Hemodynamic monitoring in critically ill patients

How to choose?

Prof. Jean-Louis TEBOUL

Medical ICU

Bicetre hospital

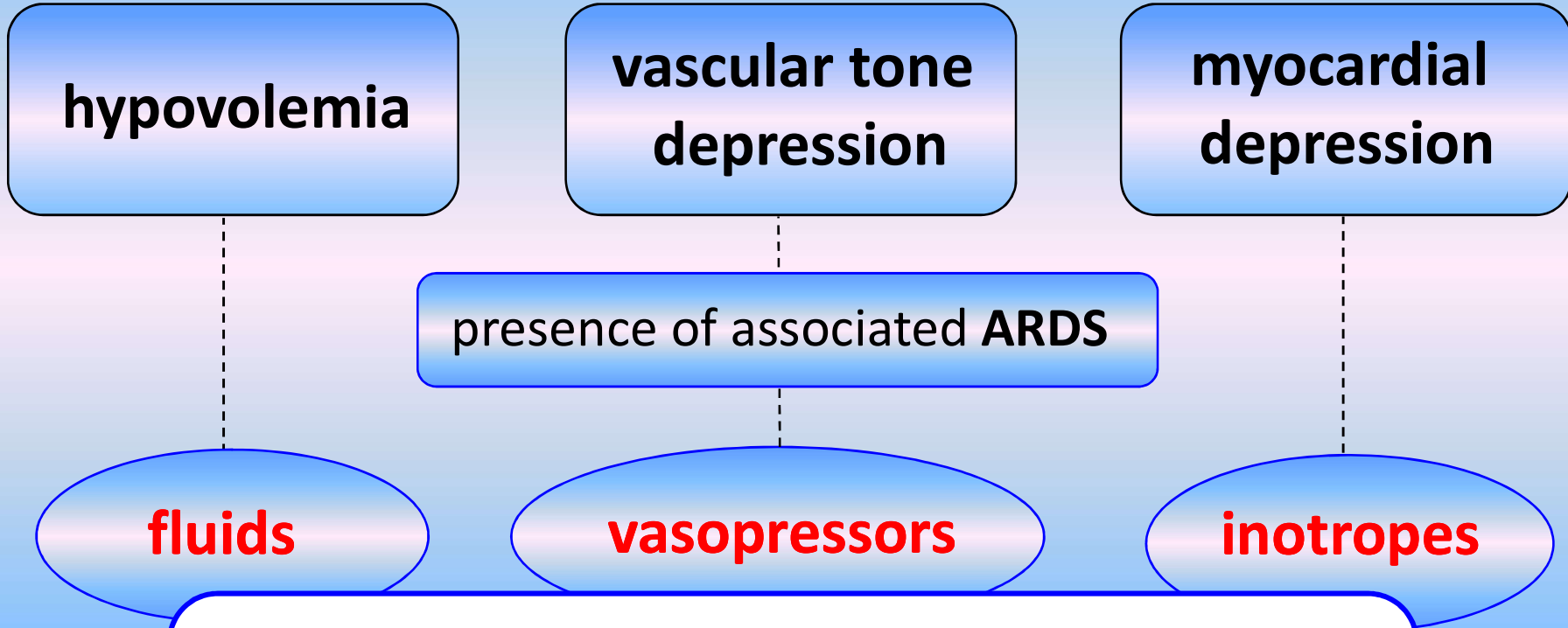
University Paris-South

France

Conflicts of interest

- Member of the Medical Advisory Board of **Getinge**
- Lectures for **Edwards LifeSciences**
- Lectures for **Masimo**
- Lectures for **Cheetah**

Various and intricate mechanisms responsible for hemodynamic failure in critically ill patients

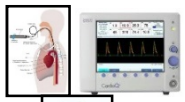


- Important to assess the **degree** of each **component** to select the most **appropriate therapeutic** option
- Important to assess the **response to treatment**

Available hemodynamic monitoring devices

- **PAC**  invasive
- **Transpulmonary thermodilution** monitors
  - → $PiCCO_2$ 
  - → VolumeView 

less invasive

- **Doppler** methods — non invasive
  - → esophageal Doppler 
  - → echocardiography 
  - → USCOM 

Many **devices**, an abundant **literature** about their **validity**

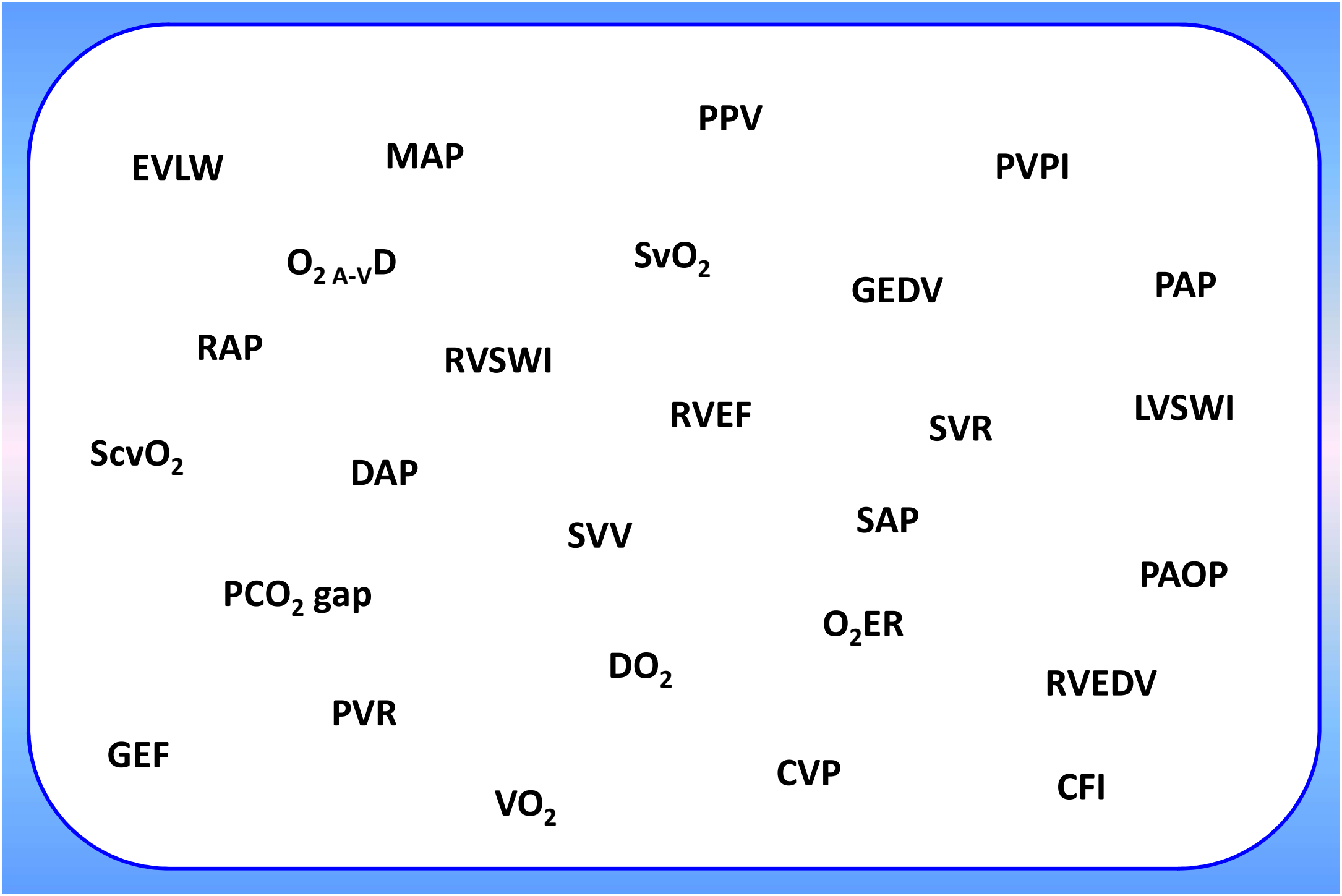
… but still a **dilemma**

as to **which ones** to use and at **what point**

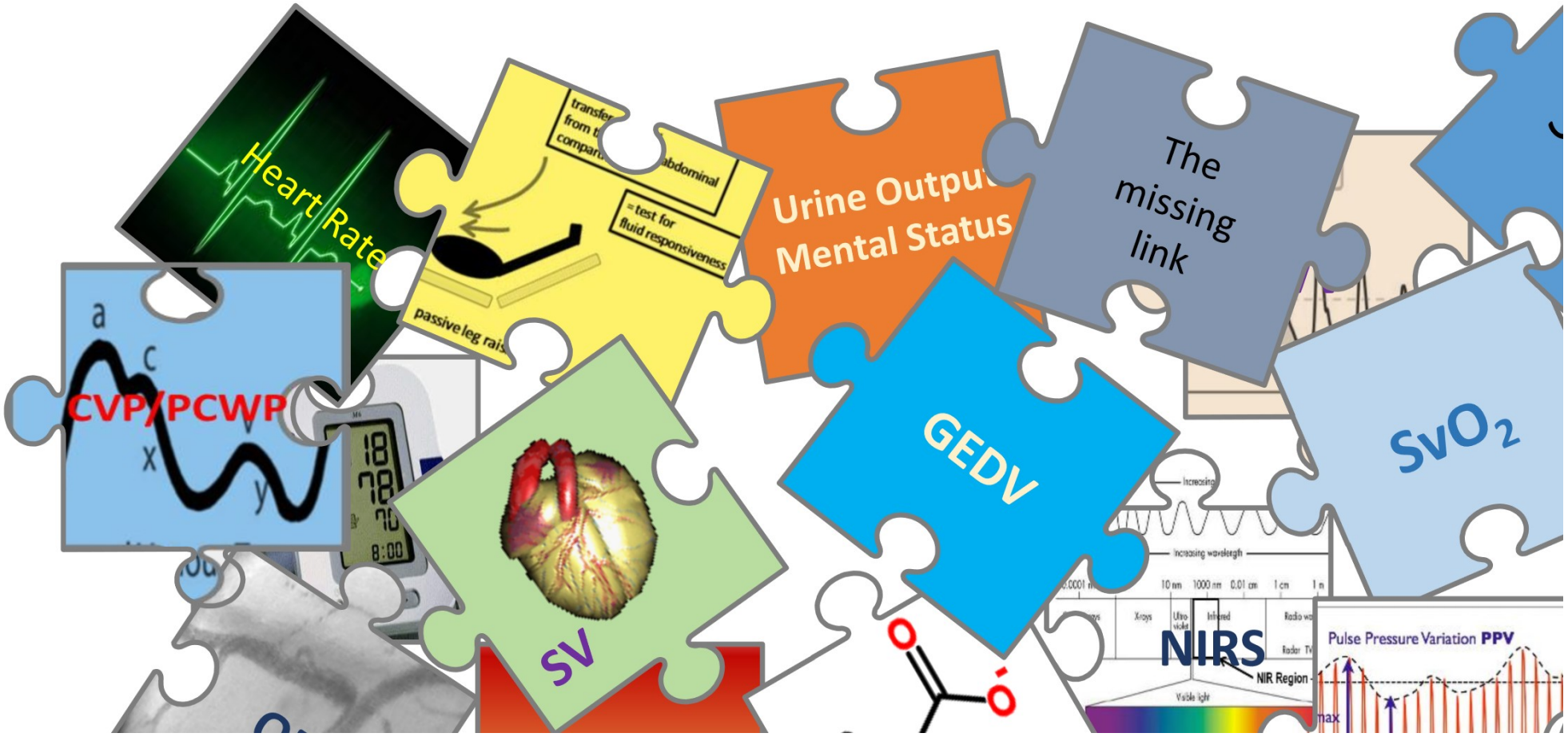
- → ProAQT/PulsioFlex 
- → Nexfin/Clearsight 

non invasive

- **Bioreactance**   non invasive
- **Pulse wave transit time**  non invasive


PPV
EVLW
MAP
PVPI
$O_{2\ A\text{-}V}D$
SvO_2
GEDV
PAP
RAP
RVSWI
RVEF
LVSWI
SVR
$ScvO_2$
DAP
SAP
SVV
PAOP
PCO_2 gap
O_2ER
DO_2
RVEDV
PVR
GEF
CVP
CFI
VO_2

The Hemodynamic Puzzle



Intensive Care Med (2014) 40:1795–1815

CONFERENCE REPORTS AND EXPERT PANEL

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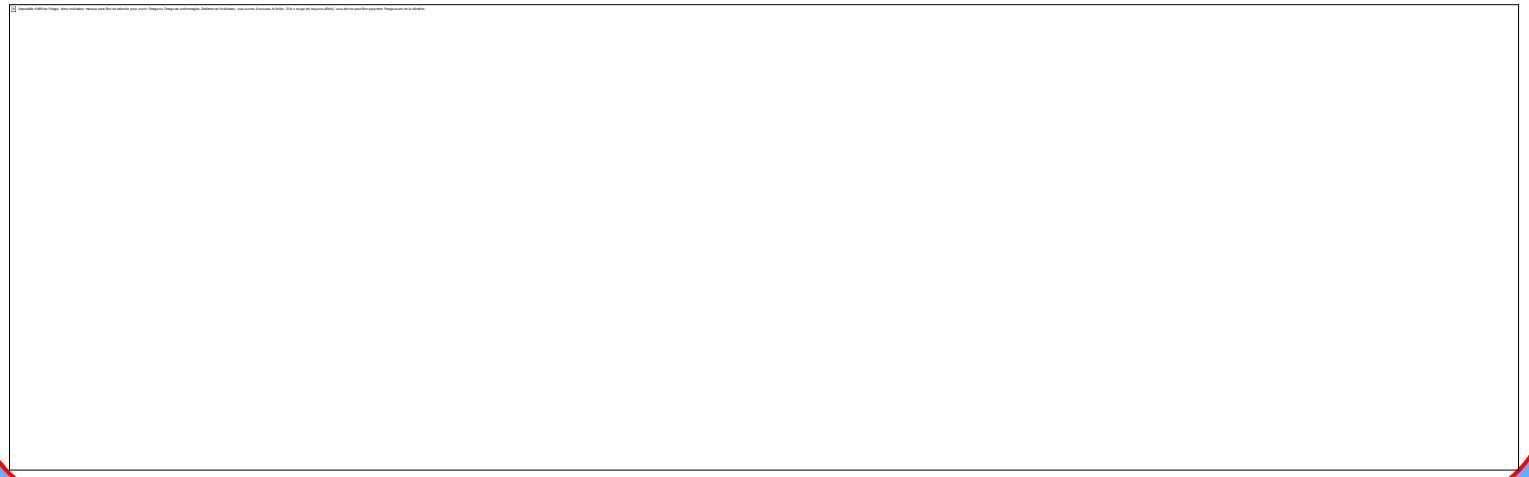
Consensus on circulatory shock and hemodynamic monitoring. Task force of the European Society of Intensive Care Medicine

