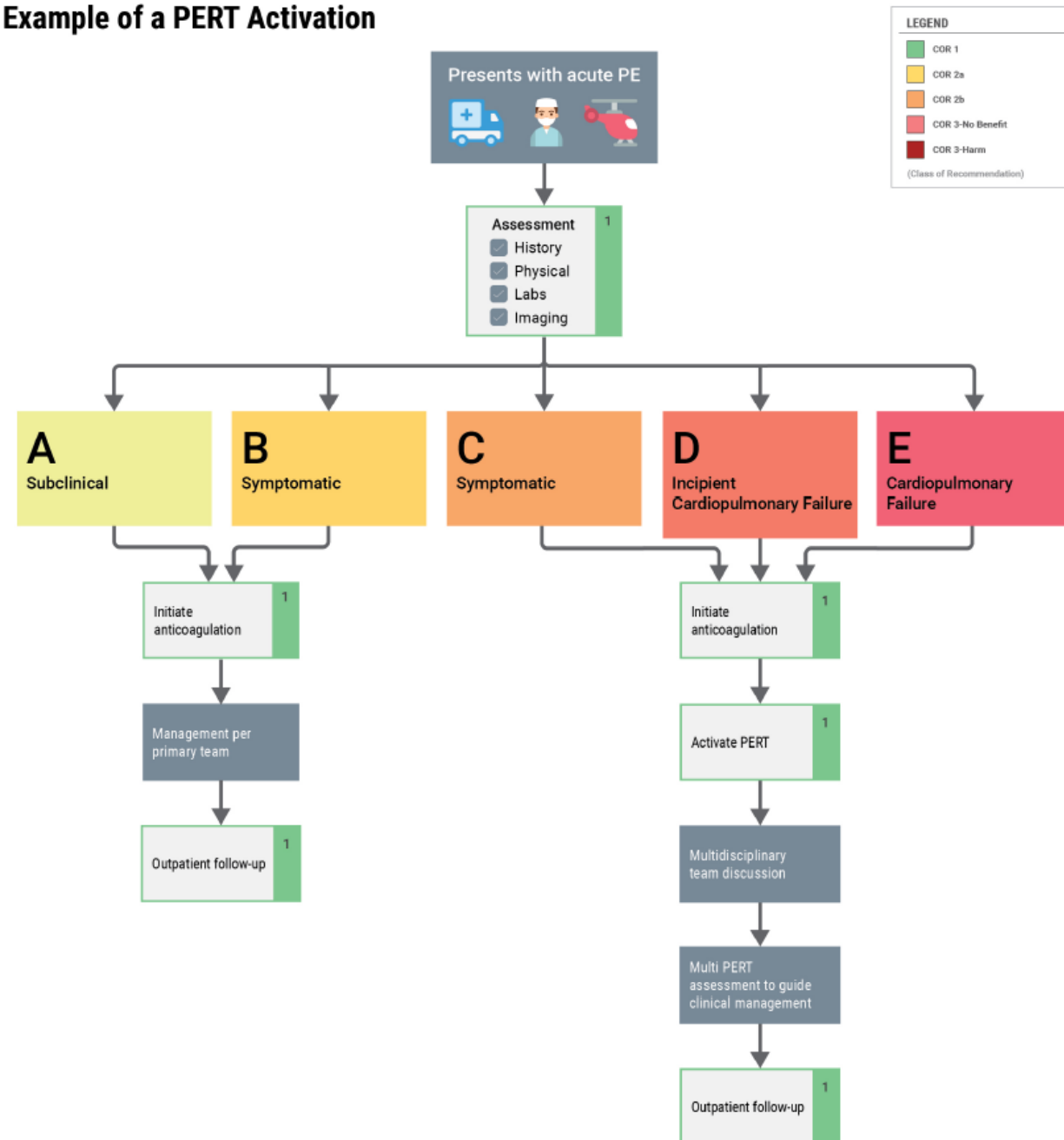
5. Advanced therapies, including systemic thrombolysis, catheter-based thrombolysis, mechanical thrombectomy, and surgical embolectomy are reasonable for patients with acute PE in AHA/ACC PE Category E1 and can be considered for patients with acute PE in AHA/ACC PE Category D1-2.
6. PE response teams (PERTs) are recommended to improve timeliness of care.

- Heparins only ?
- Systemic thrombolysis ?
- Catheter-based thrombolysis ?
- Mechanical thrombectomy ?
- Surgical thrombectomy ?
- ECMO first ?
-imaging modalities ?
-risk of bleeding ?
-underlying disease ?



Benefits of PERT

Example of a PERT Activation



- GUH: Whatsapp group
- Cardiology – Intensive Care – Surgery
- 24/7 transfer of images and information –
- On average 1-2 activations/week

AHA recommendations:

- PERT reduces time to therapy
- PERT improves allocation of resources
- PERT shortens LOS
- PERT reduces numbers of IVC filters
- PERT improves outcomes (?)

