מרכז לב,
חזה וכלי דם
ע"ש אולגה ולב לבייב

שיבא
תל השומר

Minimally Invasive Hemodynamic Monitoring

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The Olga & Lev Leviev Heart Center
Cardiology Division
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No conflicts of interest

Indications for Hemodynamic Monitoring

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Preemptive

- Patients “at risk” of deterioration
- Adapt monitoring strategy

Vincent JL in Handbook of Acute CardioVascular Monitoring, ACVC/ESC 2022

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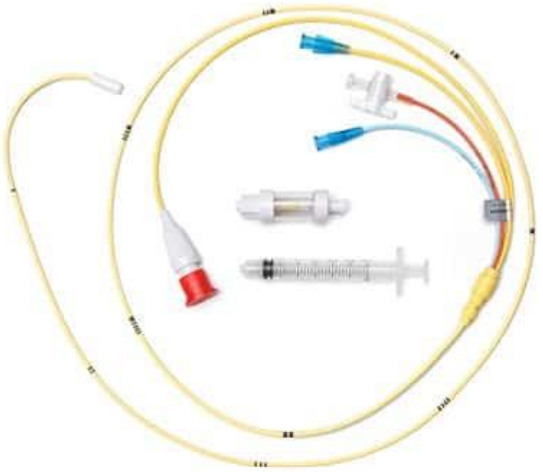
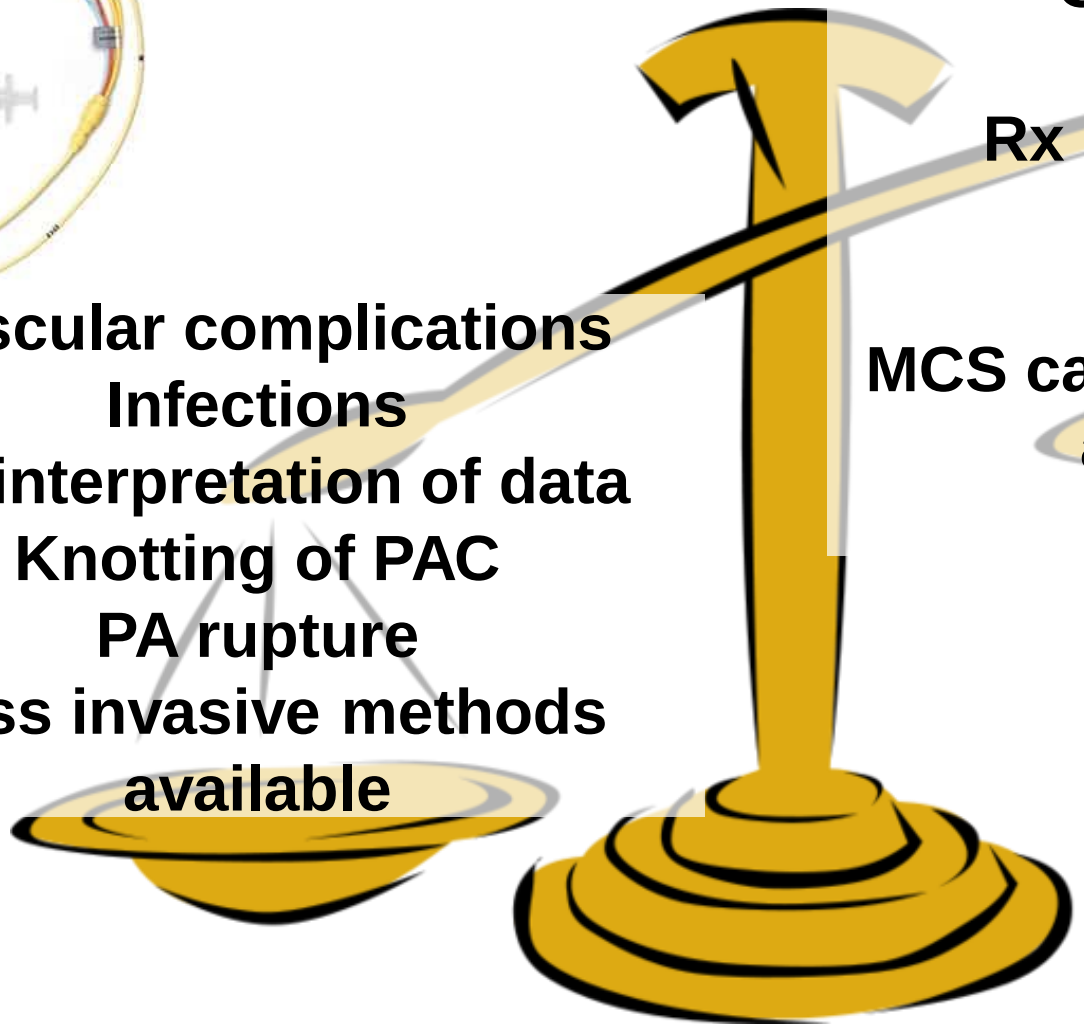
“Monitoring on its own is not a treatment and there is no evidence that any form of monitoring improves outcomes”
– Prof. JL Vincent

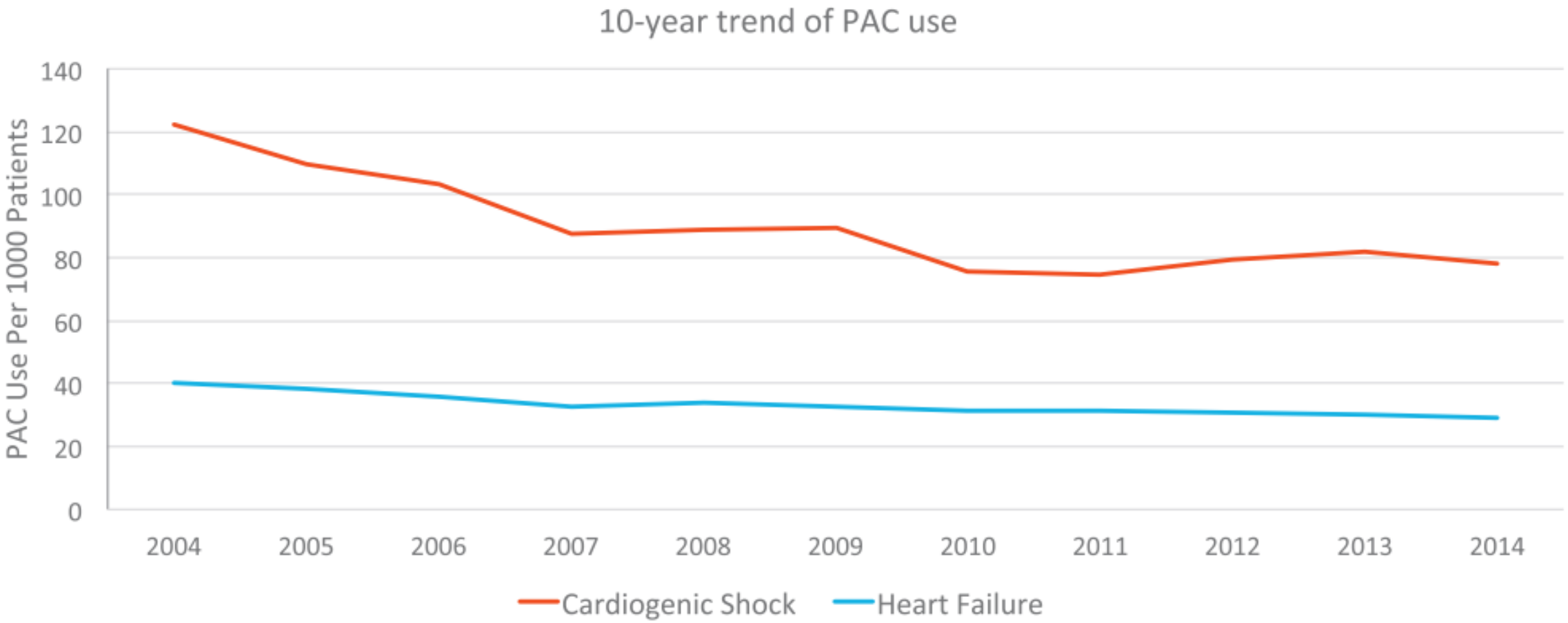


Vascular complications
Infections
Misinterpretation of data
Knotting of PAC
PA rupture
Less invasive methods available