Intensive Care Med (2016) 42:1350–1

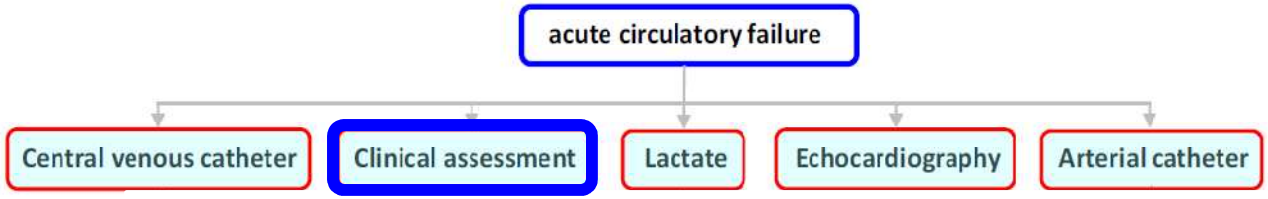


Intensive Care Med (2016) 42:1350–1

CONFERENCE REPORTS AND EXPERT PANEL

Less invasive hemodynamic monitoring in critically ill patients

[illegible]



JAMA | Original Investigation | CARING FOR THE CRITICALLY ILL PATIENT

Effect of a Resuscitation Strategy Targeting Peripheral Perfusion Status vs Serum Lactate Levels on 28-Day Mortality Among Patients With Septic Shock

The ANDROMEDA-SHOCK Randomized Clinical Trial

Glenn Hernández, MD, PhD; Gustavo A. Ospina-Tascón, MD, PhD; Lucas Petri Damiani, MSc; Elisa Estenssoro, MD; Arnaldo Dubin, MD, PhD; Javier Hurtado, MD; Gilberto Friedman, MD, PhD; Ricardo Castro, MD, MPH; Leyla Alegría, RN, MSc; Jean-Louis Teboul, MD, PhD; Maurizio Cecconi, MD, FFICM; Giorgio Ferri, MD; Manuel Jibaja, MD; Ronald Pairumani, MD; Paula Fernández, MD; Diego Barahona, MD; Vladimir Granda-Luna, MD, PhD; Alexandre Biasi Cavalcanti, MD, PhD; Jan Bakker, MD, PhD; for the ANDROMEDA-SHOCK Investigators and the Latin America Intensive Care Network (LIVEN)

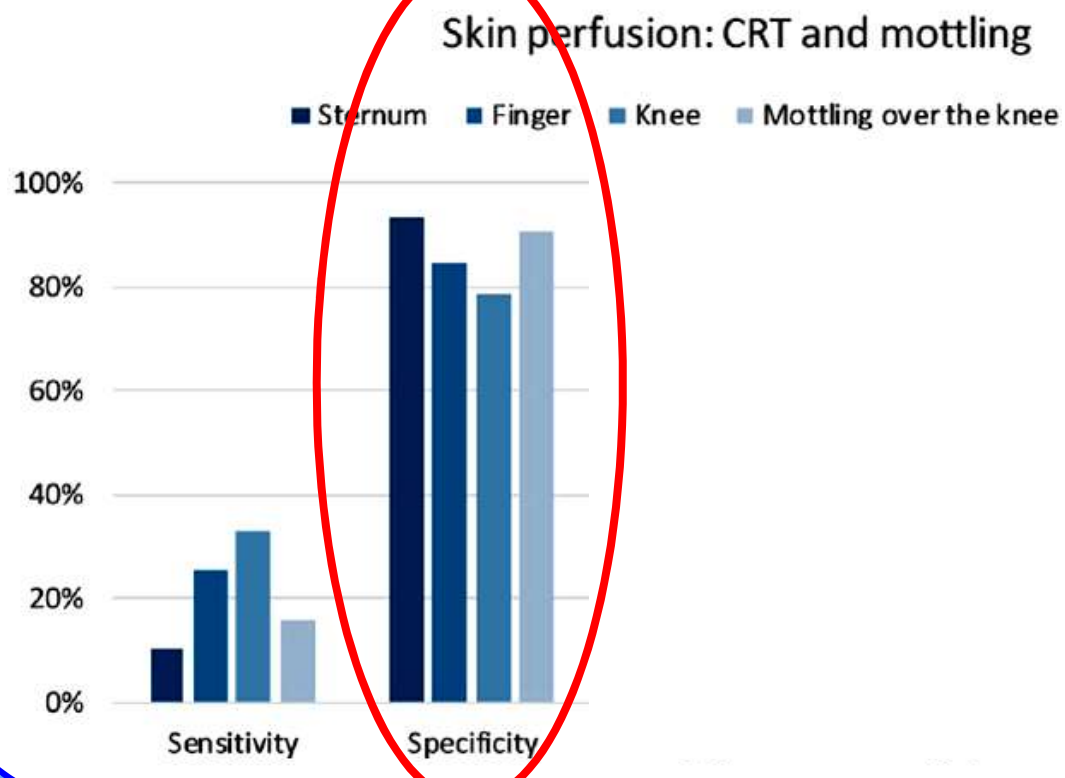
JAMA Published online February 17, 2019

ORIGINAL

The diagnostic accuracy of clinical examination for estimating cardiac index in critically ill patients: the Simple Intensive Care Studies-I

Bart Hiemstra[1*], Geert Koster[1], Renske Wiersema[1], Yoran M. Hummel[2], Pim van der Harst[2], Harold Snieder[3], Ruben J. Eck[1], Thomas Kaufmann[4], Thomas W. L. Scheeren[4], Anders Perner[5,6], Jørn Wetterslev[6,7], Anne Marie G. A. de Smet[1], Frederik Keus[1], Iwan C. C. van der Horst[1] and SICS Study Group[1]

Intensive Care Med (2019) 45:190–200



Intensive Care Med (2016) 42:1350–1

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Less invasive hemodynamic monitoring in critically ill patients

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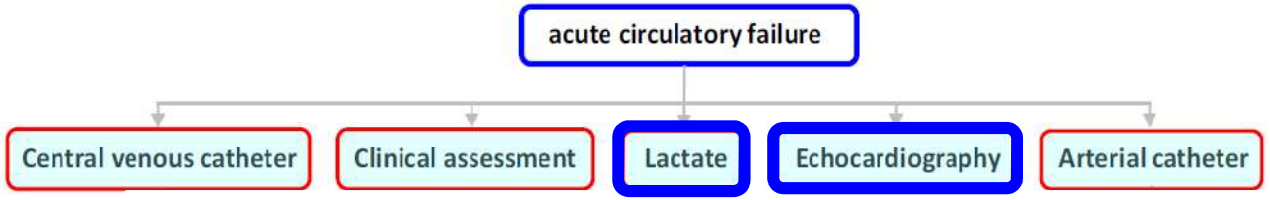

intermittent measurements of several **cardiac function** variables

Intensive Care Med (2016) 42:1350–1

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Less invasive hemodynamic monitoring in critically ill patients

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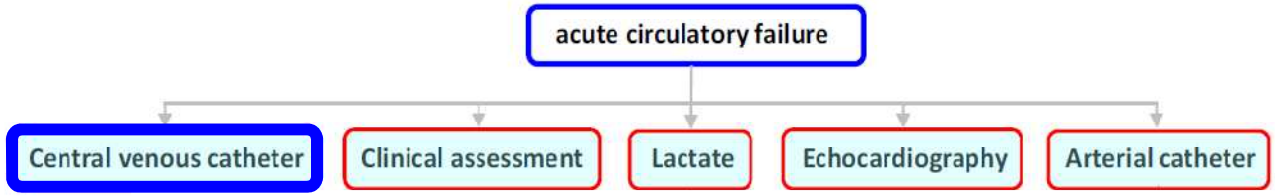
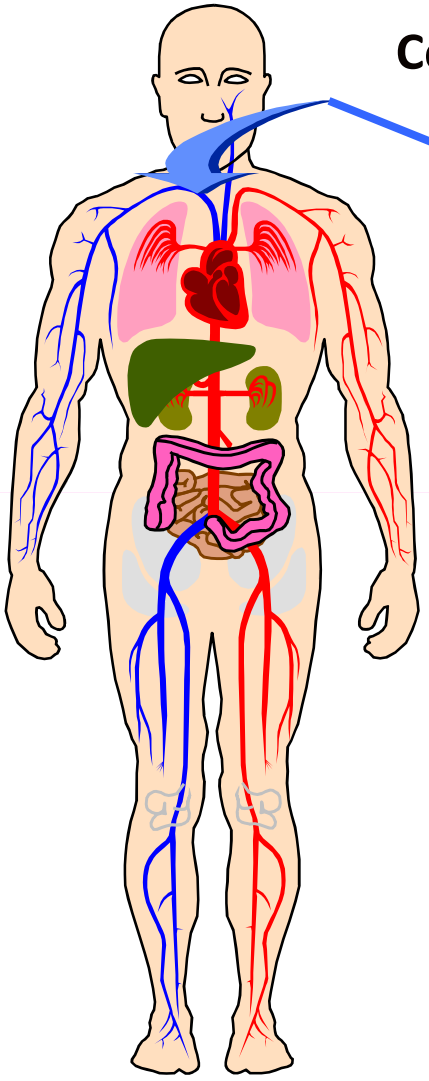




Central venous catheter

CVP $ScvO_2$ $PcvCO_2$

- Helpful to diagnose **RV dysfunction**
- Helpful to **target** the optimal **MAP**

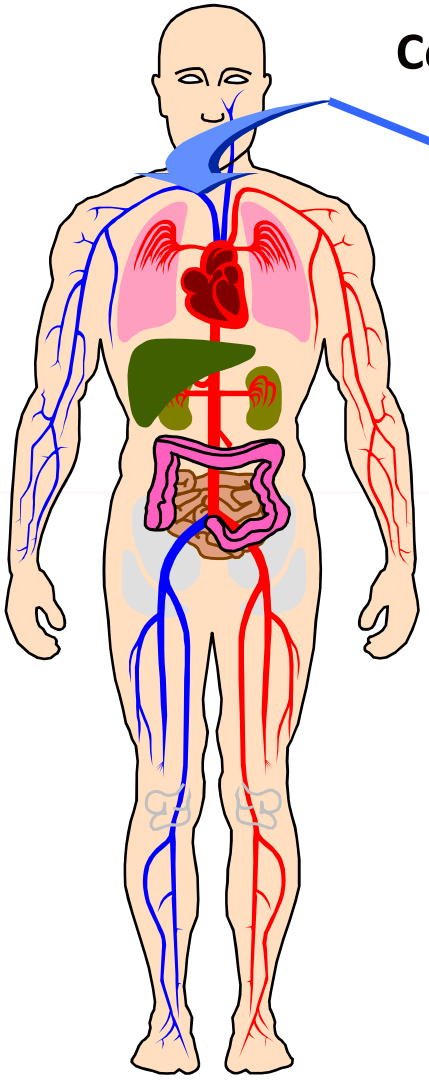
Low mean perfusion pressure is a risk factor for progression of acute kidney injury in critically ill patients – A retrospective analysis

Marlies Ostermann[1*], Anna Hall[2] and Siobhan Crichton[3]

BMC Nephrology (2017) 18:151

Mean perfusion pressure (MPP = MAP-CVP) but **not MAP** was an independent factor associated with **AKI progression**.

A value of **MPP** of **60 mmHg** was found as a cutoff.