PE: what helps



2026 Adults With Acute Pulmonary Embolism

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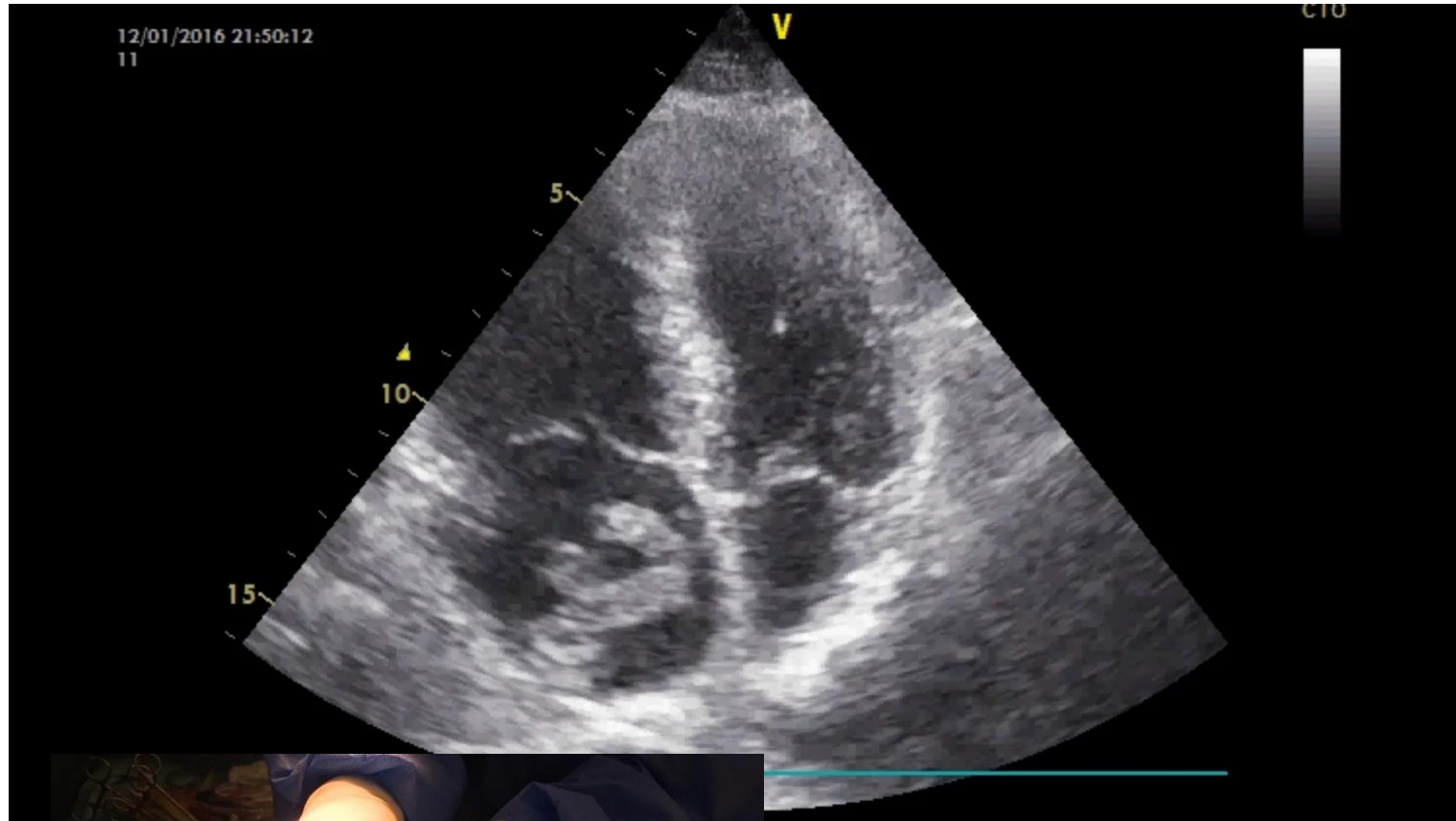
- Heparin or LMWH:
 - UFH (obese, AKI): APTT 55-70s
 - LMWH i.v. (HITS prevention): antiXa 0.6-0.8
 - Continuing anticoagulation for 3-m
 - Warfarin: INR 2-3
 - dabigatran, rivaroxaban, apixaban (RE-MEDY, RECOVER, EINSTEIN-PE, AMPLIFY...): safer option
- Thrombolysis: Stage C-E mortality RR 0.2, at 7 days with little difference to heparin (PIOPED II)
 - Systemic, limitations by thrombus selectivity
 - Catheter administered to PA – cont low dosage with reduced risk of bleeding
- Surgical embolectomy – in visible large thrombi on TTE/TEE and Stage C-E (?)
- Mechanical thrombectomy in Stage C-E (?) and risk ob bleeding