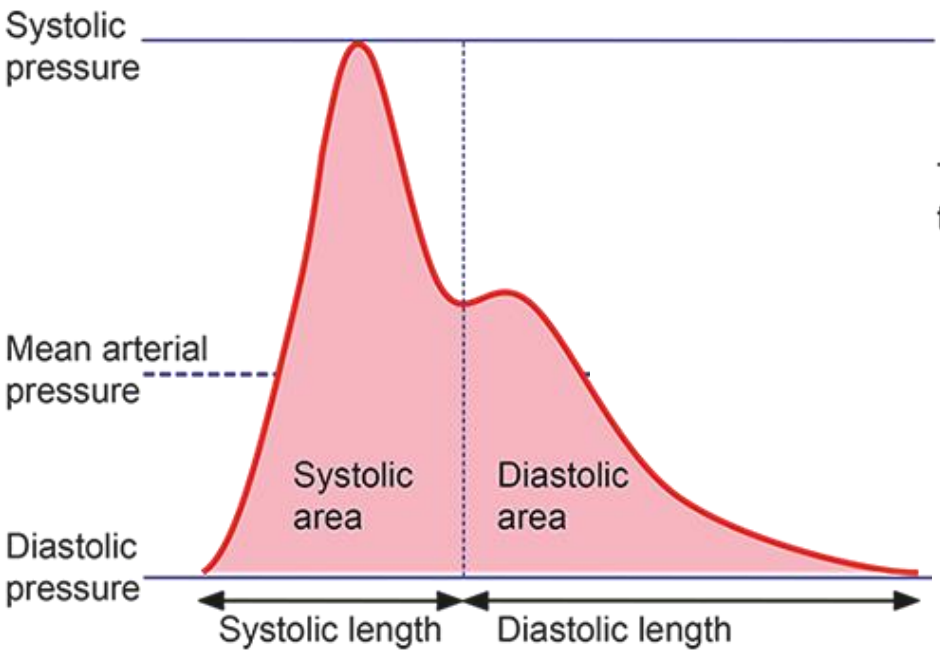
“Gold standard”
Diagnosis
Rx responsiveness
RV function
Pulm HTN
MCS candidacy, escalation and weaning

Pulmonary Artery Catheter Use Trends

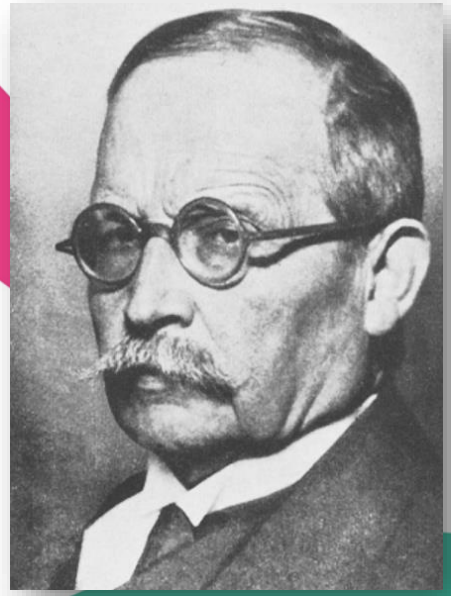


Hernandez GA et al. J of Cardiol Fail 2019

Pulse Contour Analysis



The systolic area is related to **preload** and **contractility**

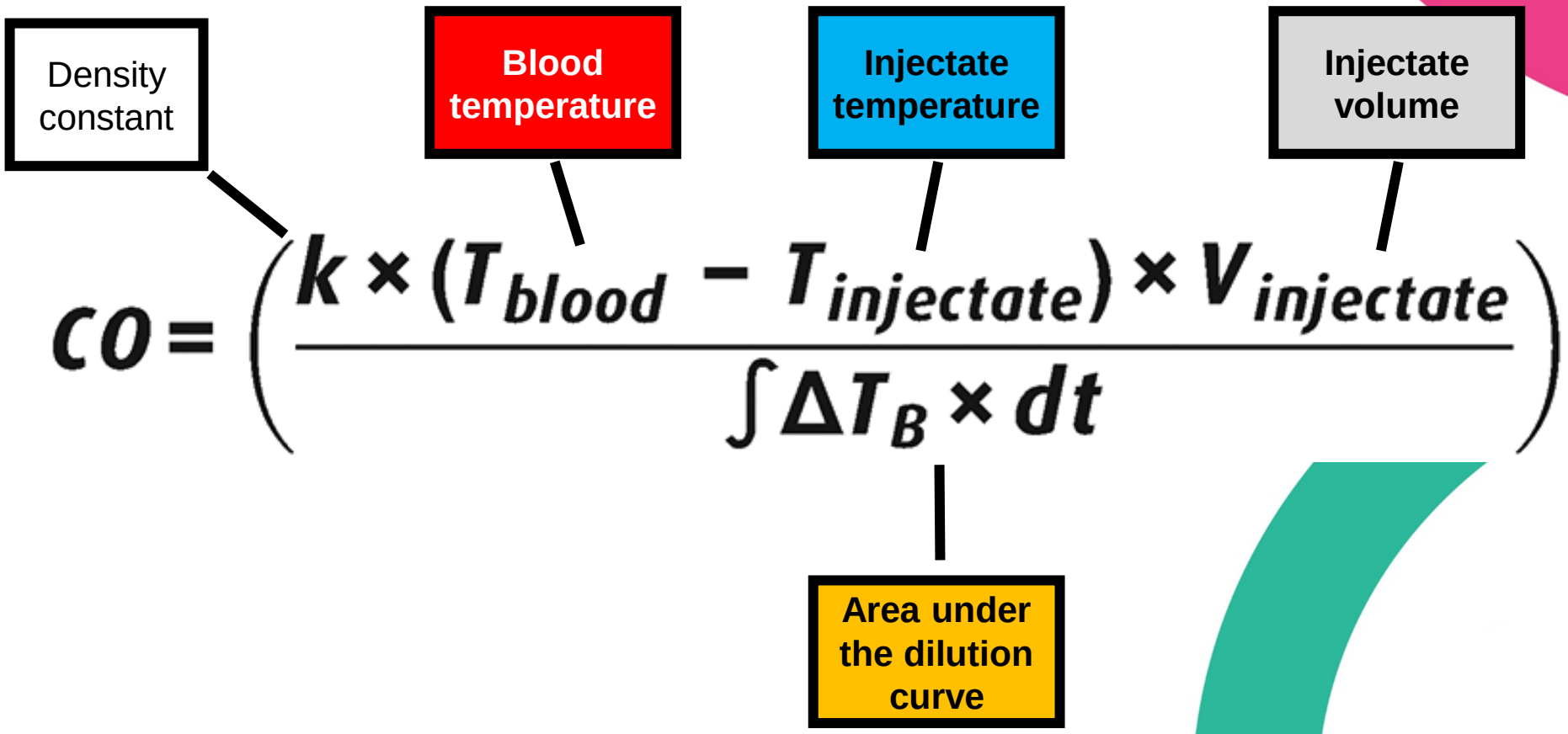


- **Continuous CO monitoring (as opposed to intermittent)**
- **Very precise assuming stable vascular tone**
- **Non-calibrated vs. calibrated**

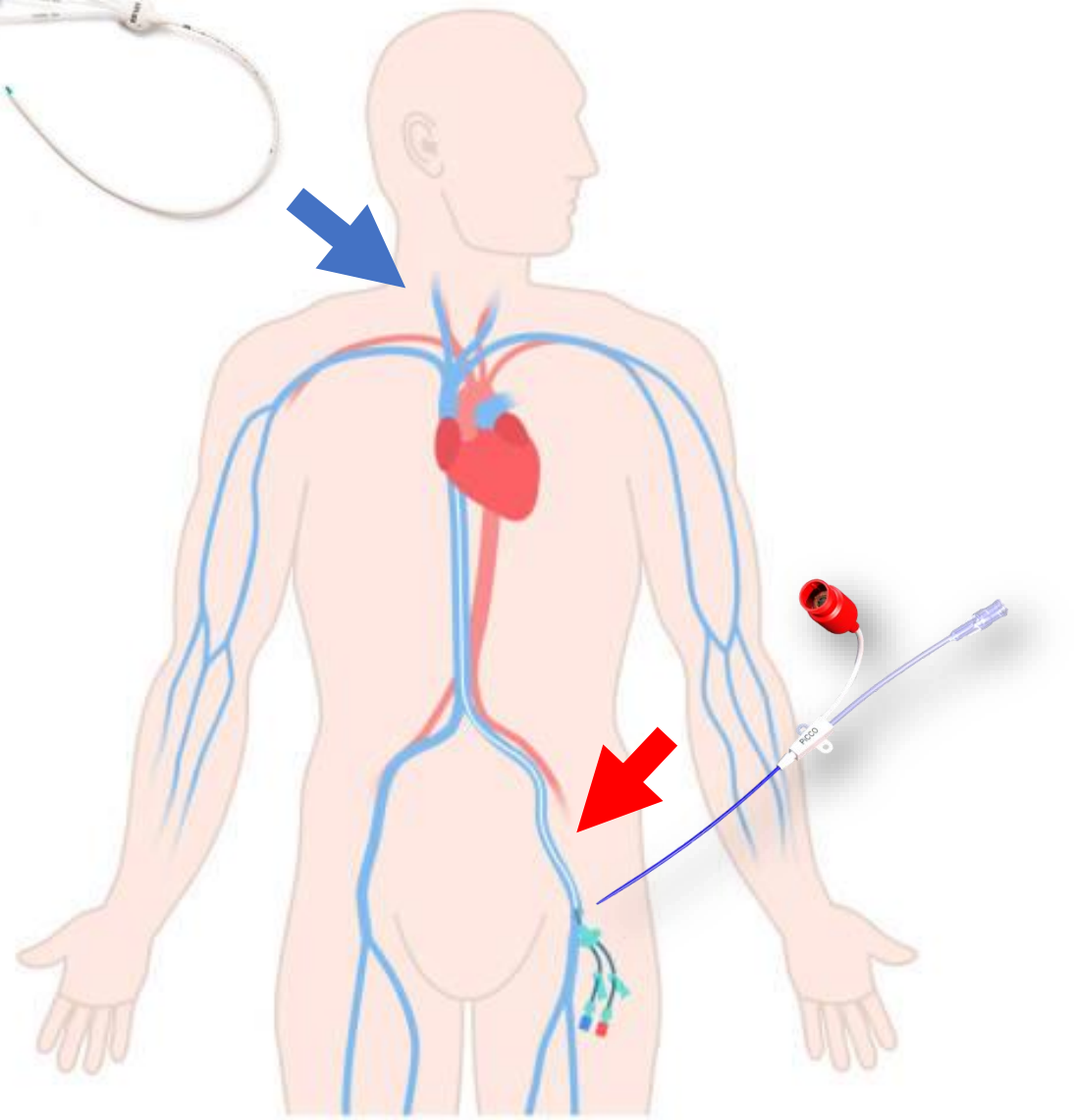
Transpulmonary Thermodilution (TPTD)-Based Monitoring Systems