Central venous catheter

CVP $ScvO_2$ $PcvCO_2$

- Helpful to diagnose **RV dysfunction**
- Helpful to **target** the optimal **MAP**
- **Not** helpful to predict **fluid responsiveness**

Does the Central Venous Pressure Predict Fluid Responsiveness? An Updated Meta-Analysis and a Plea for Some Common Sense*

Paul E. Marik, MD, FCCM[1]; Rodrigo Cavallazzi, MD[2]

Crit Care Med 2013; 41:1774-81

1802 pts

43 Citations

Summary AUC

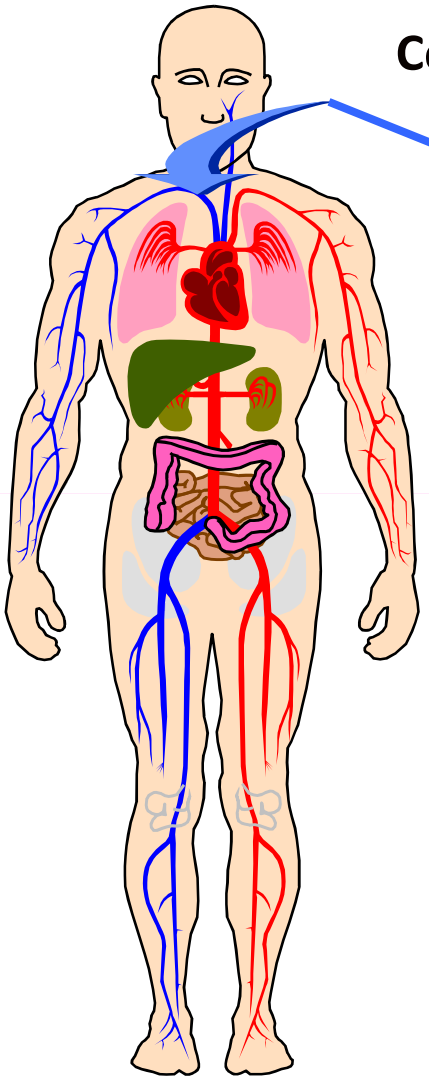
0.56

22 ICU studies

20 operating room studies

1 human vo

Predicting fluid responsiveness with **CVP** is like



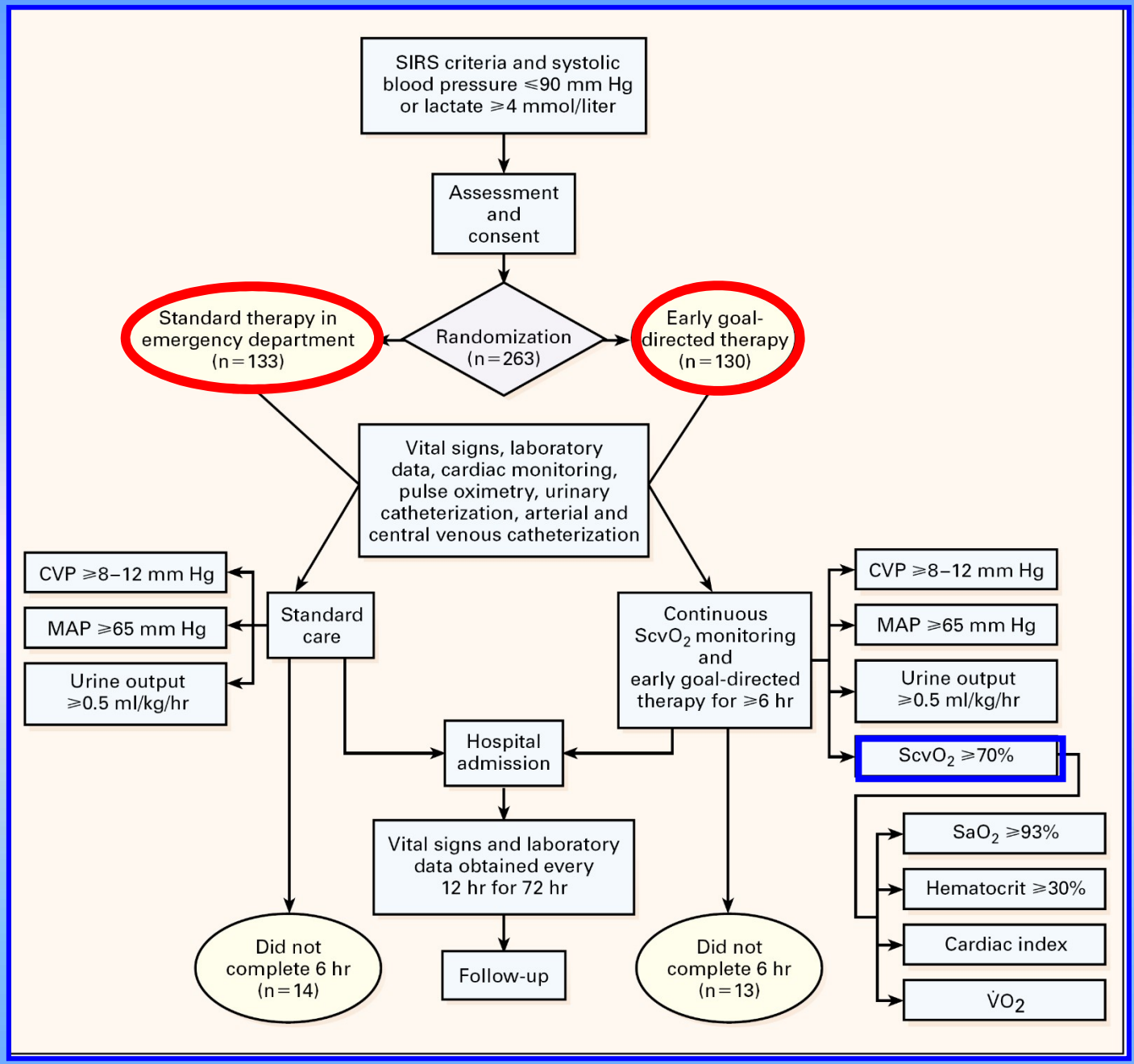
Central venous catheter

CVP $ScvO_2$ $PcvCO_2$

$$SvO_2 = SaO_2 - \frac{VO_2}{CO \times Hb \times 13.4}$$

$ScvO_2$ is an acceptable reflection of **SvO_2**

$ScvO_2$ indicator of **VO_2 / DO_2 balance**



Rivers et al. *New Engl J Med* 2001

Intensive Care Med (2013) 39:165–228
DOI 10.1007/s00134-012-2769-8

GUIDELINES

R. P. Dellinger
Mitchell M. Levy
Andrew Rhodes
Djillali Annane
Herwig Gerlach
Steven M. Opal
Jonathan E. Sevransky
Charles L. Sprung
Ivor S. Douglas
Roman Jaeschke
Tiffany M. Osborn
Mark E. Nunnally
Sean R. Townsend
Konrad Reinhart
Ruth M. Kleinpell
Derek C. Angus
Clifford S. Deutschman

Surviving Sepsis Campaign: Int Guidelines for Management of and Septic Shock, 2012

Initial resuscitation

1. Protocolized, quantitative resuscitation of patients with sepsis-induced hypoperfusion (defined as hypotension persisting after initial fluid challenge or blood lactate ≥ 4 mmol/L).

Goals during the first 6h of resuscitation:

(a) Central venous pressure 8-12 mmHg

(b) Mean arterial pressure (MAP) ≥ 65 mmHg

(c) Urine output ≥ 0.5 mL.kg^{-1} h

(d) Central venous or mixed venous oxygen saturation 70 or 65%, respectively

CONFERENCE REPORTS AND EXPERT PANEL

Surviving Sepsis Campaign: International Guidelines for Management of Sepsis and Septic Shock: 2016

Andrew Rhodes[1*], Laura E. Evans[2], Waleed Alhazzani[3], Mitchell M. Levy[4], Massimo Antonelli[5], Ricard Ferrer[6],

Christopher W. Seymour[7], Lisa Shieh[8], Khalid A. Shukri[9], Steven Q. Simpson[10], Mervyn Singer[11],
B. Taylor Thompson[47], Sean R. Townsend[48], Thomas Van der Poll[49], Jean-Louis Vincent[50], W. Joost Wiersinga[49],
Janice L. Zimmerman[51] and R. Phillip Dellinger[22]

No mention to **$ScvO_2$** anywhere

in the 93 recommendations!!

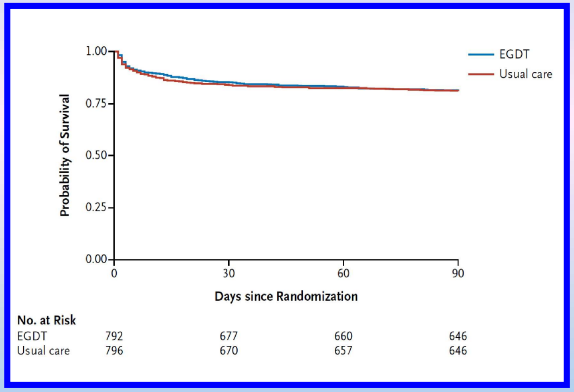
Intensive Care Med (2017) 43:304–377

Arise

Goal-Directed Resuscitation for Patients with Early Septic Shock

The ARISE Investigators and the ANZICS Clinical Trials Group*

N Engl J Med 2014;371:1496-506

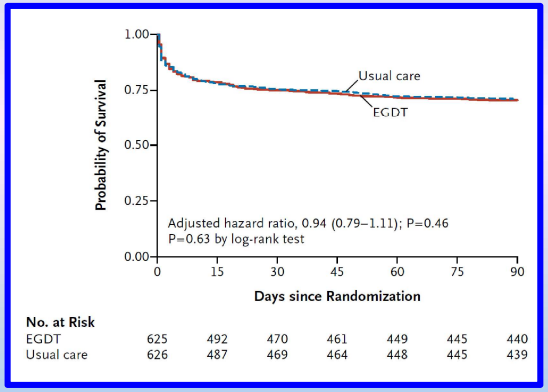


Promise

Trial of Early, Goal-Directed Resuscitation for Septic Shock

Paul R. Mouncey, M.Sc., Tiffany M. Osborn, M.D., G. Sarah Power, M.Sc., David A. Harrison, Ph.D., M. Zia Sadique, Ph.D., Richard D. Grieve, Ph.D., Rahi Jahan, B.A., Sheila E. Harvey, Ph.D., Derek Bell, M.D., Julian F. Bion, M.D., Timothy J. Coats, M.D., Mervyn Singer, M.D., J. Duncan Young, D.M., and Kathryn M. Rowan, Ph.D., for the ProMISe Trial Investigators*

N Engl J Med 2015;372:1301-11

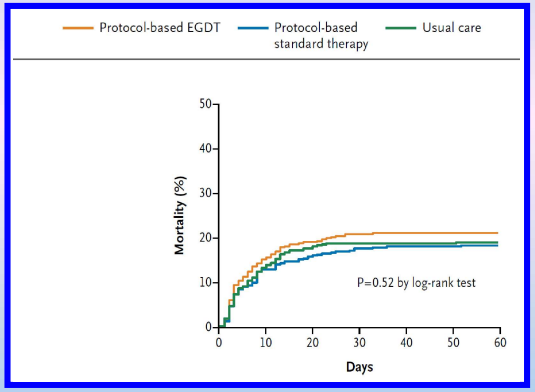


Process

A Randomized Trial of Protocol-Based Care for Early Septic Shock

The ProCESS Investigators*

N Engl J Med 2014;370:1683-93



No improved survival with **EGDT**

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Caution:

- Patients were far **less sick** than in the Rivers' study
- Mean **$ScvO_2$** was already > 70% (the **target**) at inclusion time
  - Pts received **2,500 mL** fluids **before inclusion**

By design, these studies could not show any benefit of targeting **$ScvO_2$ > 70%** when it is low

These studies could not show the **utility** of targeting

Intensive Care Med (2014) 40:1795–1815

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Consensus on circulatory shock and hemodynamic monitoring. Task force of the European Society of Intensive Care Medicine

- In patients with a **central venous catheter**, we suggest measurements of **$ScvO_2$** and **v-$aPCO_2$** to help assess the underlying pattern and the **adequacy** of c**ardiac output** as well as to **guide therapy**

Level 2; QoE moderate (B)

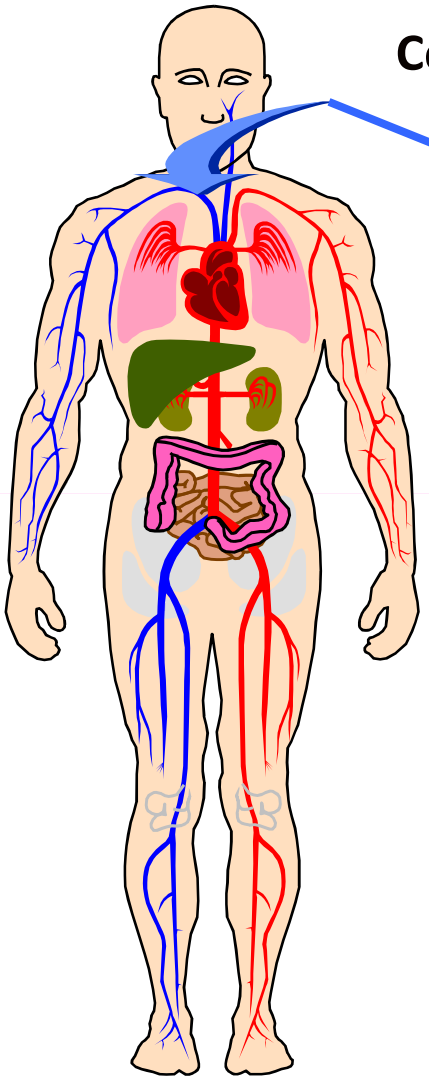
Intensive Care Med (2016) 42:1350–1

CONFERENCE REPORTS AND EXPERT PANEL

Less invasive hemodynamic monitoring in critically ill patients

[illegible][1*] [illegible][2] [illegible][3] [illegible][4] [illegible]

$ScvO_2$ is used as a surrogate of mixed venous blood oxygen saturation (SvO_2), which reflects in real time the balance between oxygen consumption and oxygen delivery. Hence, a low $ScvO_2$ may indicate insufficient global oxygen delivery in case of shock and incite one to increase it.