AHA/ACC PE Risk Outcomes Category	Systemic Lysis	CDL	MT	Surgery
A-C1	3-Harm A	3-NB C-EO	3-NB C-EO	3-NB C-EO
C2	3-Harm B-R	2b C-LD (unclear)	2b C-LD (unclear)	3-NB C-EO
C3	2b C-LD (unclear)	2b C-LD (unclear)	2b C-LD (unclear)	3-NB C-EO
D1-2	2b C-LD (may be considered)	2b B-NR (may be considered)	2b B-NR (may be considered)	2b C-LD (unclear)
E1	2a C-LD	2a C-LD	2a B-NR	2a B-NR
E2	2a C-LD	N/A	N/A	3-NB B-NR

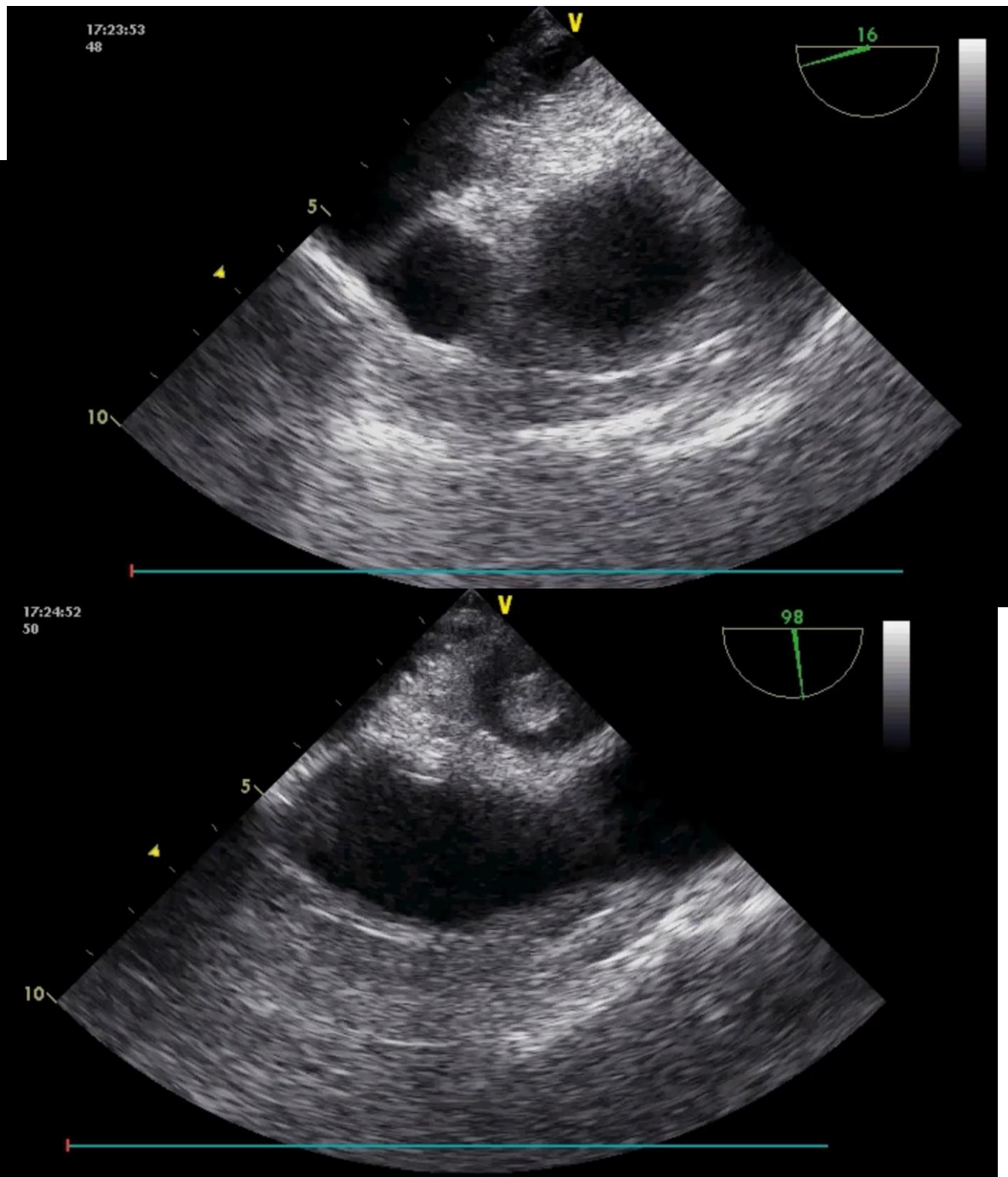
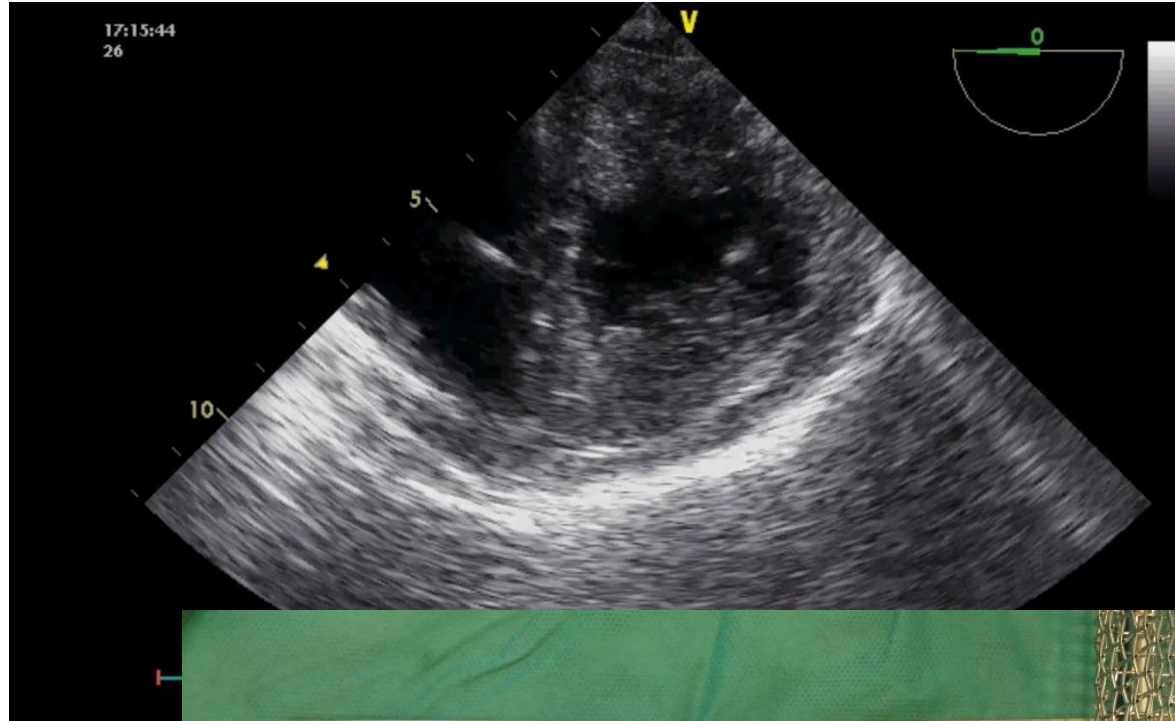
Surgical embolectomy