- TPTD cardiac output
- Continuous CO monitoring (Pulse Contour Analysis)
- Volumetric hemodynamics

Stewart-Hamilton Equation

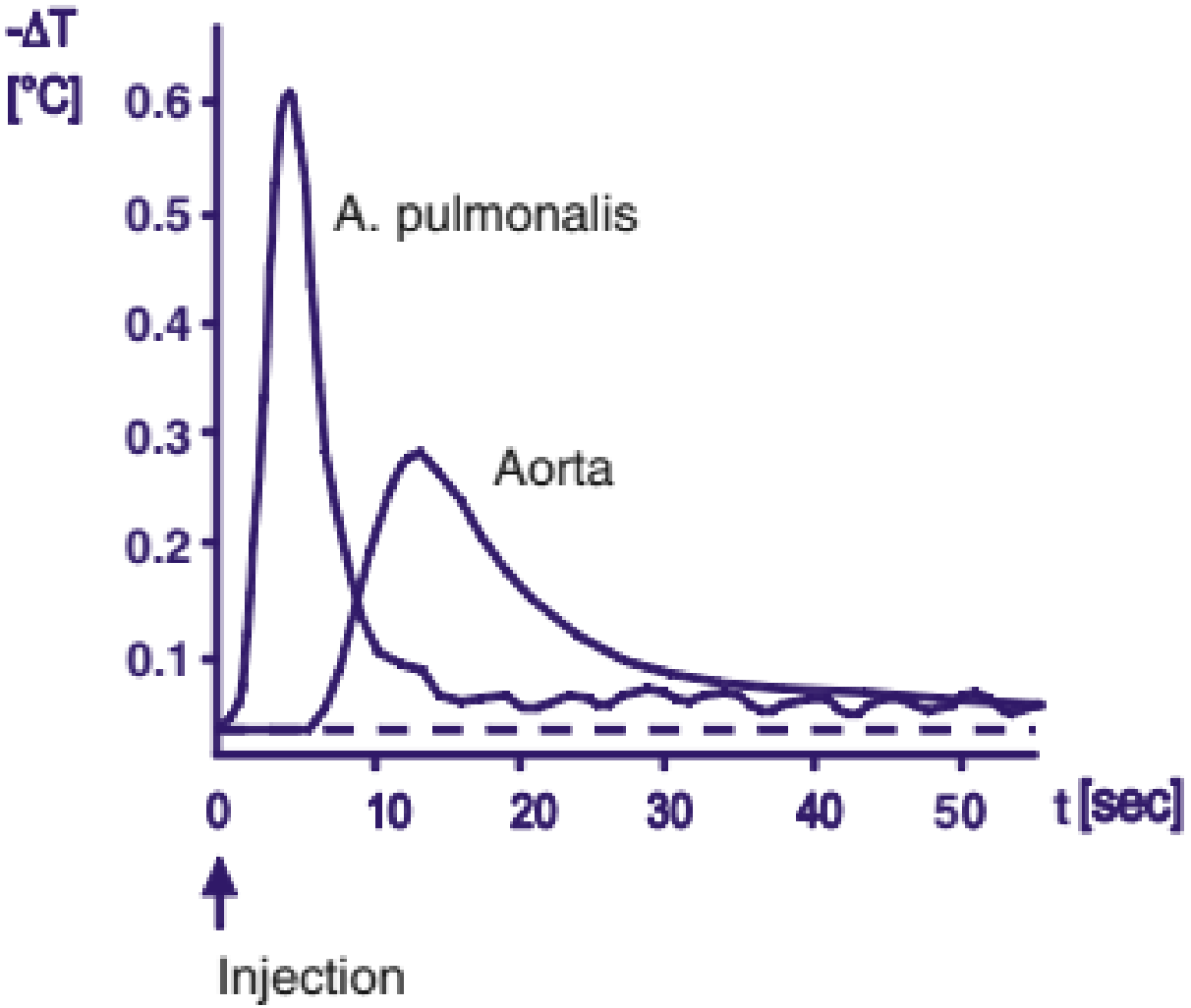



5
10
15
20
ml




PICCO

Comparison of PA and TD Thermodilution Curves



Sakka SG et al. J Clin Monit Comput 2012

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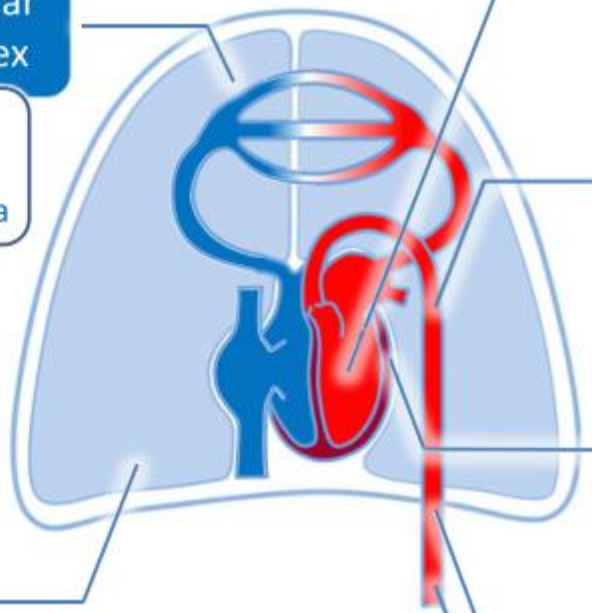


N < 3

Pulmonary vascular permeability index

Differentiates hydrostatic pulmonary oedema and ARDS.
Indicates the risk of pulmonary oedema

N < 10 mL/kg

Extravascular lung water

Increases in case of hydrostatic pulmonary oedema and ARDS.
Quantifies the volume of pulmonary oedema

N : 680–800 mL/m²

Global end-diastolic volume

Volume of the 4 cardiac cavities at end-diastole. Index of cardiac preload

Cardiac output

Measured by transpulmonary thermodilution (intermittent))

N : 4.5-6.5/min

Cardiac function index

Indices of cardiac systolic function

Global ejection fraction

N : 25-35%

Cardiac output

Measured by pulse contour analysis (in real-time)

Stroke volume/pulse pressure variation

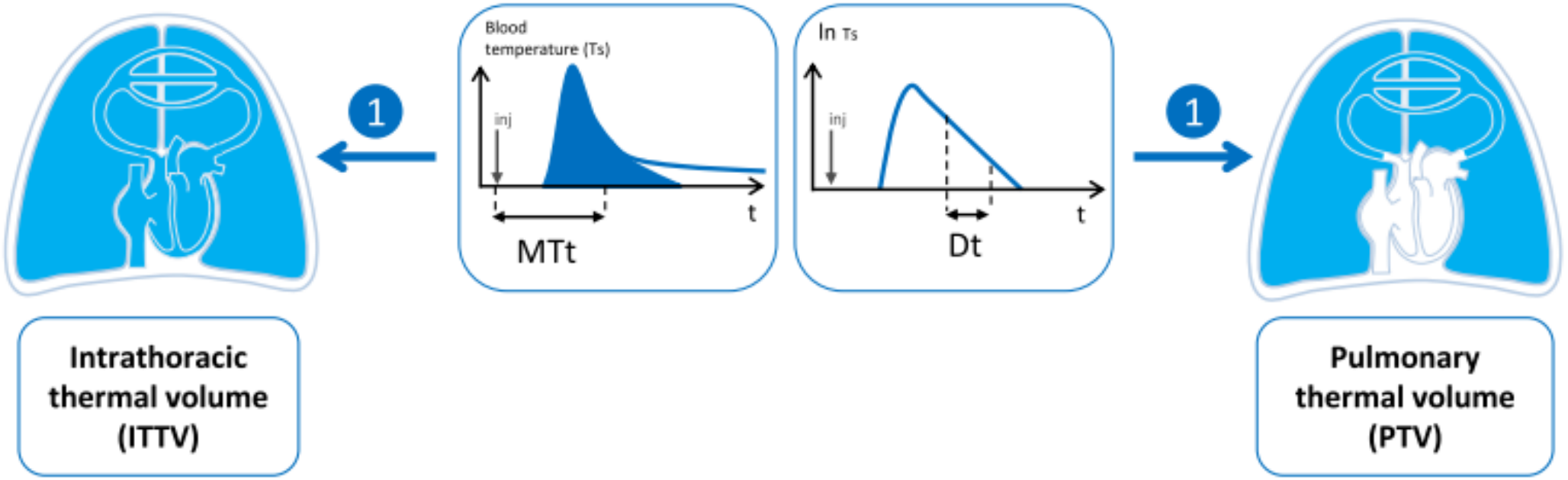
Measured by arterial and pulse contour analysis