Central venous catheter

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[illegible]

coupling arterial and central venous blood sampling allows calculation of the venous-to-arterial carbon dioxide pressure difference (PCO_2 gap), which could be a good indicator of the adequacy of CO relative to the actual global metabolic conditions and could be helpful in conditions where oxygen extraction is altered while $ScvO_2$ is within the normal range. In this particular case, an abnormally high PCO_2 gap (>6 mmHg) could suggest that CO should be elevated to improve tissue oxygenation

simplified

Fick equation

$$PcvCO_2 - PaCO_2 = k \cdot \frac{VCO_2}{\text{Cardiac Output}}$$

$PcvCO_2$ - $PaCO_2$ marker of "adequacy" of venous blood flow to clear the CO_2 produced in the peripheral tissues

- A **normal ΔPCO_2** suggests that **elevation** of **CO cannot** be a priority in the therapeutic strategy
- A **high ΔPCO_2** suggests that **elevation** of **CO can** be a **good** therapeutic option

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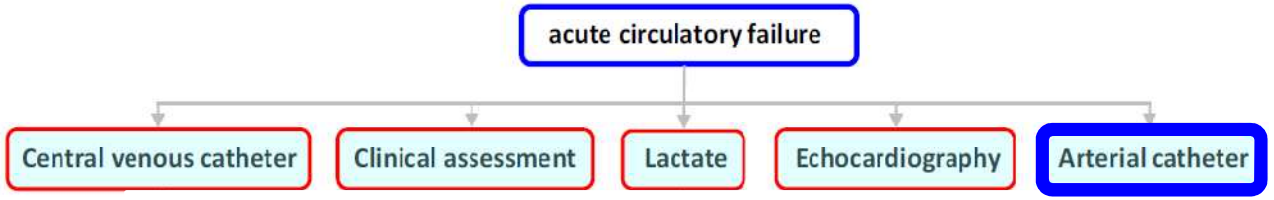
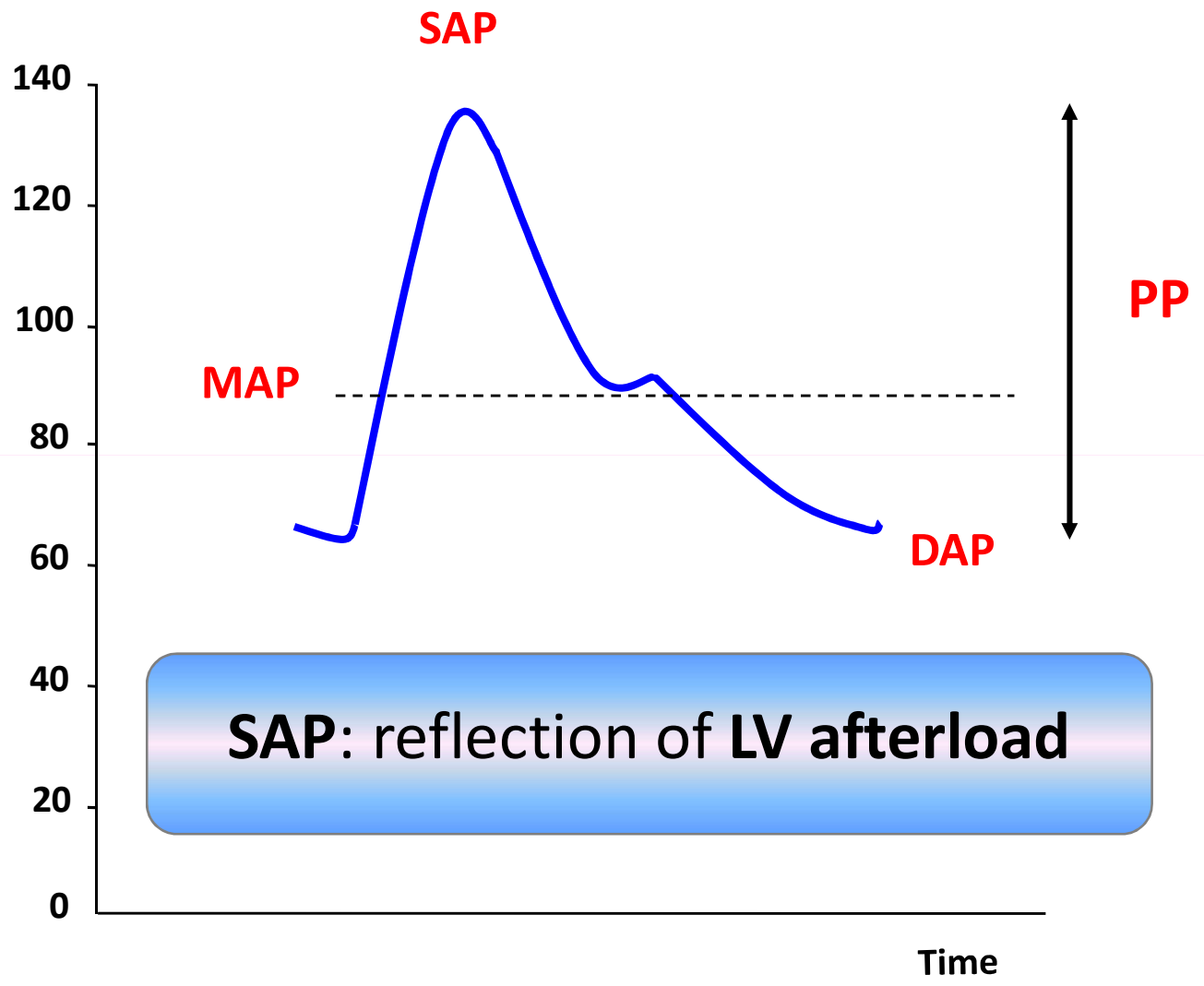
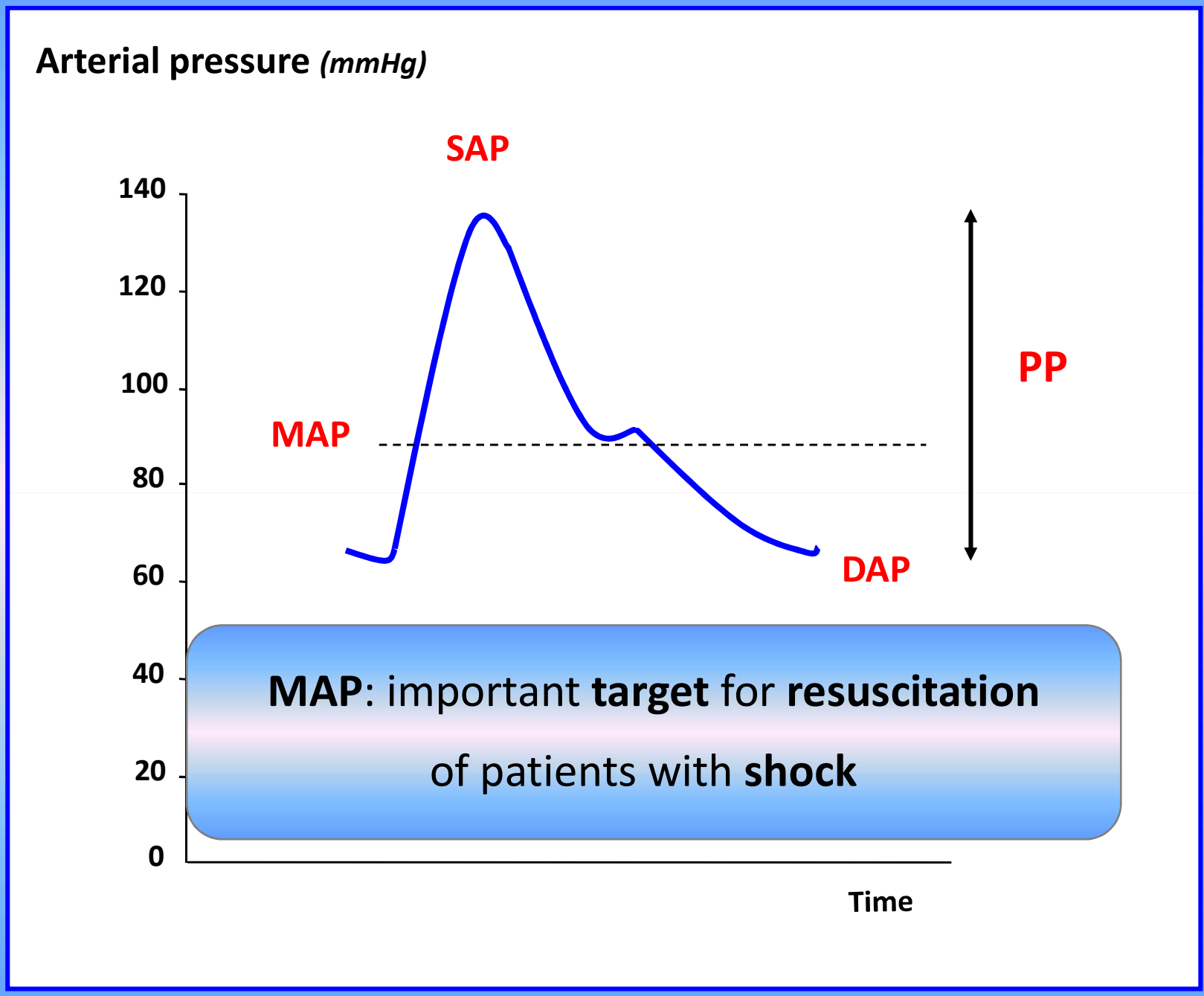
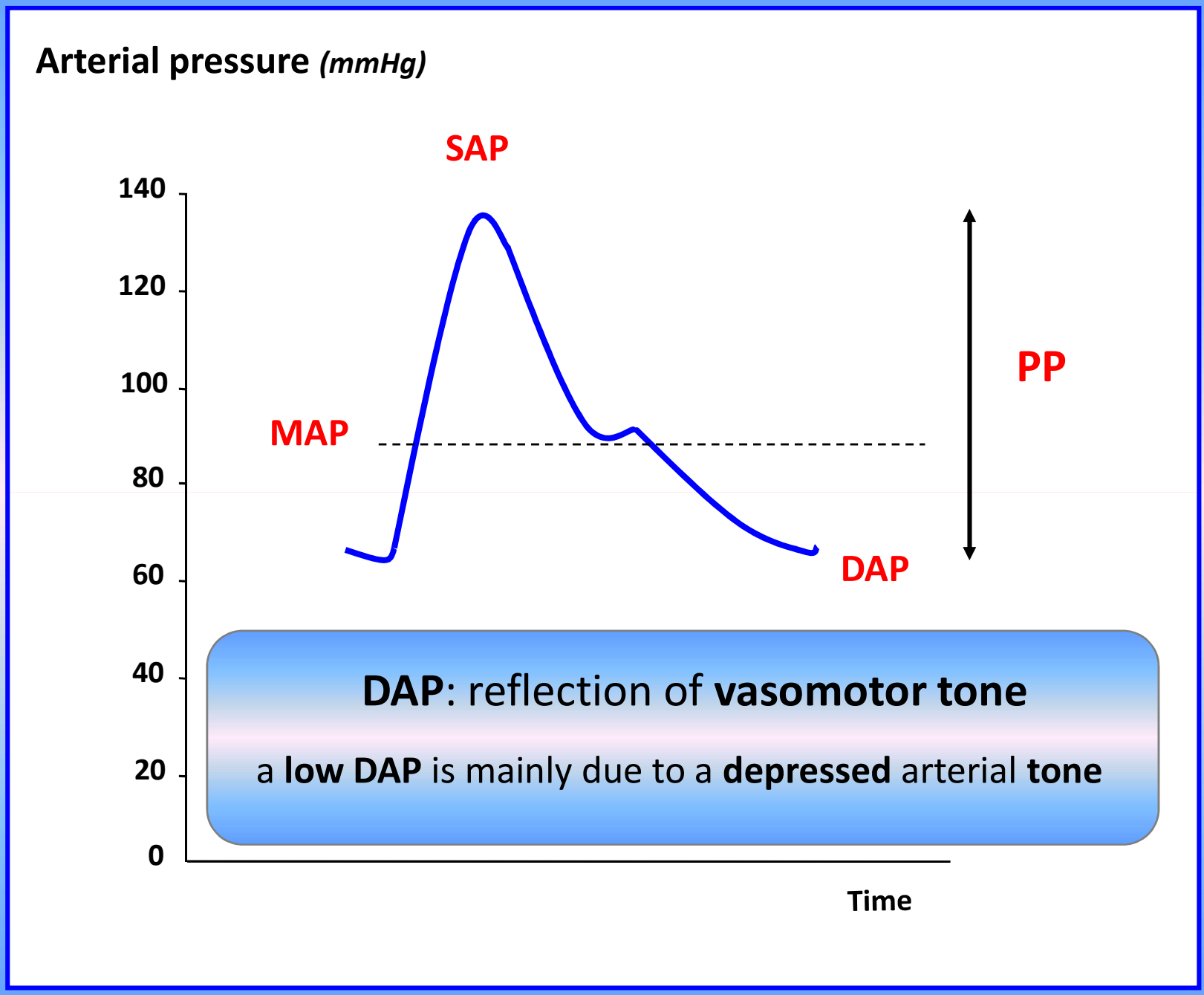