- In shock with mobile visible thrombi
- Thrombi in IA septum
- Unsuccessful thrombolysis – thrombus selectivity ?
- Trendelenburg operation
- Mortality < 6% in experienced centres (Leacche M, J Thorac Cardiovasc Surg 2005)



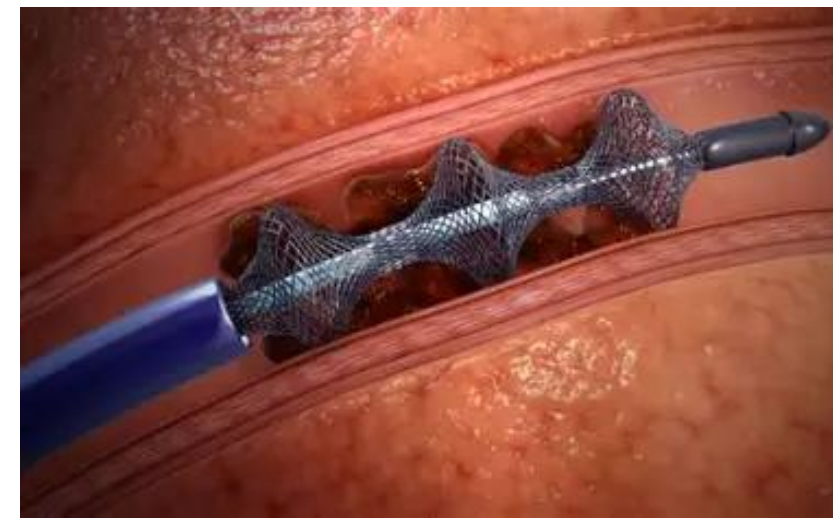
OHCA, woman 58y...

Trendenbourg op. after failed thrombolysis



INARI flow retrieval

- INARI 16-20-24 F, fem./jug. Approach – sheath 24F



- No thrombolysis related bleeding
- RV and PH recovery
- Flame study: <10% mortality
- Flash, Flame registries

The **FLASH** data shows thrombus removal results in immediate improvements in cardiac function, acute symptom relief, and sustained long-term outcomes at 6 months.