Monnet X et al. Critical Care 2017

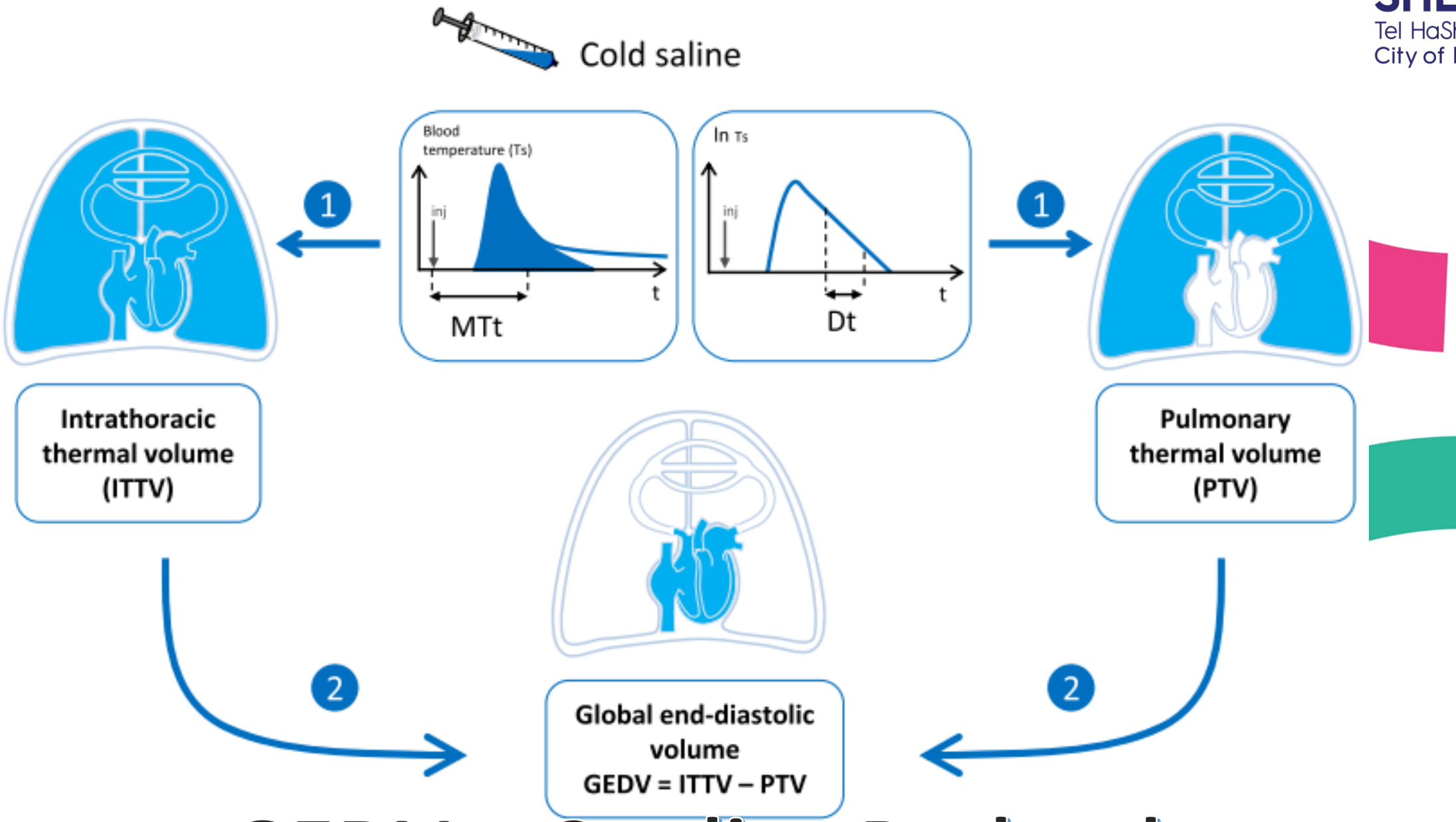
Cold saline

Mean Transit time (MTt) X CO = ITTV

Downslope time (Dt) X CO = PTV

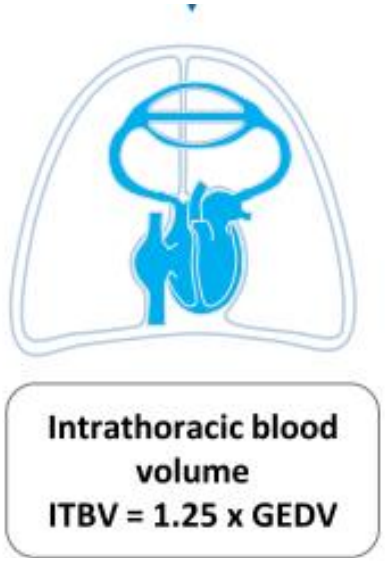


Monnet X et al. Critical Care 2017



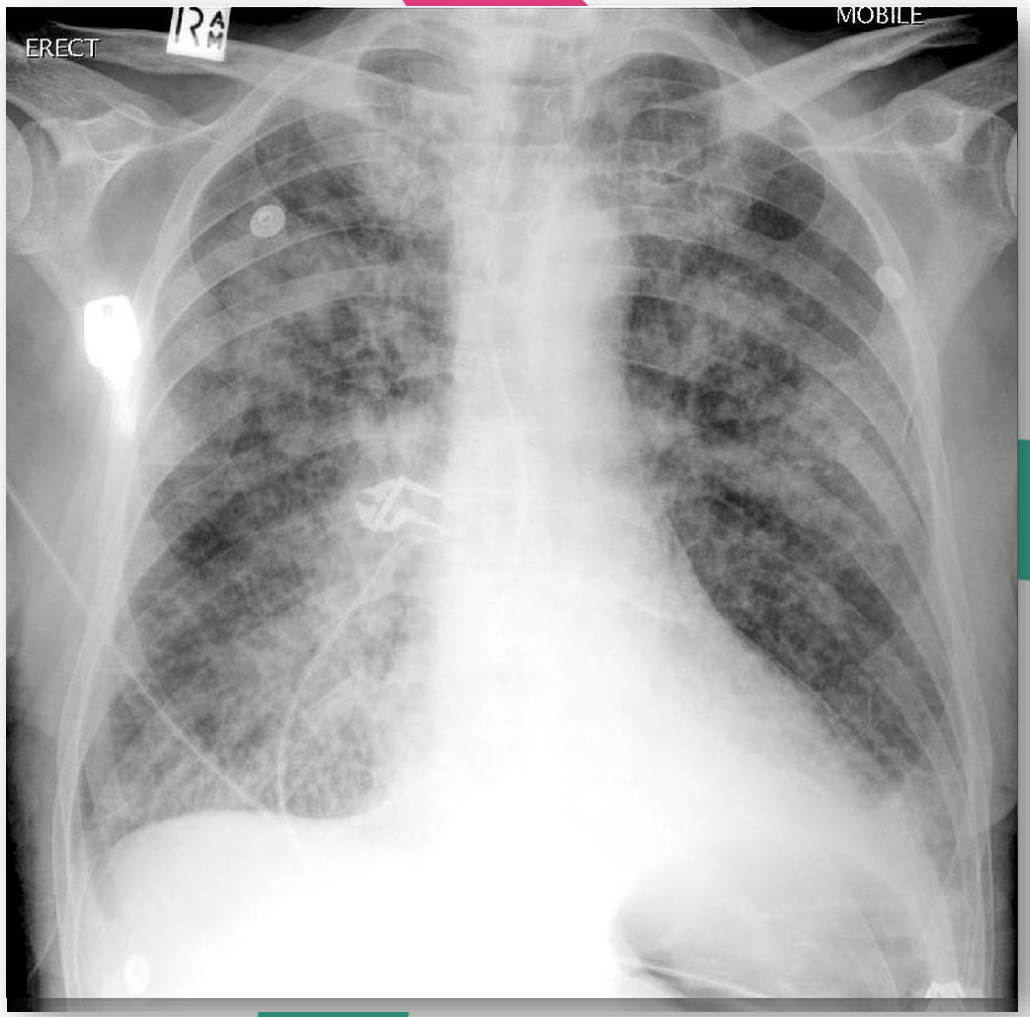
GEDV = Cardiac Preload

Extravascular Lung Water (EVLW)