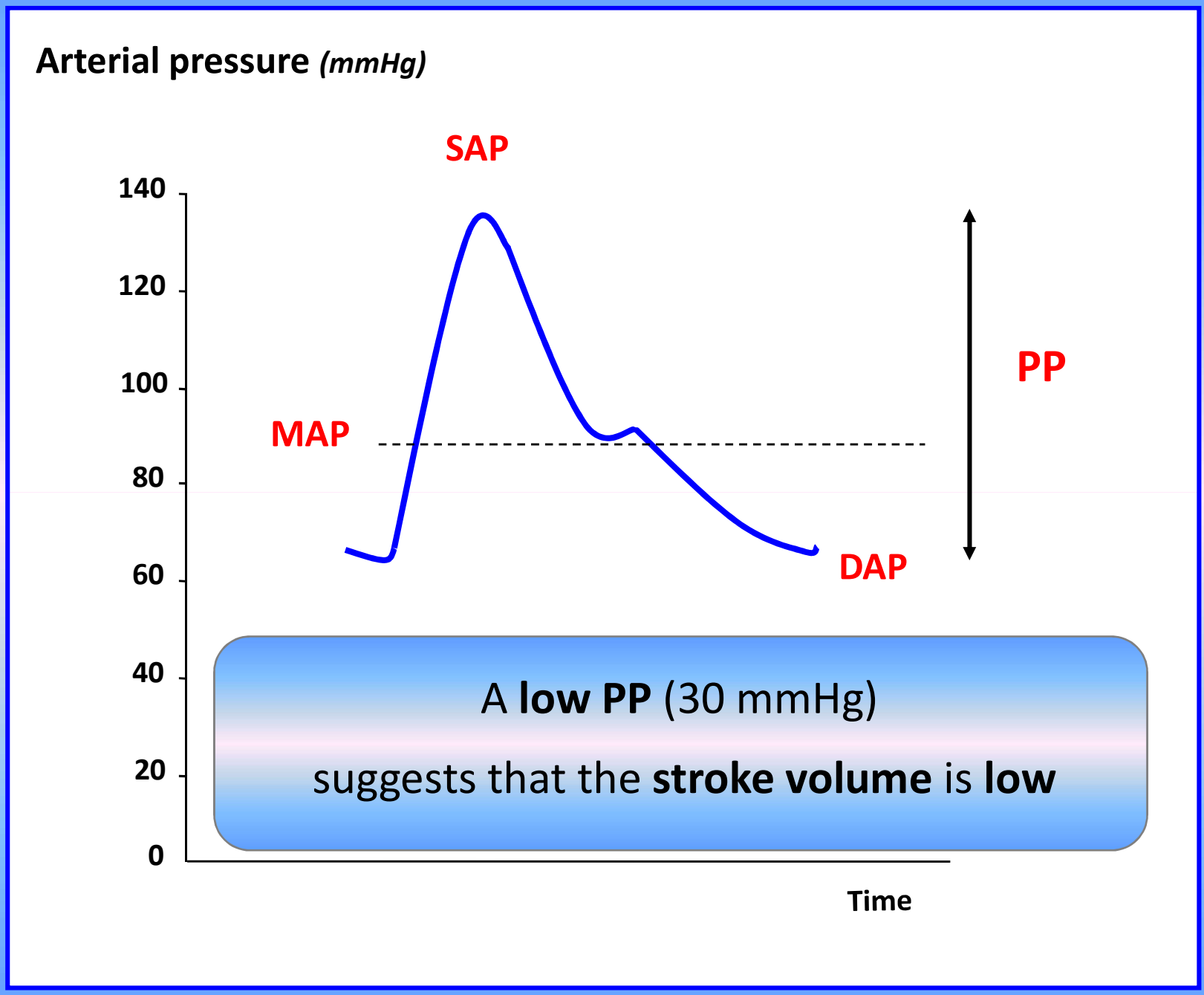
Arterial pressure ***(mmHg)***

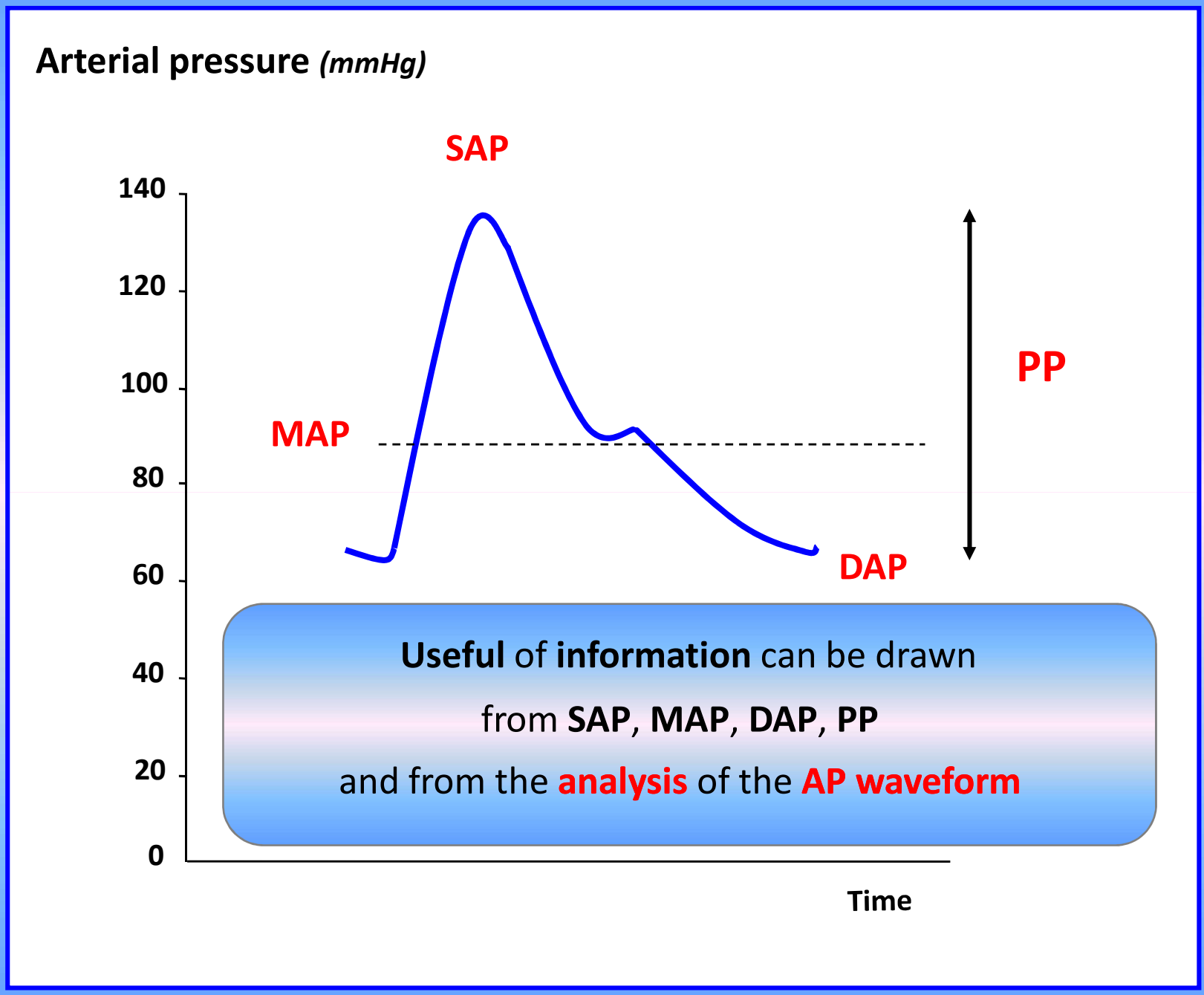


SAP: reflection of **LV afterload**


Arterial pressure (mmHg)
SAP
140
120
100
MAP
80
60
40
20
0
PP
DAP
MAP: important target for resuscitation
of patients with shock
Time


Arterial pressure (mmHg)
SAP
140
120
100
MAP
80
60
40
20
0
PP
DAP
Time
DAP: reflection of vasomotor tone
a low DAP is mainly due to a depressed arterial tone


Arterial pressure (mmHg)
SAP
140
120
100
MAP
80
60
40
20
0
PP
DAP
A low PP (30 mmHg)
suggests that the stroke volume is low
Time

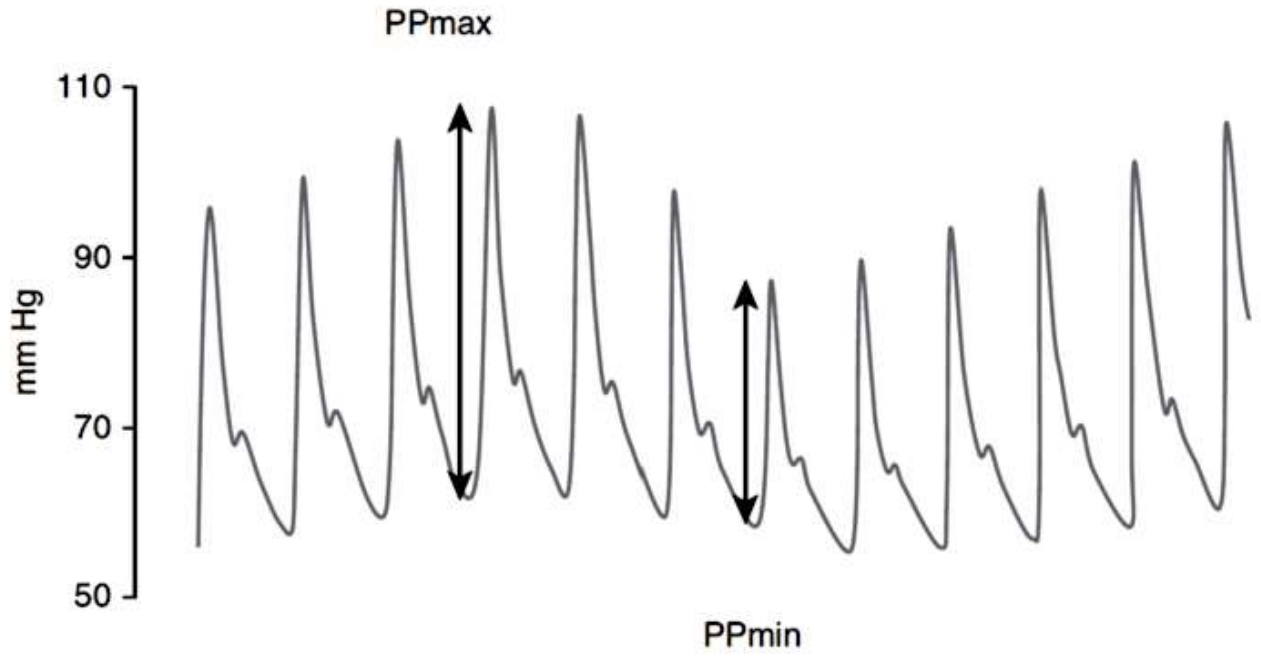

Arterial pressure (mmHg)
SAP
140
120
100
MAP
80
60
40
20
0
PP
DAP
Time
Useful of information can be drawn
from SAP, MAP, DAP, PP
and from the analysis of the AP waveform

Arterial Pulse Pressure Variation with Mechanical Ventilation

Jean-Louis Teboul[1], Xavier Monnet[1], Denis Chemla[2], and Frédéric Michard[3]

Am J Respir Crit Care Med Vol 199, Iss 1, pp 22–31, Jan 1, 2019

$$PPV = \frac{PPmax - PPmin}{(PPmax + PPmin) / 2}$$



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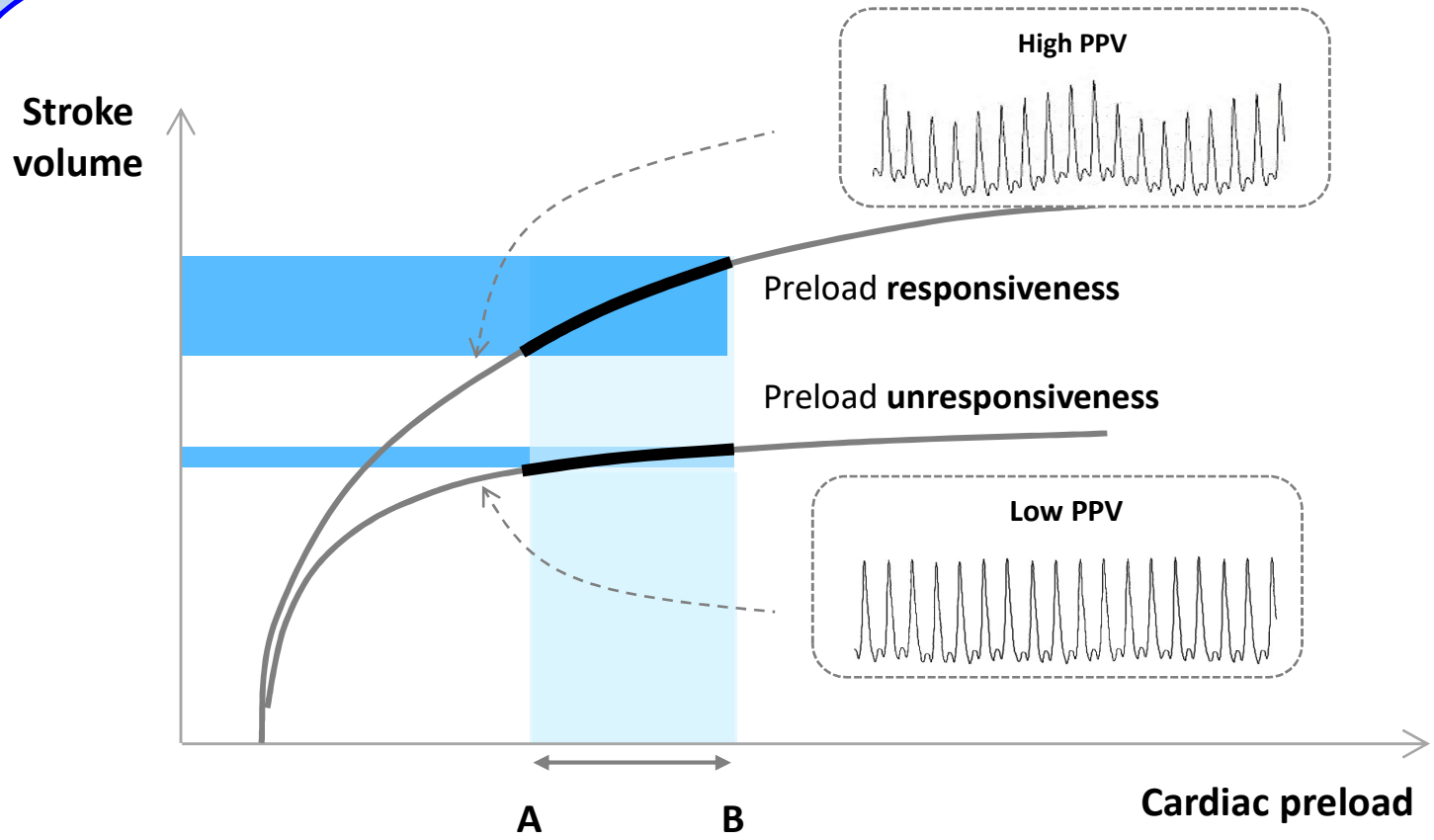
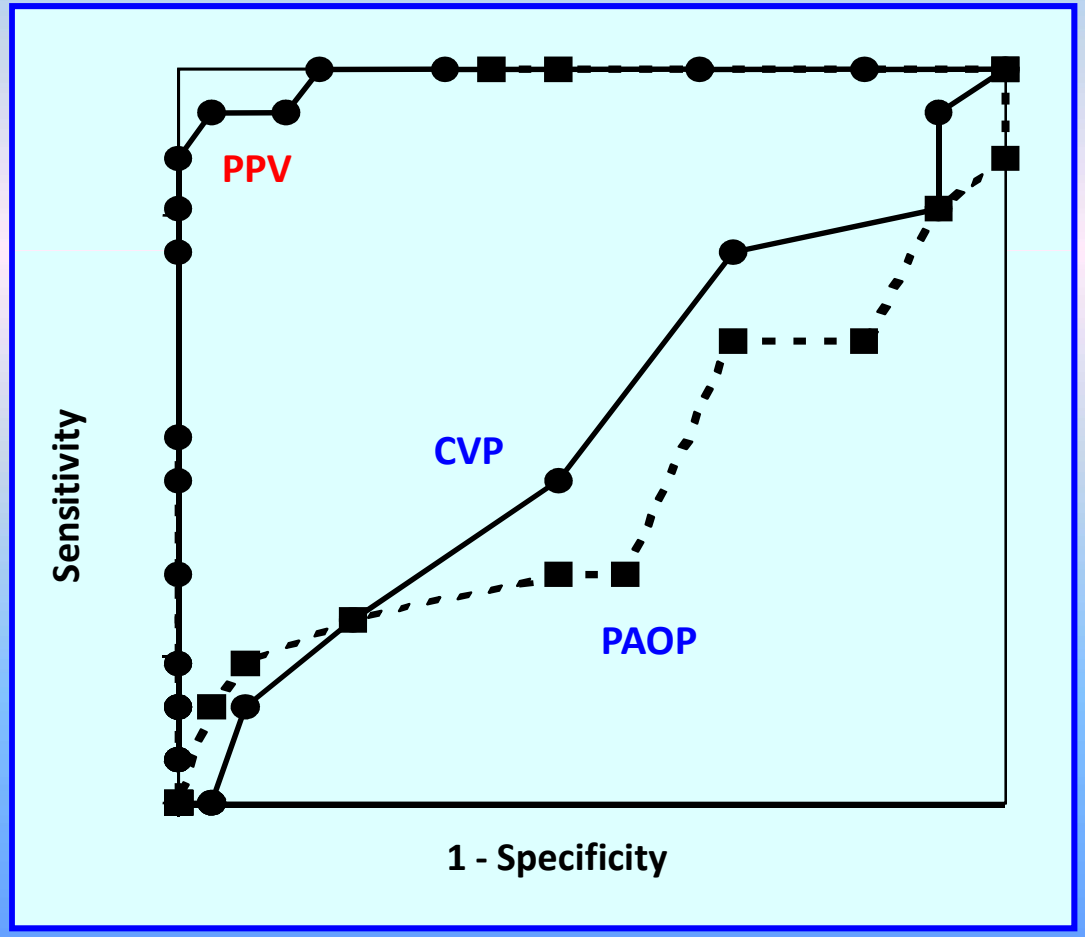