95.1%

Normal RV function
at 6 months²
(n=247)

90.1%

Mild or absent
dyspnea at 6 months²
(n=343)

1.0%

CTEPH at
6 months²
(n=581)

Triever Aspiration Catheters:

- **Triever16**, **Triever20**, and **Triever24** catheters are **highly trackable** to navigate tortuous anatomy.



Penumbra Lightning

- 12-16 F, PC assisted vacuum -100 kPa, 16F sheath fem
- effect in smaller calibre pulmonary vessels
- No thrombolysis associated bleeding
- RV recovery
- Extract-PE, Strike-PE studies
- Designed for peripheral thrombectomy



Lightning Flash® 3.0



Lightning Bolt® 12



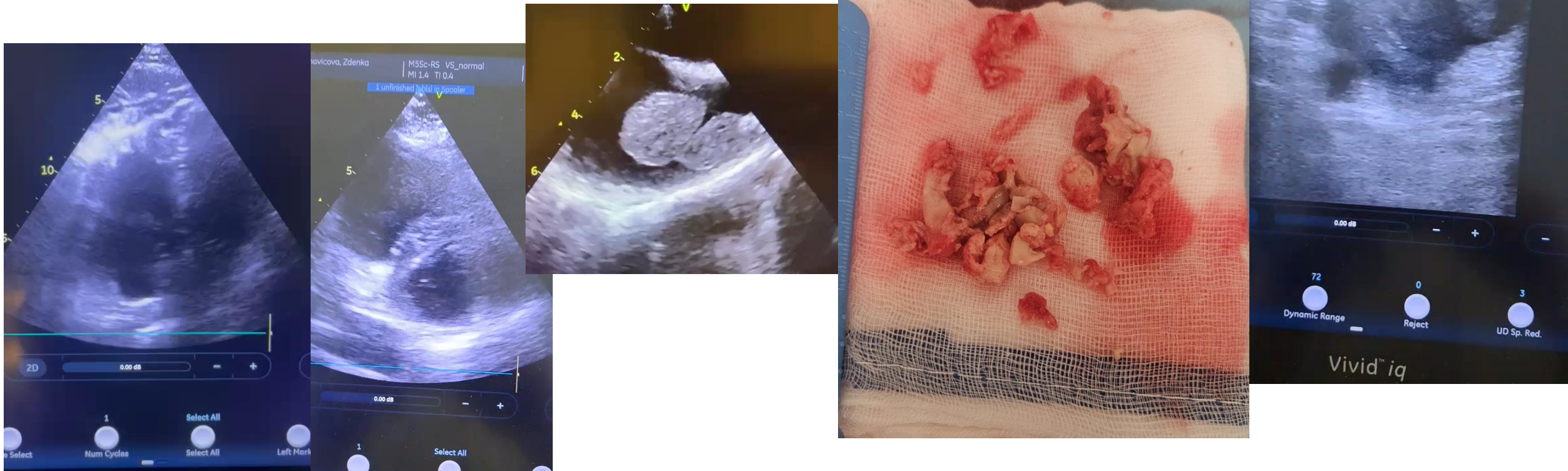
Lightning Bolt® 7



Lightning Bolt® 6X with TraX™