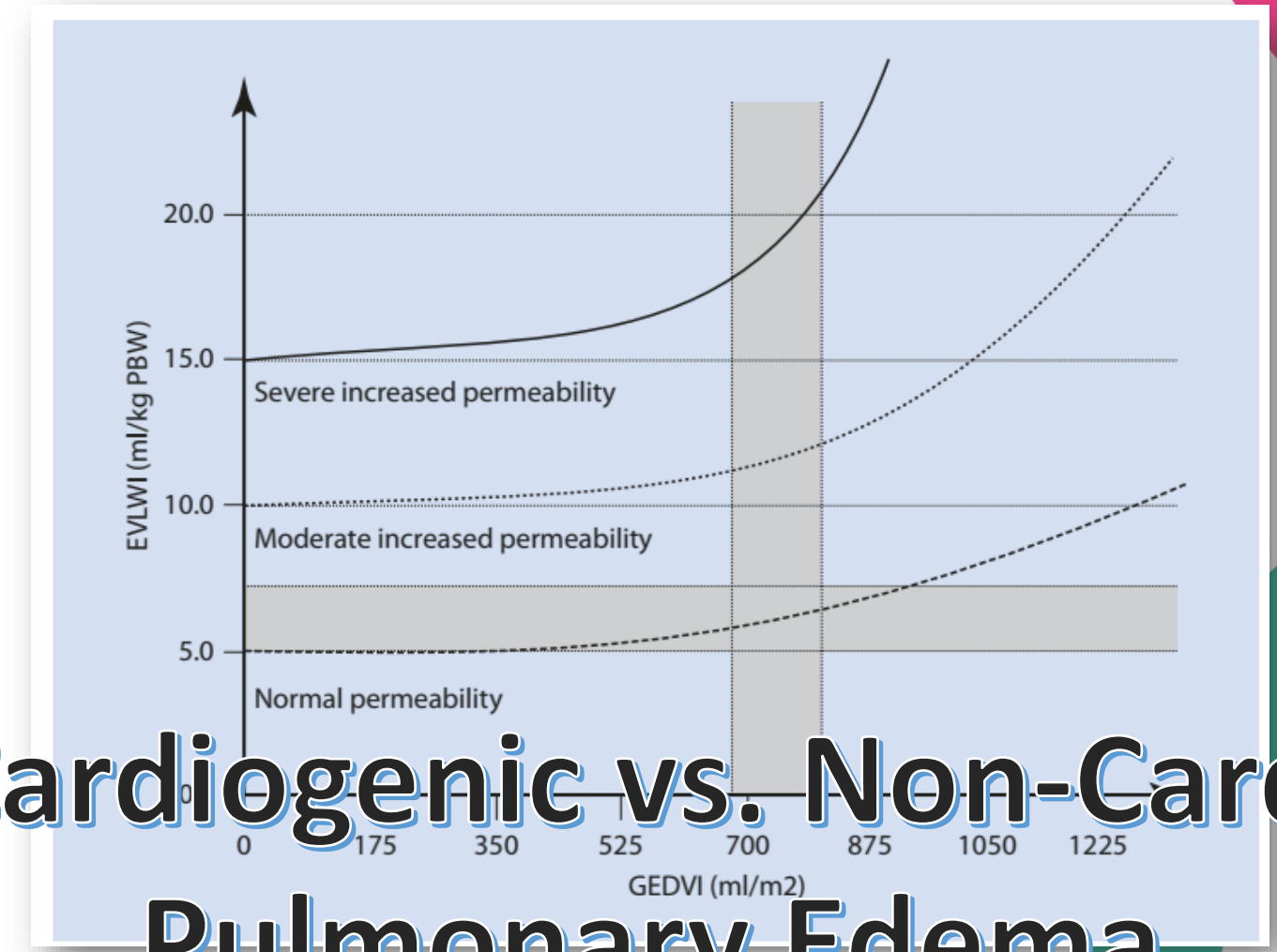
EVLW = Pulmonary Edema

Cardiogenic or non-Cardiogenic Pulmonary Edema?