Relation between Respiratory Changes in Arterial Pulse Pressure and Fluid Responsiveness in Septic Patients with Acute Circulatory Failure

FRÉDÉRIC MICHARD, SANDRINE BOUSSAT, DENIS CHEMLA, NADIA ANGUEL, ALAIN MERCAT, YVES LECARPENTIER, CHRISTIAN RICHARD, MICHAEL R. PINSKY, and JEAN-LOUIS TEBOUL

Am J Respir Crit Care Med 2000; 162:134-8



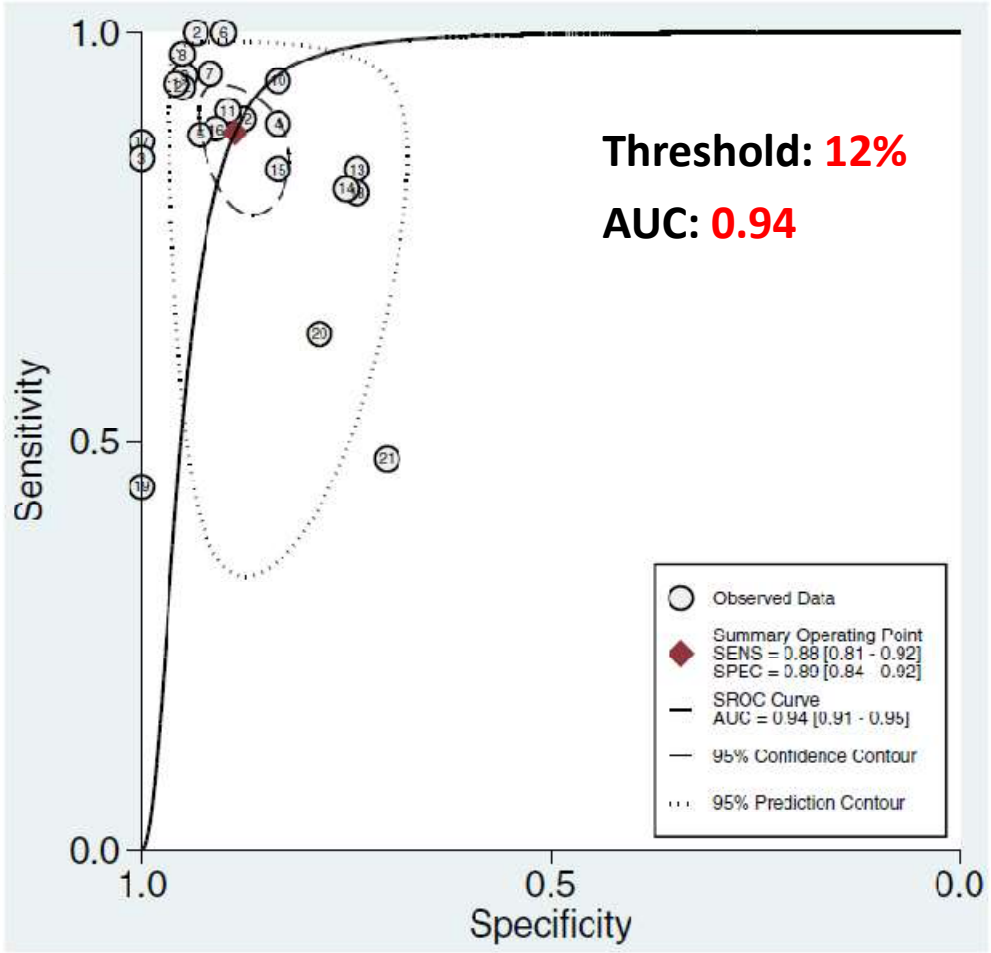
22 studies

Does pulse pressure variation predict fluid responsiveness in critically ill patients? A systematic review and meta-analysis

Xiaobo Yang and Bin Du*

Critical Care 2014, **18**:650

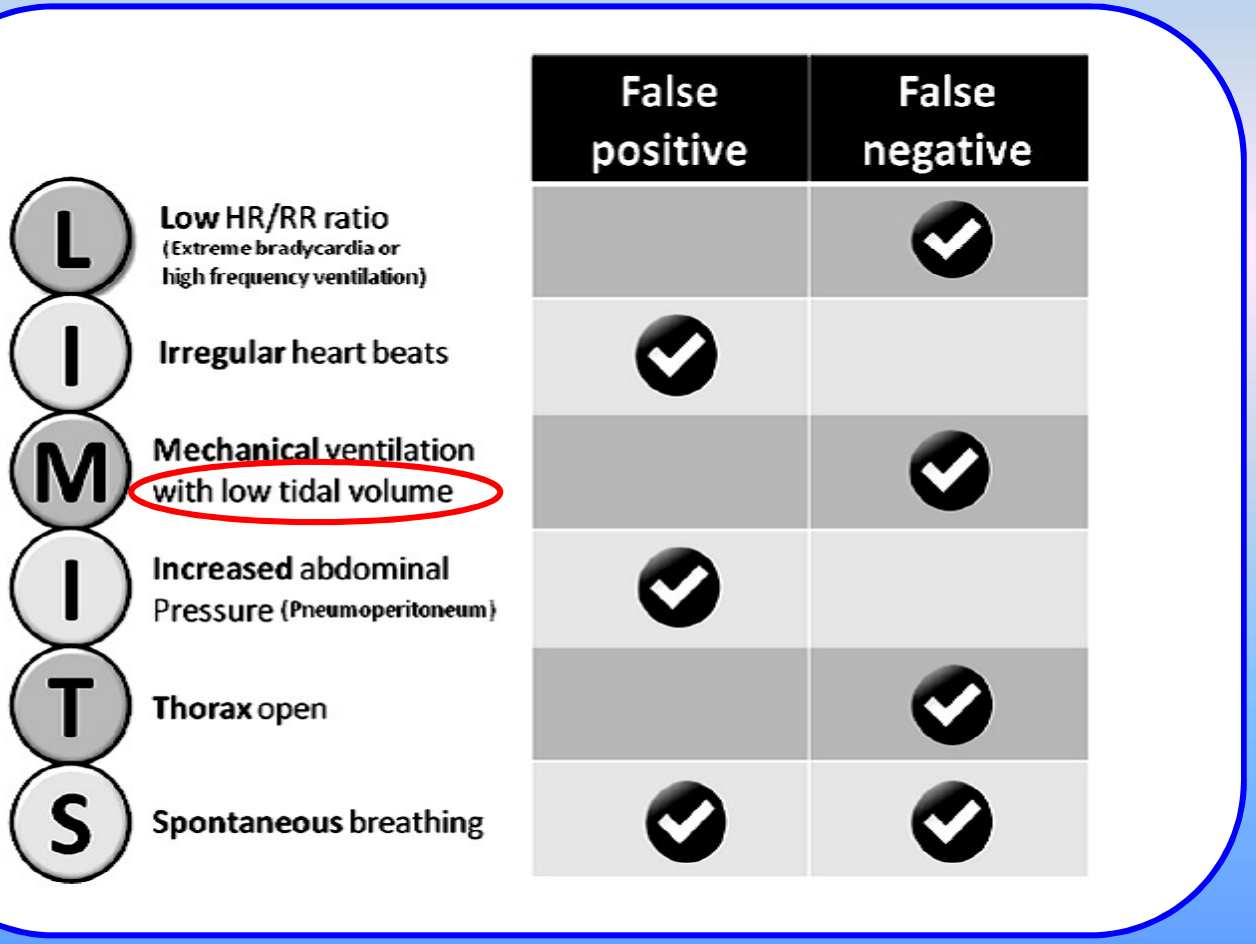
807 pts



Applicability of pulse pressure variation: how many shades of grey?

Frederic Michard[1*], Denis Chemla[2] and Jean-Louis Teboul[3]

Critical Care (2015) 19:144



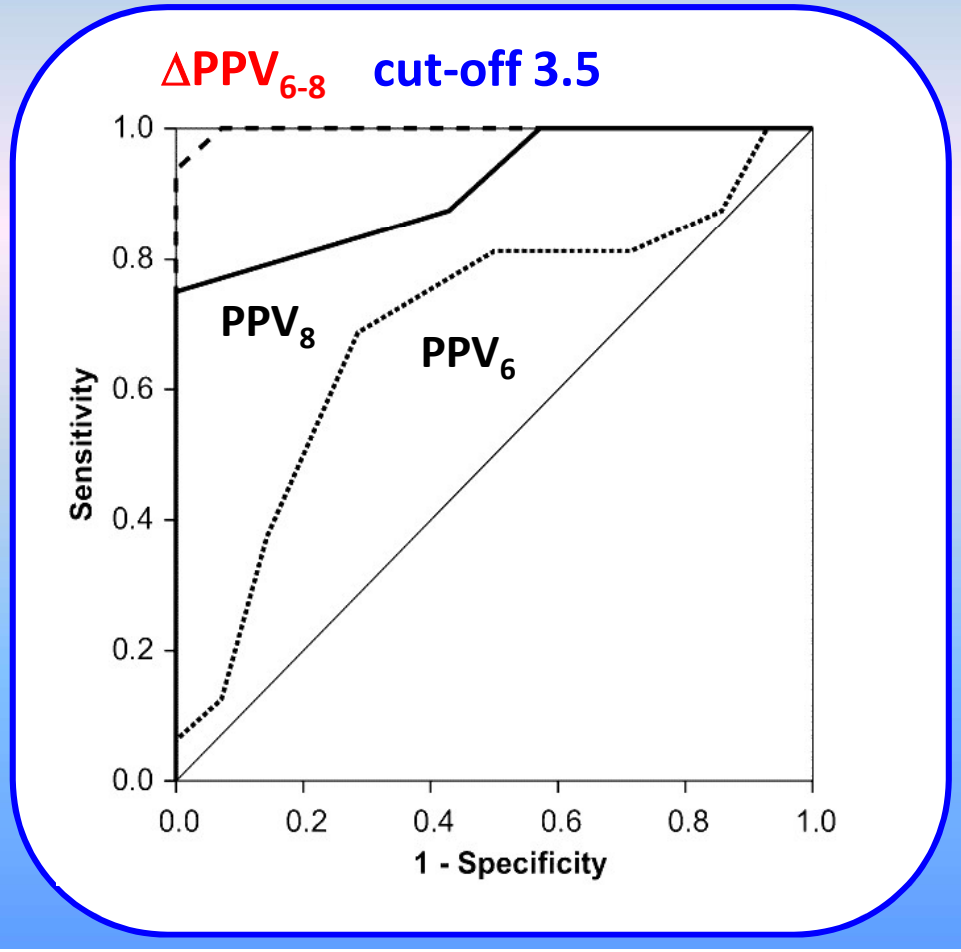
Crit Care Med 2017; 45:415–421

Tidal volume challenge

Transient (1 min) **increase**

in **tidal volume**

from **6** to **8 mL/kg**

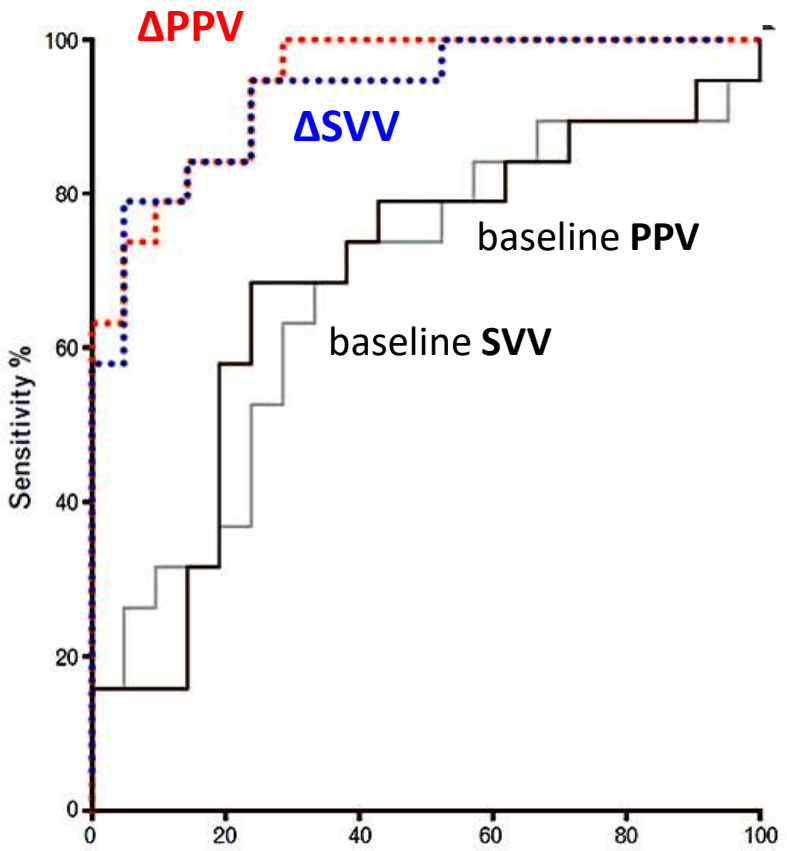


Tidal volume challenge to predict fluid responsiveness in the operating room

A prospective trial on neurosurgical patients undergoing protective ventilation

Antonio Messina, Claudia Montagnini, Gianmaria Cammarota, Silvia De Rosa, Fabiana Giuliani, Lara Muratore, Francesco Della Corte, Paolo Navalesi and Maurizio Cecconi