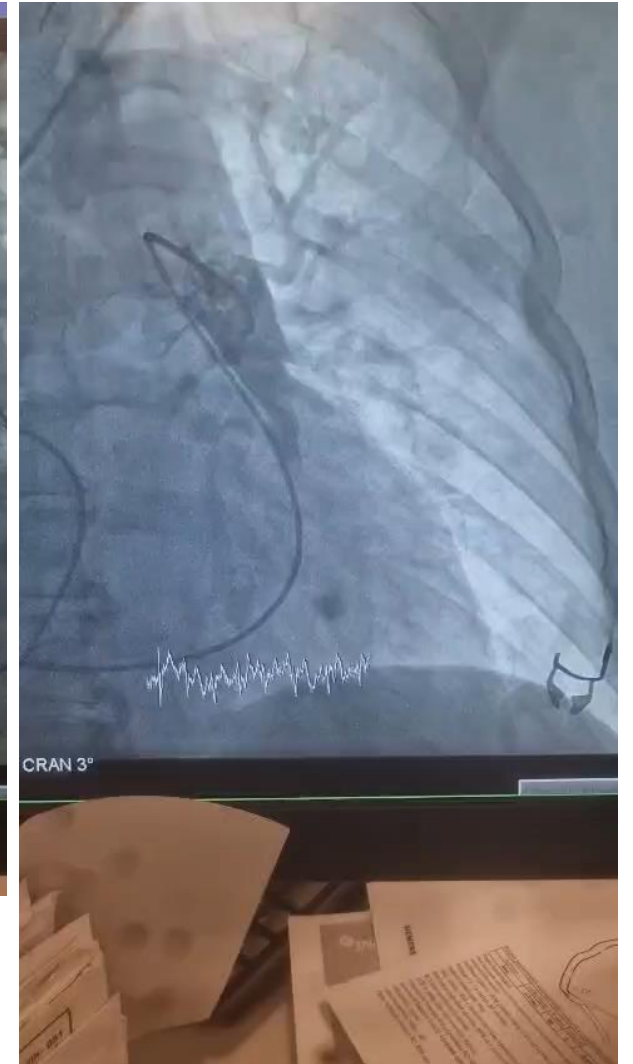
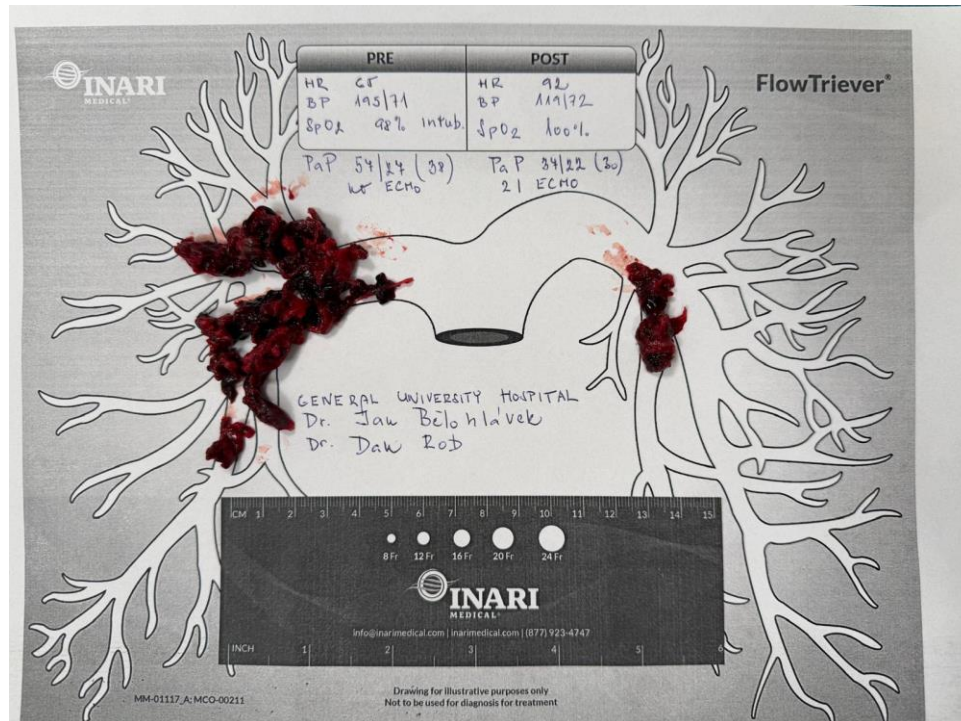
PERT activation: Ovarian carcinoma, 51 years

- Cardiogenic shock, massive PE
- INARI retrieval of tumour+thrombus (DVT)
- Discharged home after 10 days, continues chemotherapy



PERT activation: OHCA 6 weeks after spinal surgery, woman 54 years

- intermittent ROSC, INARI retrieval
- Extubated after 3 days
- Discharged after 2 weeks

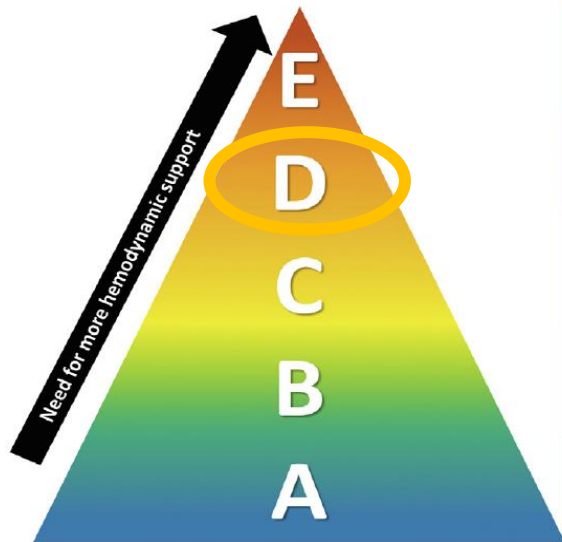


PERT activation: CS, 41 years, extreme BMI

- IHCA for CS (PE)
- 235 cm, 240 kg, BMI 44
- Cannulated at 2nd unsuccessful TL
- VA ECMO FF 29F-23F, prograde 7F
- FlowTrievers on VA-ECMO