Images from radiopaedia.org

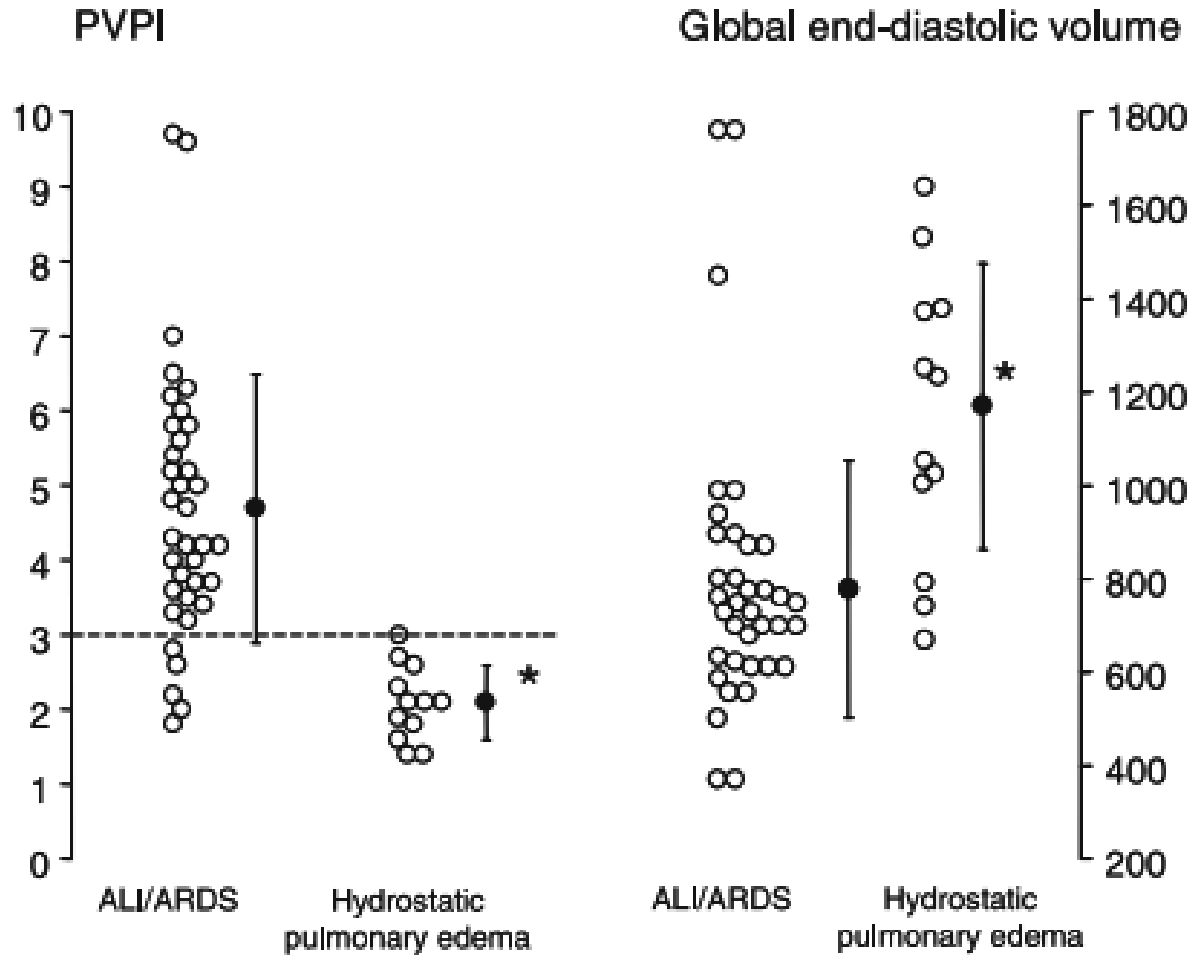
Pulmonary Vascular Permeability Index

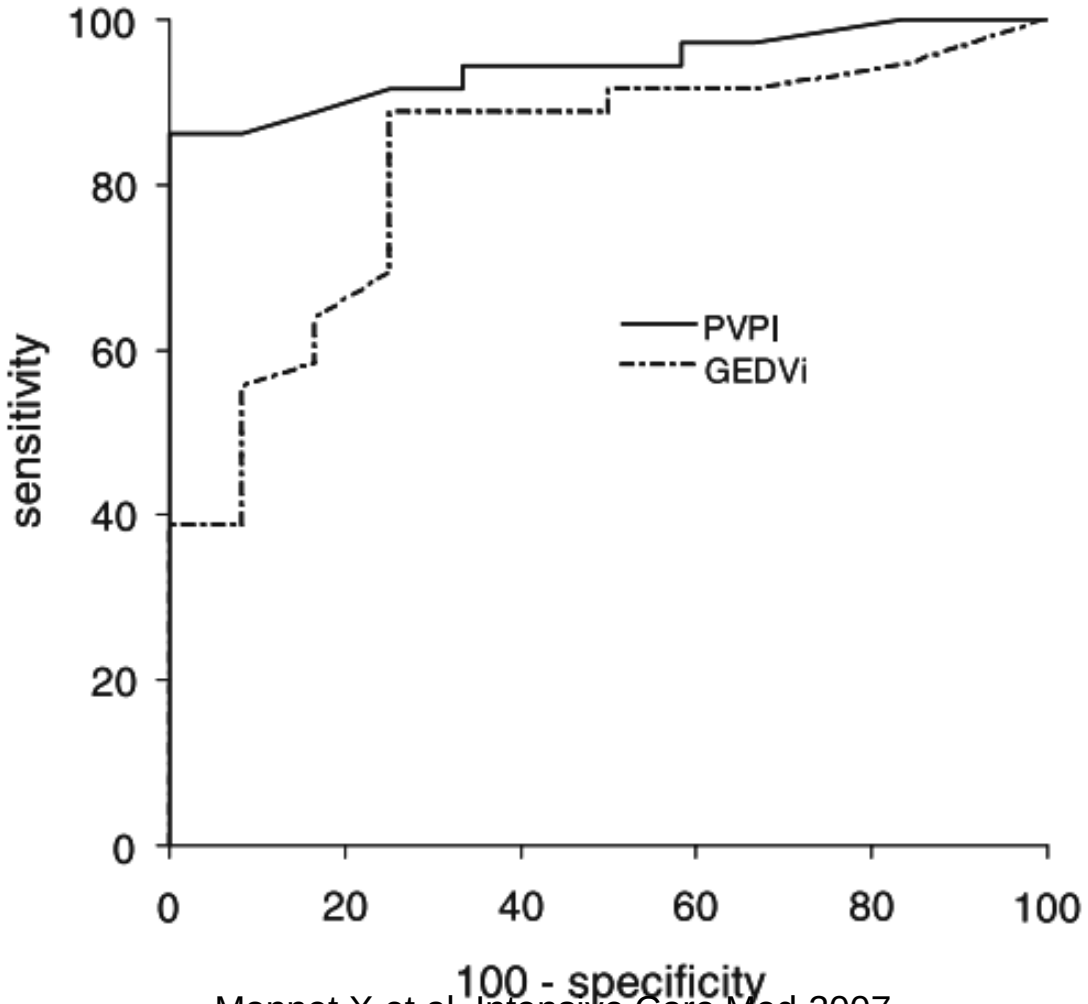


PVPI = "Cardiogenic vs. Non-Cardiogenic" Pulmonary Edema

Hemodynamic Monitoring 1st Ed. Springer - ESICM, 2019

Pulmonary Permeability Diagnoses
Etiology of Pulmonary Edema



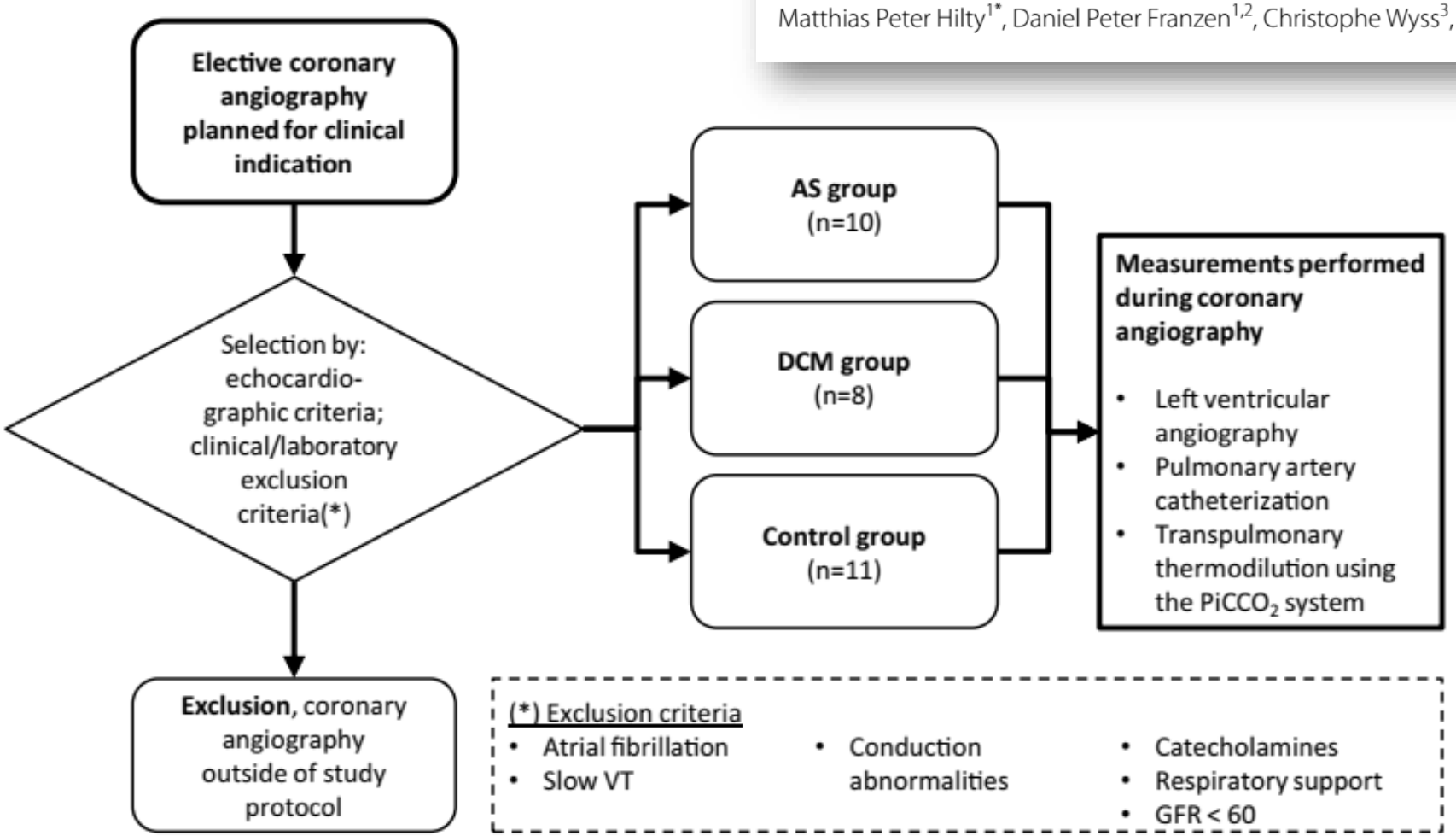


Monnet X et al. Intensive Care Med 2007

RESEARCH Open Access

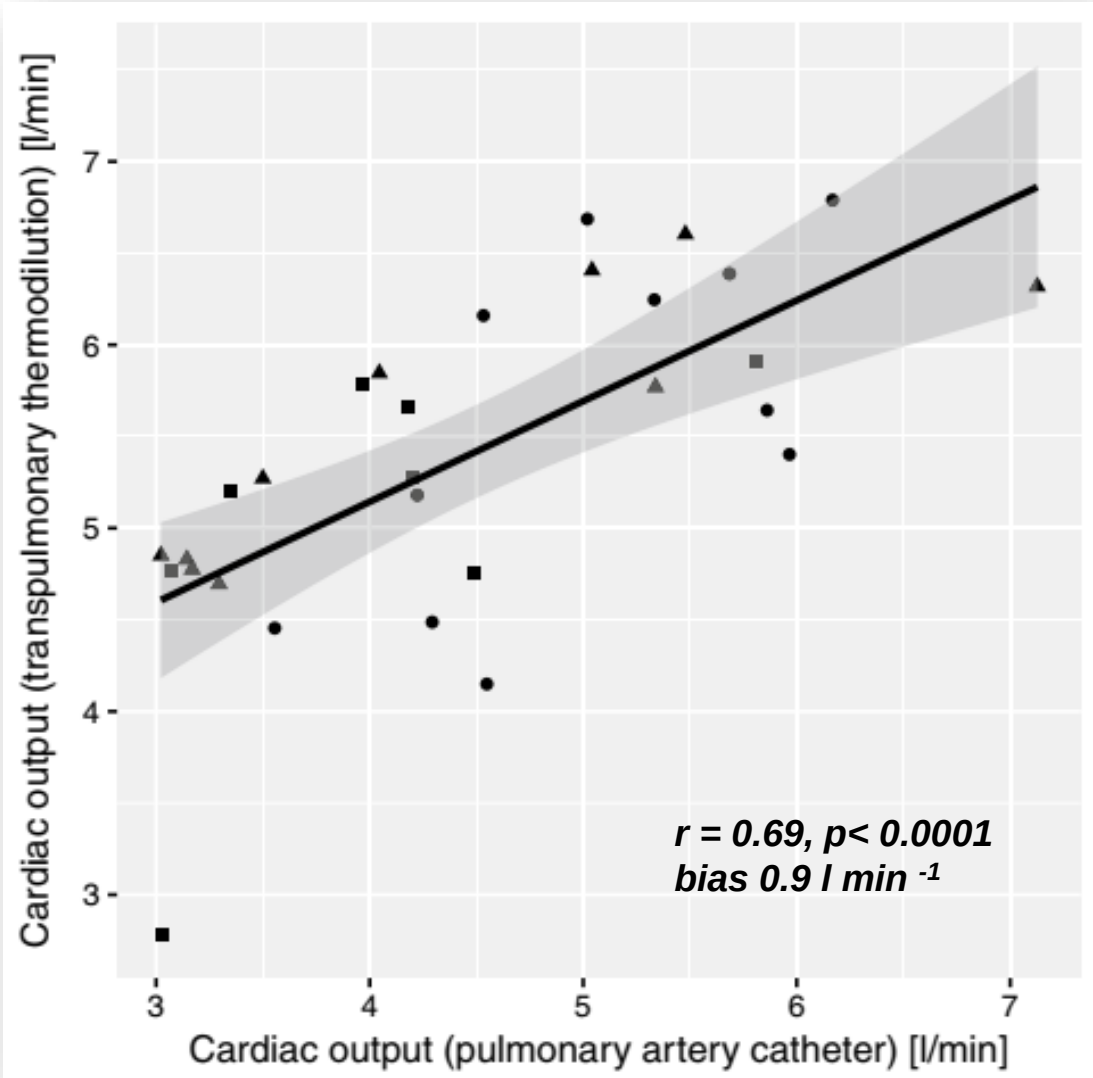
Validation of transpulmonary thermodilution variables in hemodynamically stable patients with heart diseases