Eur J Anaesthesiol 2019; **36:**1–9



ΔPPV = **increase** in **PPV** during **TVC**

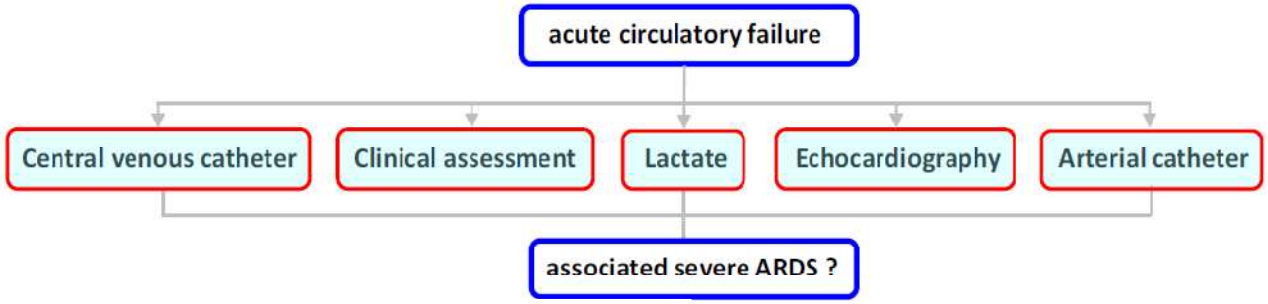
ΔSVV = **increase** in **SVV** during **TVC**

Intensive Care Med (2016) 42:1350–1

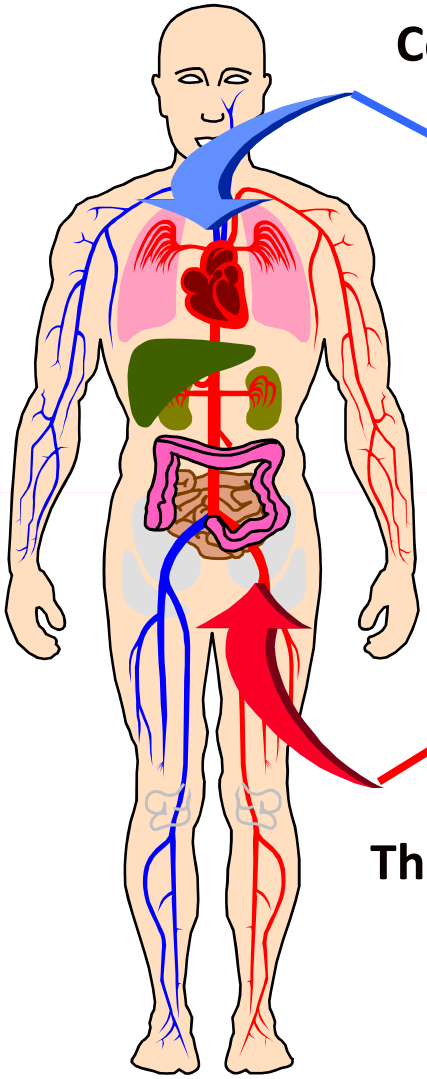
CONFERENCE REPORTS AND EXPERT PANEL

Less invasive hemodynamic monitoring in critically ill patients

[illegible]



Central Venous Catheter *(cold bolus injection)*



Thermodilution femoral arterial catheter

Transpulmonary thermodilution

→ **Intermittent** cardiac output

Pulse contour analysis

→ **Continuous** cardiac output

Transpulmonary thermodilution

systems are not just

CO monitoring systems

REVIEW

Transpulmonary thermodilution: advantages and limits

Xavier Monnet[1,2,3*] and Jean-Louis Teboul[1,2]

Critical Care (2017) 21:147

GEDV

a measure of global

cardiac preload

REVIEW

Transpulmonary thermodilution: advantages and limits

Xavier Monnet[1,2,3*] and Jean-Louis Teboul[1,2]

Critical Care (2017) 21:147

CFI and GEF

markers of

global systolic function

REVIEW

Transpulmonary thermodilution: advantages and limits

Xavier Monnet[1,2,3*] and Jean-Louis Teboul[1,2]

Critical Care (2017) 21:147

EVLW

quantitative measure

of pulmonary edema

Ann. Intensive Care (2015) 5:38

Annals of Intensive Care
a SpringerOpen Journal

REVIEW Open Access

Extravascular lung water in critical care: recent advances and clinical applications

Mathieu Jozwiak[1,2,3*], Jean-Louis Teboul[1,2,3] and Xavier Monnet[1,2,3]

	Study	Number of patients	Prognostic value
General critically ill patients	Sakka et al. [4]	373	Independent predictor of ICU mortality
Severe sepsis or septic shock patients	Martin et al. [3]	29	Higher EVLWI in ICU non-survivors
	Chung et al. [75]	33	Independent predictor of in-hospital survival
	Chung et al. [76]	67	Independent factor for the development of MODS
	Chew et al. [73]	51	Higher EVLWI in ICU non-survivors
	Mallat et al. [78]	55	Independent predictor of ICU mortality
ARDS patients	Philips [85]	59	Good predictor of ICU mortality
	Craig et al. [45]	44	Independent predictor of ICU mortality
	Brown et al. [37]	59	Independent predictor of ICU mortality
	Jozwiak et al. [36]	200	Independent predictor of Day-28 mortality

REVIEW

Transpulmonary thermodilution: advantages and limits

Xavier Monnet[1,2,3*] and Jean-Louis Teboul[1,2]

Critical Care (2017) 21:147

PVPI

measure of

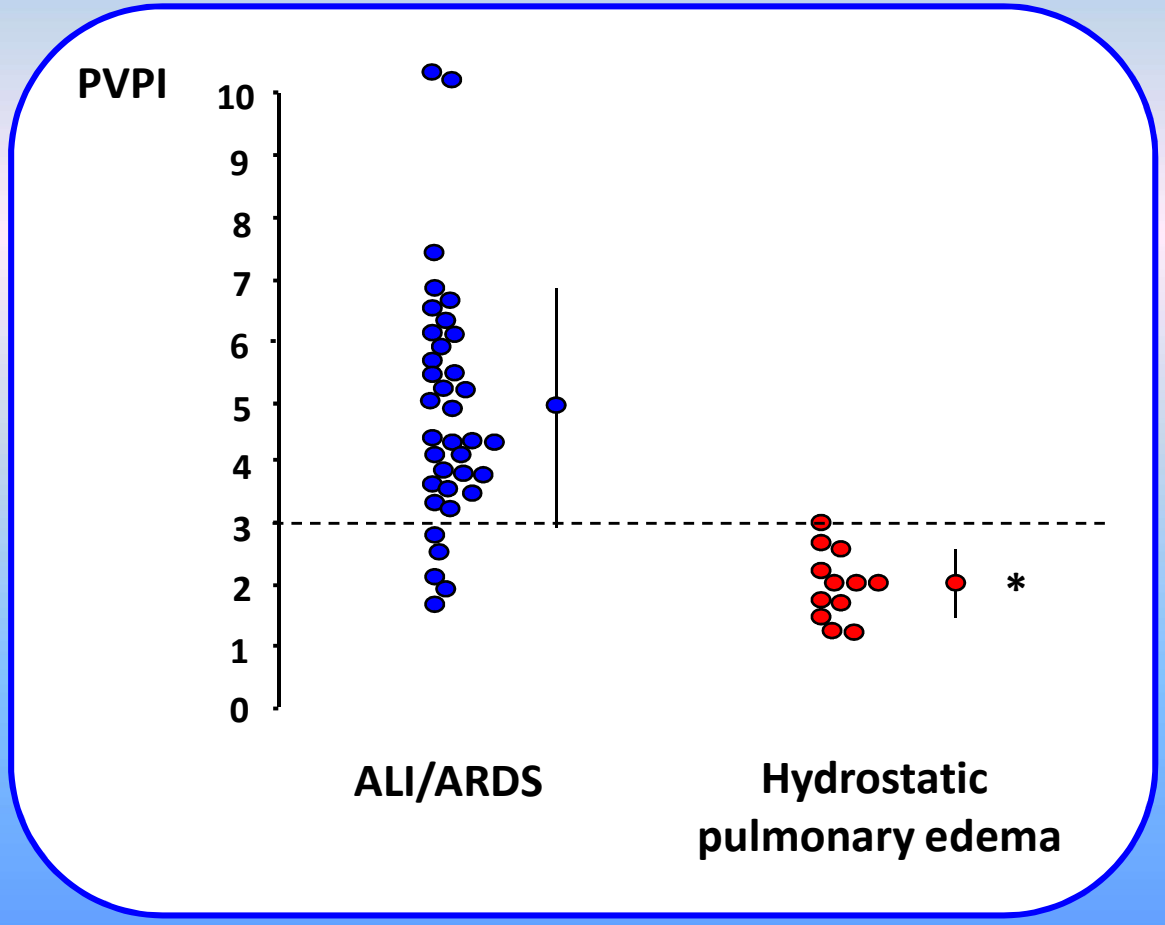
lung capillary leak

Intensive Care Med (2007) 33:448–453

ORIGINAL

Xavier Monnet
Nadia Anguel
David Osman
Olfa Hamzaoui
Christian Richard
Jean-Louis Teboul

Assessing pulmonary permeability by transpulmonary thermodilution allows differentiation of hydrostatic pulmonary edema from ALI/ARDS



cut-off value = 3

Se = 85 %
Sp = 100 %

Extravascular Lung Water is an Independent Prognostic Factor in Patients with Acute Respiratory Distress Syndrome

Mathieu Jozwiak, MD; Serena Silva, MD; Romain Persichini, MD; Nadia Anguel, MD; David Osman, MD; Christian Richard, MD; Jean-Louis Teboul, MD, PhD; Xavier Monnet, MD, PhD

Crit Care Med 2013;41:472–480

PVPI is an independent predictor of mortality in ARDS patients

200 pts

	Odds Ratio (CI 95%)		p value
Maximal blood lactate	1.27	(1.12 - 1.45)	0.0002
Mean PEEP	0.78	(0.67 – 0.91)	0.002
Minimal PaO_2 / FiO_2	0.98	(0.97 - 0.99)	0.0009
SAPS II	1.03	(1.01 - 1.05)	0.008
$PVPI_{max}$	1.07	(1.02 - 1.12)	0.03
Mean fluid balance	1.0004	(1.0000 – 1.0007)	0.03

D_{28} mortality 54%

REVIEW

Transpulmonary thermodilution: advantages and limits

Xavier Monnet[1,2,3*] and Jean-Louis Teboul[1,2]

Critical Care (2017) 21:147

Continuous cardiac output (CCO)

Useful for performing **diagnostic** and **therapeutic tests**

(**PLR**, **fluid challenge**, etc…)

REVIEW

Transpulmonary thermodilution: advantages and limits

Xavier Monnet[1,2,3*] and Jean-Louis Teboul[1,2]

Critical Care (2017) 21:147

SVV and PPV

for guiding

fluid administration

Transpulmonary thermodilution systems

Useful for guiding fluid management

especially in patients with ARDS and septic shock

Fluid infusion benefit / risk ratio

- What to do when **PPV** or **SVV** are **not interpretable**?
- **EVLW** and **PVPI** for assessing **lung tolerance** to fluid infusion