With permission

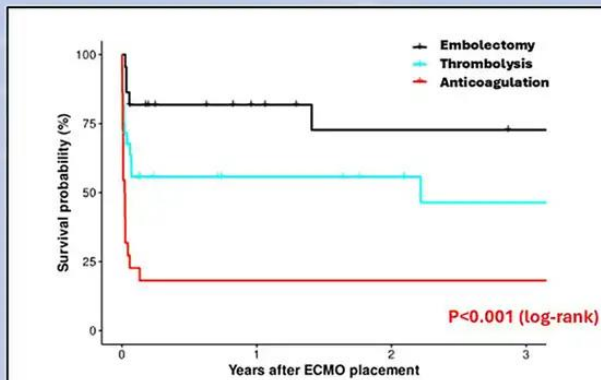


MT – pros and limits

ECMO Combined with Embolectomy May Yield Better Outcomes Than ECMO Alone or with Thrombolysis for Acute High-Risk Pulmonary Embolism

Retrospective comparison of patients with high-risk pulmonary embolism (HR-PE) treated with:

- ECMO with embolectomy (22 patients)
- ECMO with thrombolysis (28 patients)
- ECMO alone (8 patients)
- Median support: 5 days (IQR 4-6 days)



Survival to hospital discharge

- ECMO with embolectomy: 82%
- ECMO with thrombolysis: 57%
- ECMO alone: 18%

1-year survival

- ECMO with embolectomy: 82%
- ECMO with thrombolysis: 56%
- ECMO alone: 18%

In-hospital complications and support time did not differ.

ECMO with early percutaneous or surgical embolectomy may provide a survival benefit over ECMO alone in patients with high-risk pulmonary embolism

ASAIO
 Journal

The Official Publication of the
 American Society for Artificial Internal Organs

Fujimoto R et al., *ASAIO Journal*, 2026 |

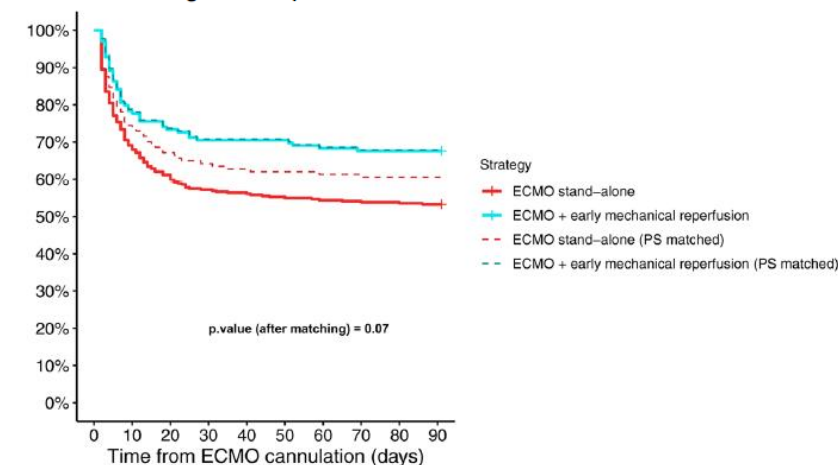
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Survival probability

- 492 PE on VA-ECMO, 69% CA, 28% mechanical reperfusion.
- 137 vs 137 matching
- 90-day mortality 32% reperfusion vs 39% ECMO stand-alone:
 - HR 0.68 [95% CI, 0.45-1.03], p=0.07
- Early mechanical reperfusion improved ECMO weaning without prior TL (HR 1.56 [95% CI, 1.03-2.36]; P = .04)

Early mechanical reperfusion in high-risk pulmonary embolism supported by venoarterial extracorporeal membrane oxygenation: a multicenter international cohort study

David Levy^{1,2}, Matthieu Petit³, Benjamin Assouline⁴, Alexander Dietl⁵, Guillaume Lebreton^{6,10}, Raphaël Giraud^{4,10}, Joshua Ihle⁷, Paul Masi⁸, Sally Newman⁹, Anna Condella¹⁰, Jordi Riera^{11,10}, Marc Pierrot¹², Alexandre Mansour¹³, Shinichiro Ohshima¹⁴, Lise Thellier¹⁵, Dirk W. Donker¹⁶, Celine Besnard¹⁷, Alice Vennier^{18,19}, Hadrien Winiszewski²⁰, Guido Tavazzi²¹, Jonathan Taylor²², Julien Dessajan²³, Philipp M. Lepper²⁴, Pauline Yeung Ng²⁵, Juan I. Chico²⁶, Christophe Guervilly²⁷, Louis Pot²⁸, Dieter Dauwe²⁹, Philip Fortuna³⁰, Fabio Silvio Taccone³¹, Baptiste Compagnon³², Jae-Seung Jung^{33,10}, Zied Ltaief^{34,10}, Roberto Roncon-Albuquerque³⁵, Pierre Denormandie³⁶, Marco Giani³⁷, Thibault Duburcq³⁸, Giacomo Grasselli³⁹, Hélène Nougé^{40,10}, Adrien Werquin⁴⁰, Olivier Sanchez^{41,42,10}, Antoine Beurton^{43,10}, Martin Balik^{44,10}, Marie Jungling⁴⁵, Maria Heinrich^{5,10}, Thomas Mueller⁵, Alain Combes^{1,2}, Matthieu Schmidt^{1,2,*}, for the CATAPULTE Investigator Group[†]