Matthias Peter Hilty[1*], Daniel Peter Franzen[1,2], Christophe Wyss[3], Patric Biaggi[3] and Marco Maggiorini[1]



Hilty MP et al. Ann Int Care 2017

Correlation in CO Measurements in Pulmonary Artery Thermodilution and TPTD



Hilty MP et al. Ann Int Care 2017

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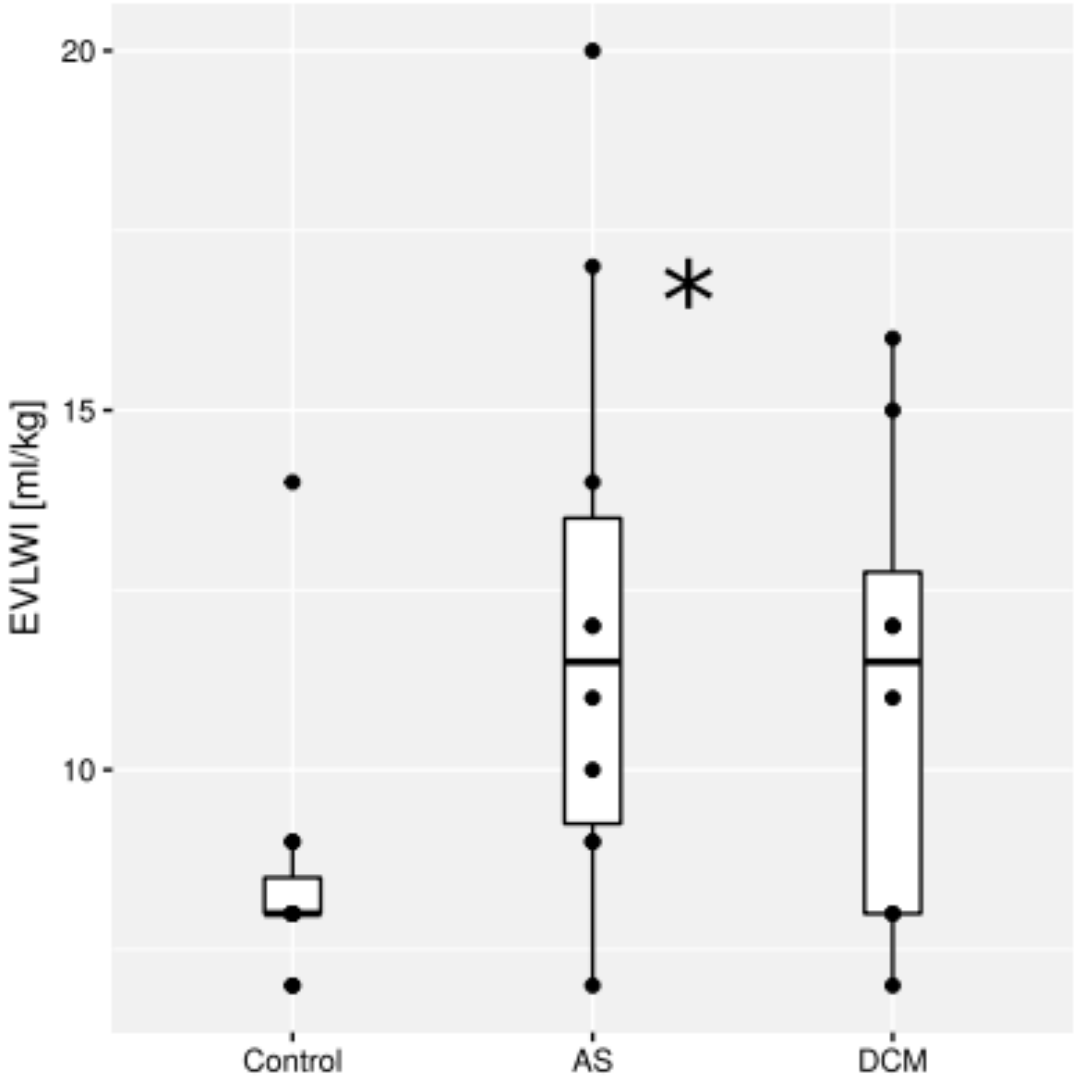
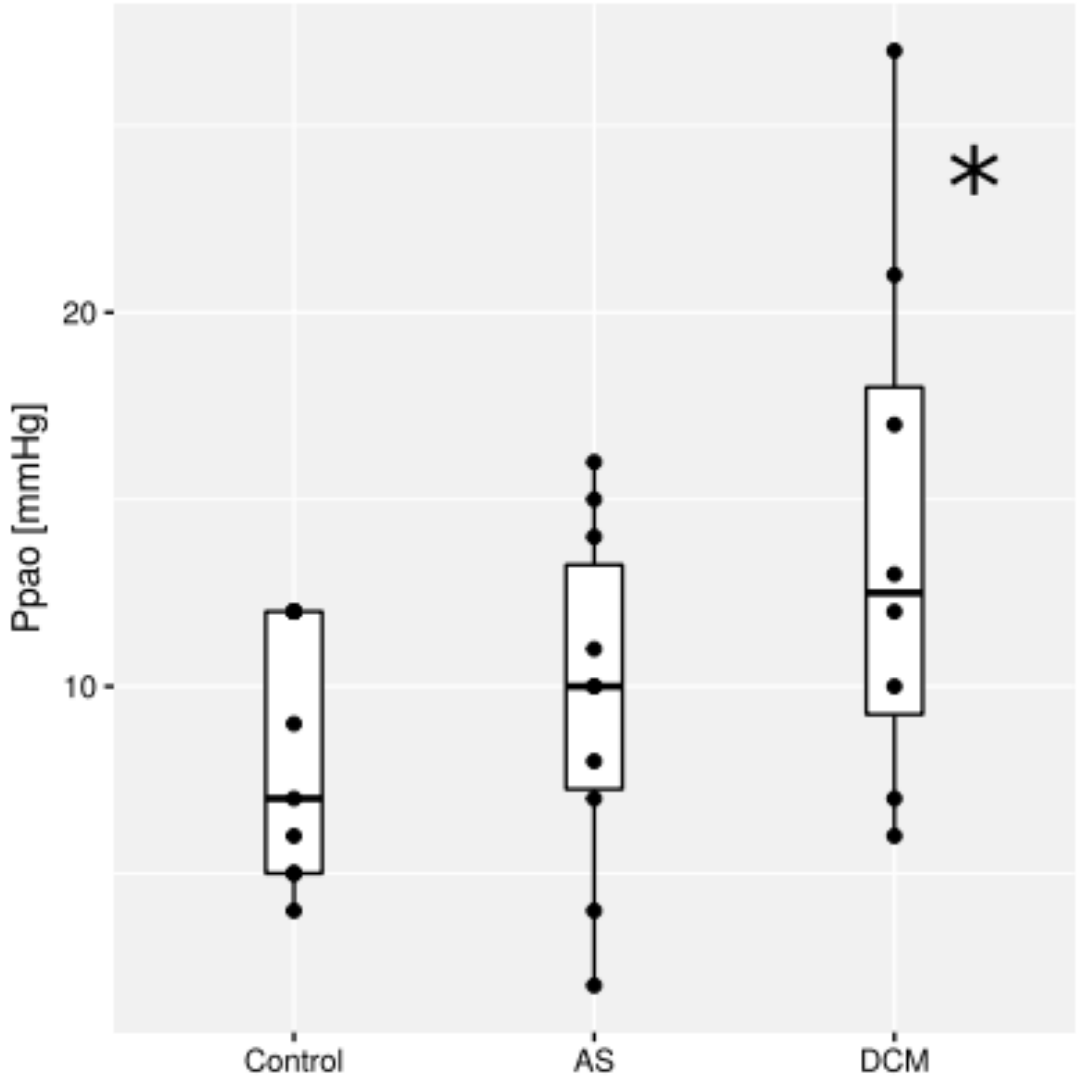
Extra-Vascular Lung Water and PAWP





Hilty MP et al. Ann Int Care 2017

TPTD Correlates Well with Pulmonary Artery Thermodilution In HF

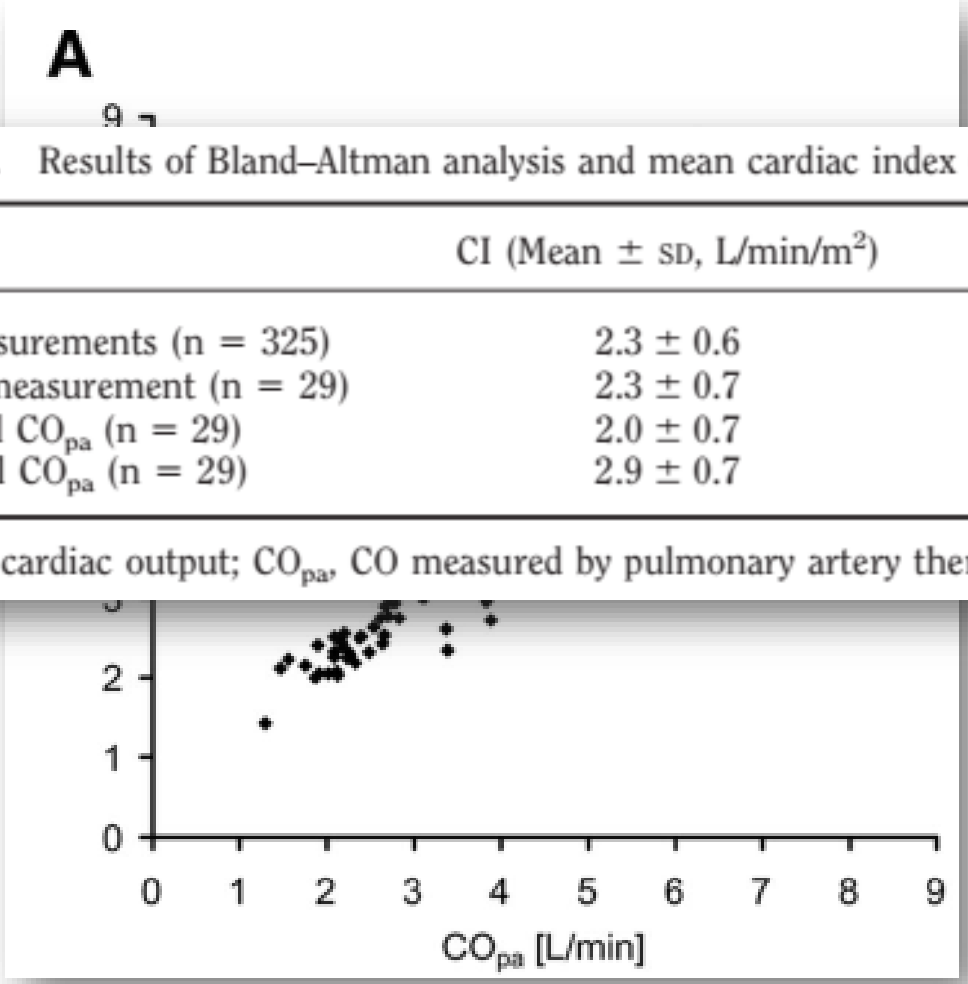


Table 2. Results of Bland–Altman analysis and mean cardiac index (CI)

	CI (Mean ± SD, L/min/m^2)	Mean CO (L/min)	Bias CO_{tp}–CO_{pa} (L/min)	2 SD (L/min)	Error (%)
All measurements (n = 325)	2.3 ± 0.6	4.4	0.45	1.20	27.3
Initial measurement (n = 29)	2.3 ± 0.7	4.3	0.38	1.16	26.9
Minimal CO_{pa} (n = 29)	2.0 ± 0.7	3.8	0.39	1.13	29.8
Maximal CO_{pa} (n = 29)	2.9 ± 0.7	5.5	0.58	1.51	27.4

CO, cardiac output; CO_{pa}, CO measured by pulmonary artery thermodilution; CO_{tp}, CO measured by transpulmonary thermodilution.

Friesecke S et al. Crit Care Med 2009

Pitfalls of TPTD

- Depends on correct injection technique
- Demographic data very important
- Overestimates volumes in AS, MR and TR, shunts, PE
- Not reliable with IABP, aortic aneurysm, cardiac tamponade, ECMO
- Underestimates volumes in S/P lung resection, atelectasis, pleural effusions

Complications

British Journal of Anaesthesia 106 (4): 482–6 (2011)
Advance Access publication 26 December 2010 · doi:10.1093/bja/aeq377

BJA

Complications related to less-invasive haemodynamic monitoring‡

F. J. Belda[1*], G. Aguilar[1], J. L. Teboul[2], D. Pestaña[3], F. J. Redondo[4], M. Malbrain[5], J. C. Luis[6], F. Ramasco[7], A. Umgelter[8], J. Wendon[9], M. Kirov[10] and E. Fernández-Mondéjar[11], for the PICS Investigators Group†

- N=514 w/ PiCCO monitoring
- 475 femoral, 26 radial, 9 axillary, 4 brachial arteries
- First attempt success rate 86%
- Minor bleeding and removal of catheter ~ 3.5%
- “Small hematomas” 4.5%
- Catheter-related infection 0.78%
- Ischemia 0.4% and femoral artery thrombosis 0.2%

Belda FJ et al. Brit J of Anaesth 2011

When to Use TPTD?

More suitable for TPTD	Less suitable for TPTD
Mixed, non-responsive severe forms of shock	Shock non-responsive to initial therapies
Severe ARDS and hemodynamically unstable	Severe RV dysfunction
No contraindications (severe PAD, etc.)	Severe pulmonary hypertension and need to tailor PHTN therapies
	Advanced HF therapies candidates
	Patients already on MCS

My Personal Take on Minimally Invasive Hemodynamic Monitoring

- What are the questions I want to answer?
- How will the information added by the system change management?
- Did I review pitfalls/contraindications?

My Personal Take on Minimally Invasive Hemodynamic Monitoring

- Avoid trusting a single parameter and rather use other methods to confirm/rule out suspected diagnosis
- Discontinue invasive monitoring and remove catheters “one day before planned”

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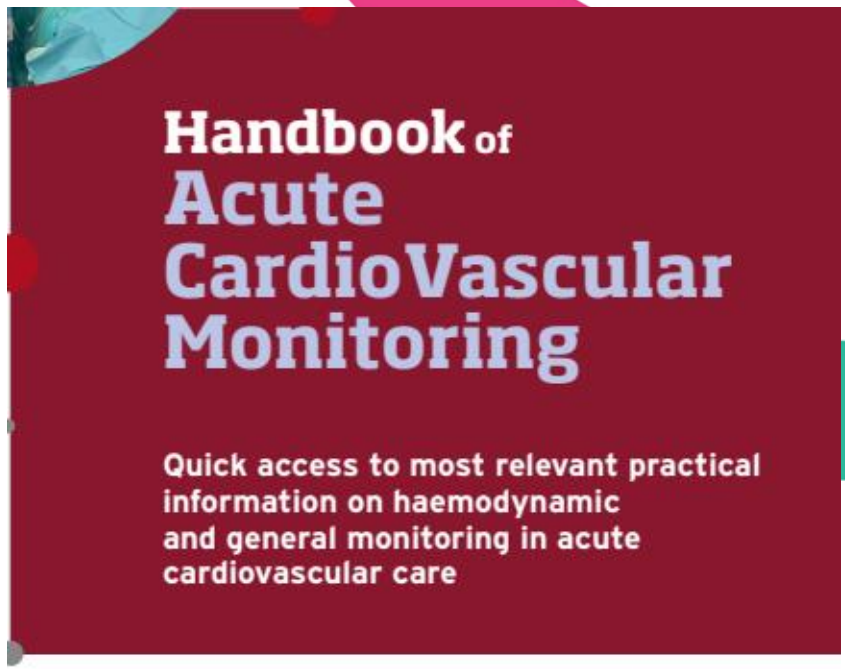
2.2.2 -Full Non-invasive assessment of CO

Dr. Katia Orvin, MD
Department of Cardiology, Rabin Medical Center, Petach Tikva,
Sackler Faculty of Medicine, Tel Aviv University, Tel Aviv, Israel

Prof. Doron Zahger, MD, FESC
Department of Cardiology, Soroka Medical Center,
Faculty of Health Sciences, Ben Gurion University
of the Negev, Beer-Sheva, Israel



ACVC
Association for
Acute CardioVascular Care

ESC
European Society
of Cardiology

Thank You!

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