Risk Table: All Patients

ECMO stand-alone 353 244 216 202 199 195 192 191 190 188

ECMO + early mechanical reperfusion 139 109 102 98 98 98 95 94 94 94

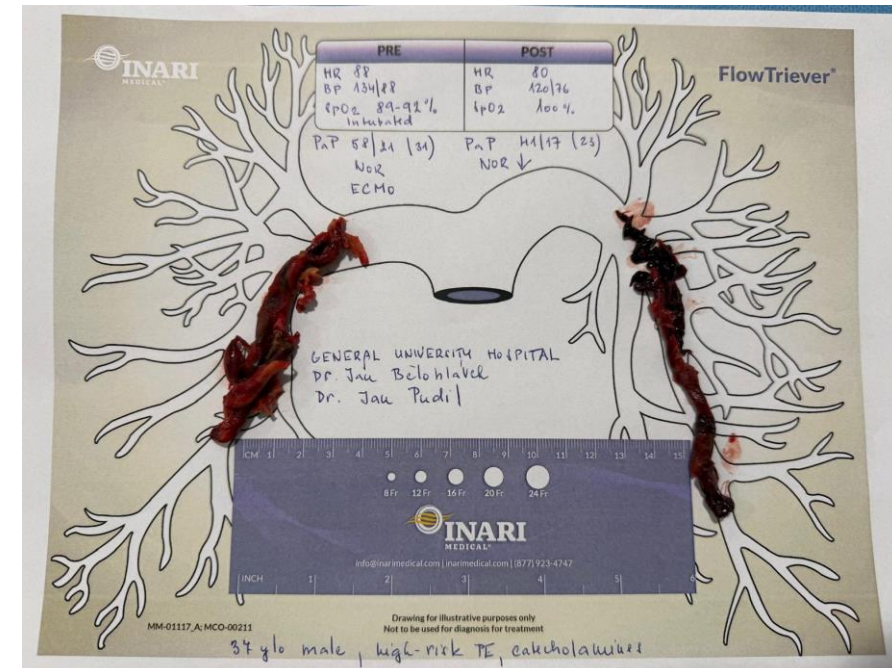
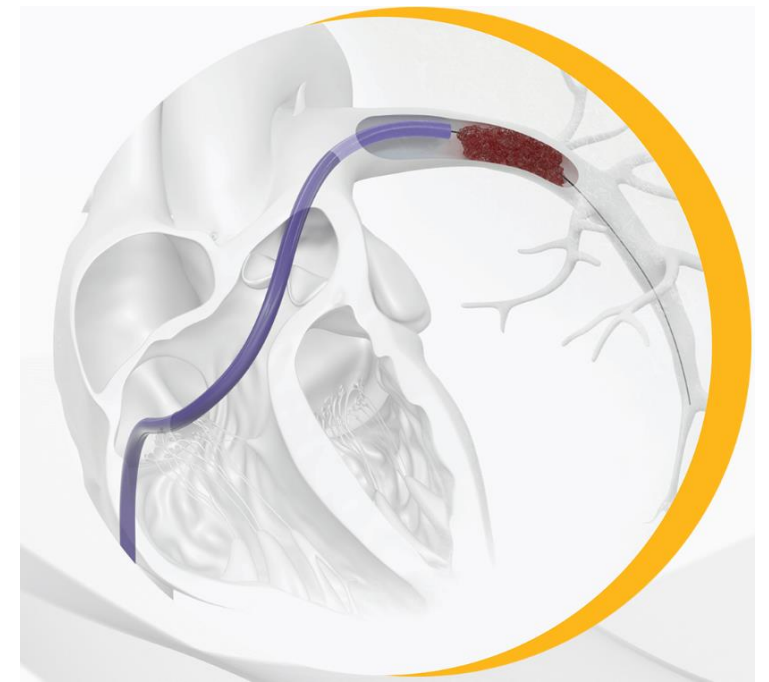
Risk Table: PS matched

ECMO stand-alone (PS matched) 137 102 92 88 86 85 84 84 83 83

ECMO + early mechanical reperfusion (PS matched) 137 108 101 97 97 97 94 93 93 93

Take home messages

- PERT helps
- ACCE is mandatory
- Diagnosis of PE is possible without CT angio
- Imaging outperforms biomarkers (...time and expenses)
- Thrombolysis buys time for safe dissolution with long-time heparins
- Mechanical thrombectomy prevents bleeding risk....and sternotomy 😊
 - Costs ~10.000 Eur per procedure
 - So far no data on ensuing peripheral CTEPH (III)
- Trendelenburg and PEA for acute-on-chronic resistant to thrombolysis – ideally in PH centres with skilled surgeons



Thank you for your attention !

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