⟹ **decision**

- **to start**
- **to continue** **fluid infusion**
- **to stop**

Intensive Care Med (2008) 34:659–663

CLINICAL COMMENTARY

Xavier Monnet
Jean-Louis Teboul

Passive leg raising

transfer of blood
from the legs and abdominal
compartments

PLR mimics fluid challenge

The hemodynamic response to PLR

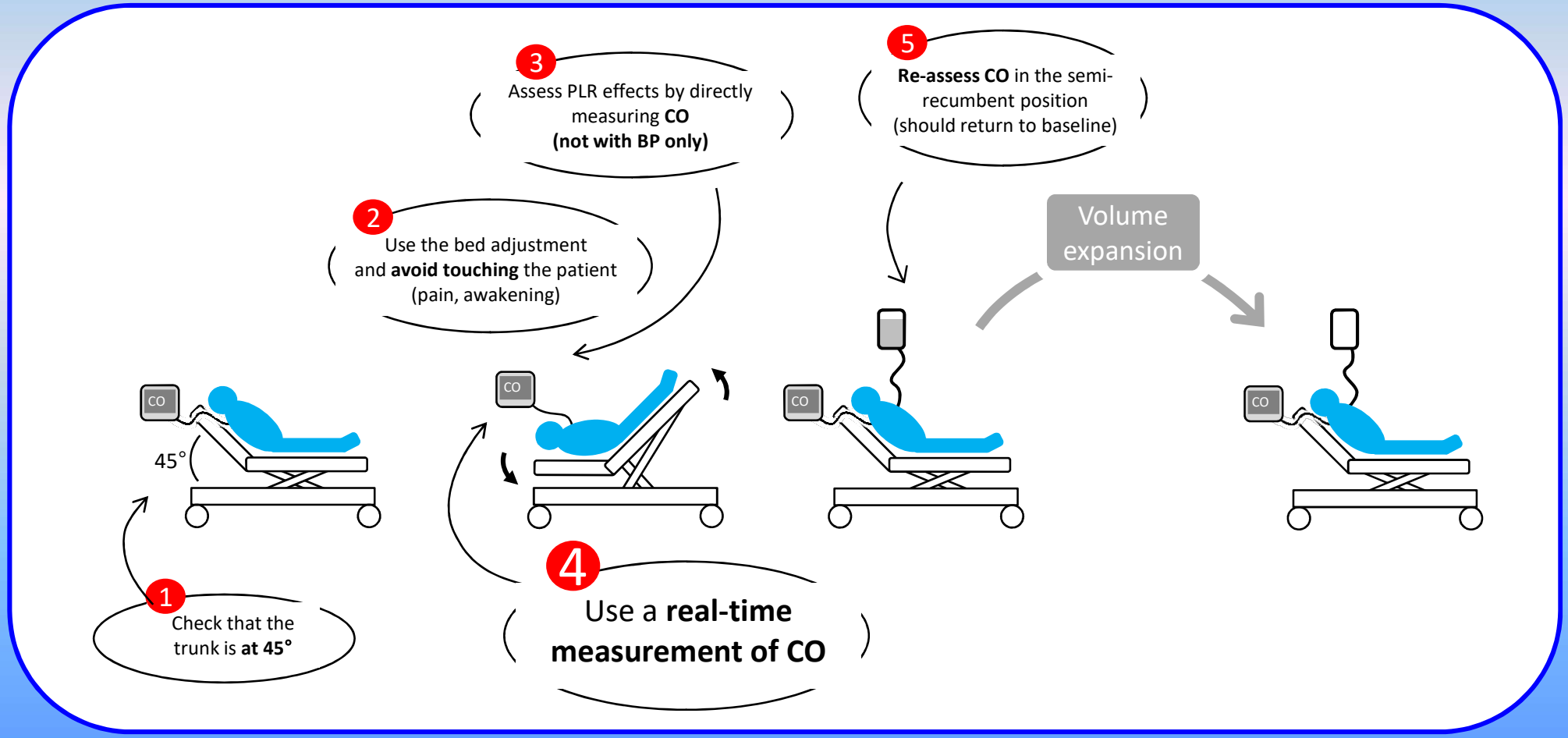
can predict the hemodynamic response to volume infusion

EDITORIAL

Passive leg raising: five rules, not a drop of fluid!

Xavier Monnet[1,2*] and Jean-Louis Teboul[1,2]

Crit Care 2015, 19:18



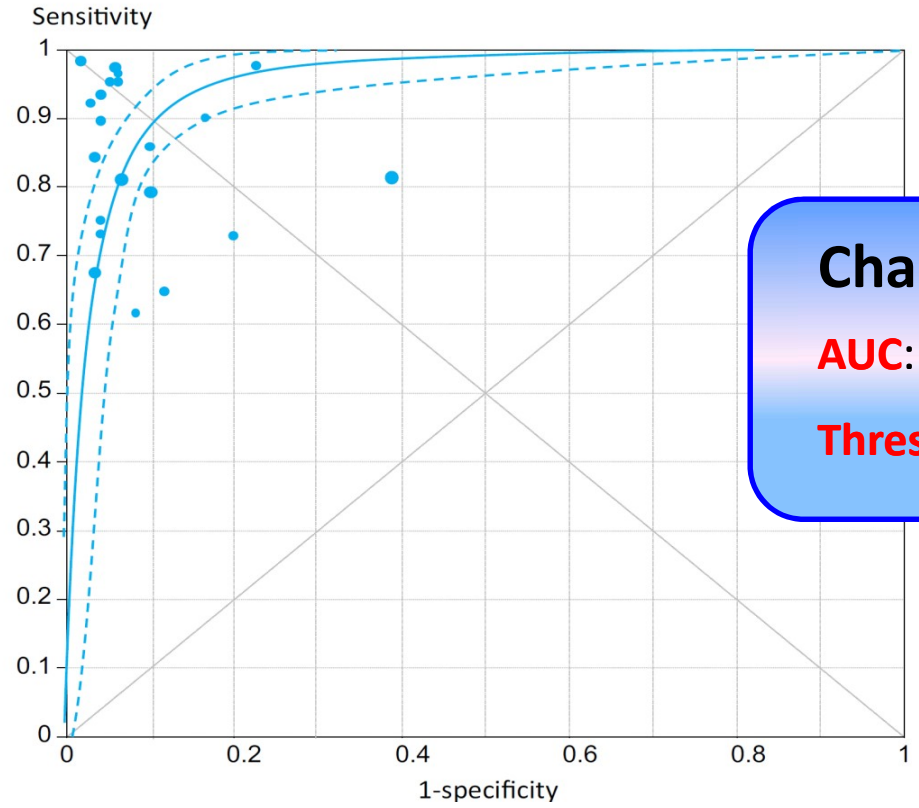
Intensive Care Med (2016) 42:1935–1947
DOI 10.1007/s00134-015-4134-1

ORIGINAL

Xavier Monnet
Paul Marik
Jean-Louis Teboul

Passive leg raising for predicting responsiveness: a systematic rev

21 ***clinical studies***



995 ***pts***

Changes in CO

AUC: 0.95 ± 0.01

Threshold: 10%

Transpulmonary thermodilution systems

Useful for guiding fluid management

especially in patients with ARDS and septic shock

Fluid infusion benefit / risk ratio

- **PPV** and **SVV**, if applicable
- **Pulse contour CO** response to PLR

} prediction of **fluid responsiveness**

- **EVLW** and **PVPI** for assessing **lung tolerance** to fluid infusion

⟹ **decision**

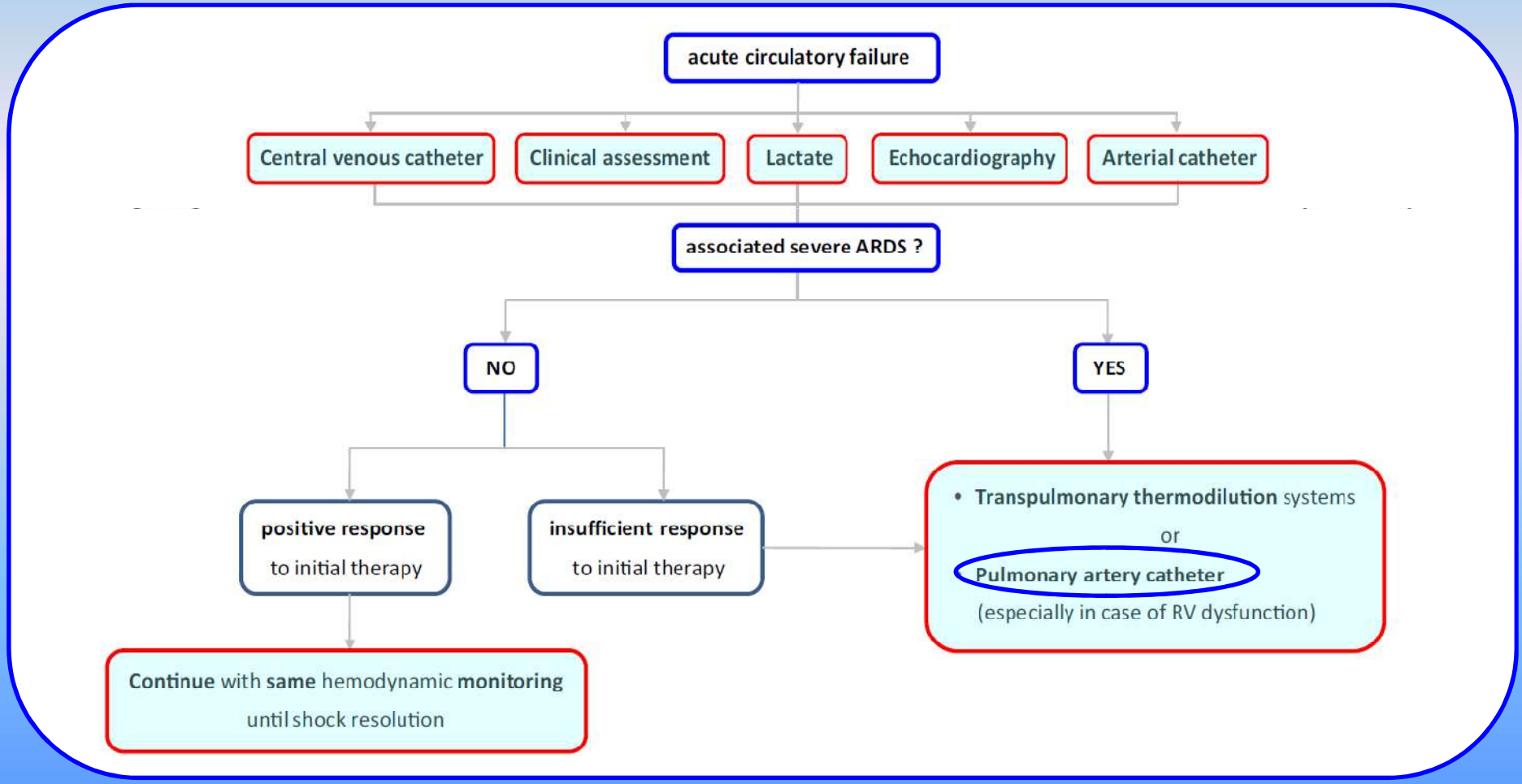
- **to start**
- **to continue** **fluid infusion**
- **to stop**

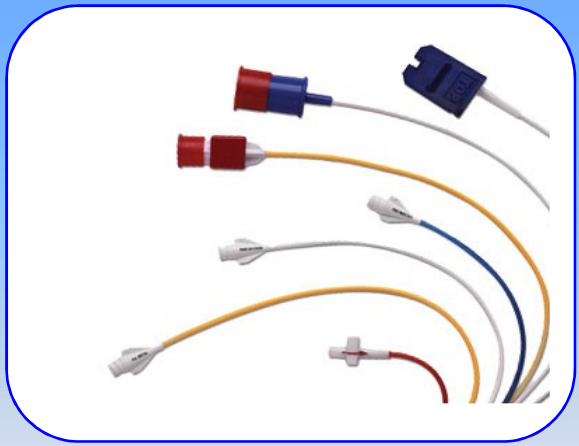
Intensive Care Med (2016) 42:1350–1

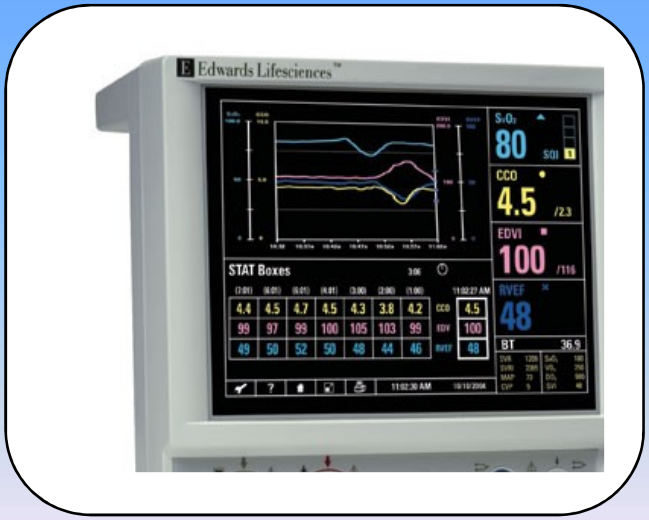
CONFERENCE REPORTS AND EXPERT PANEL

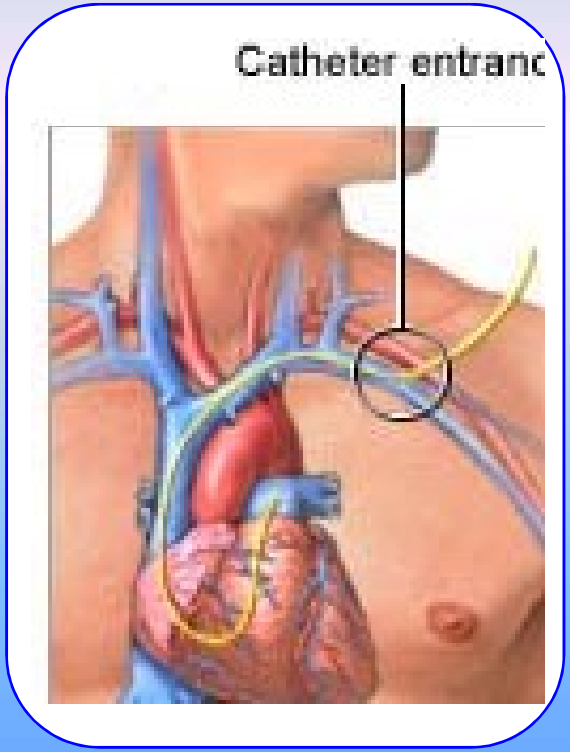
Less invasive hemodynamic monitoring in critically ill patients

[illegible]









Continuous CO and SvO_2 monitoring

+

Intermittent measurements of

RAP PAP PAOP

+

Intermittent calculation of

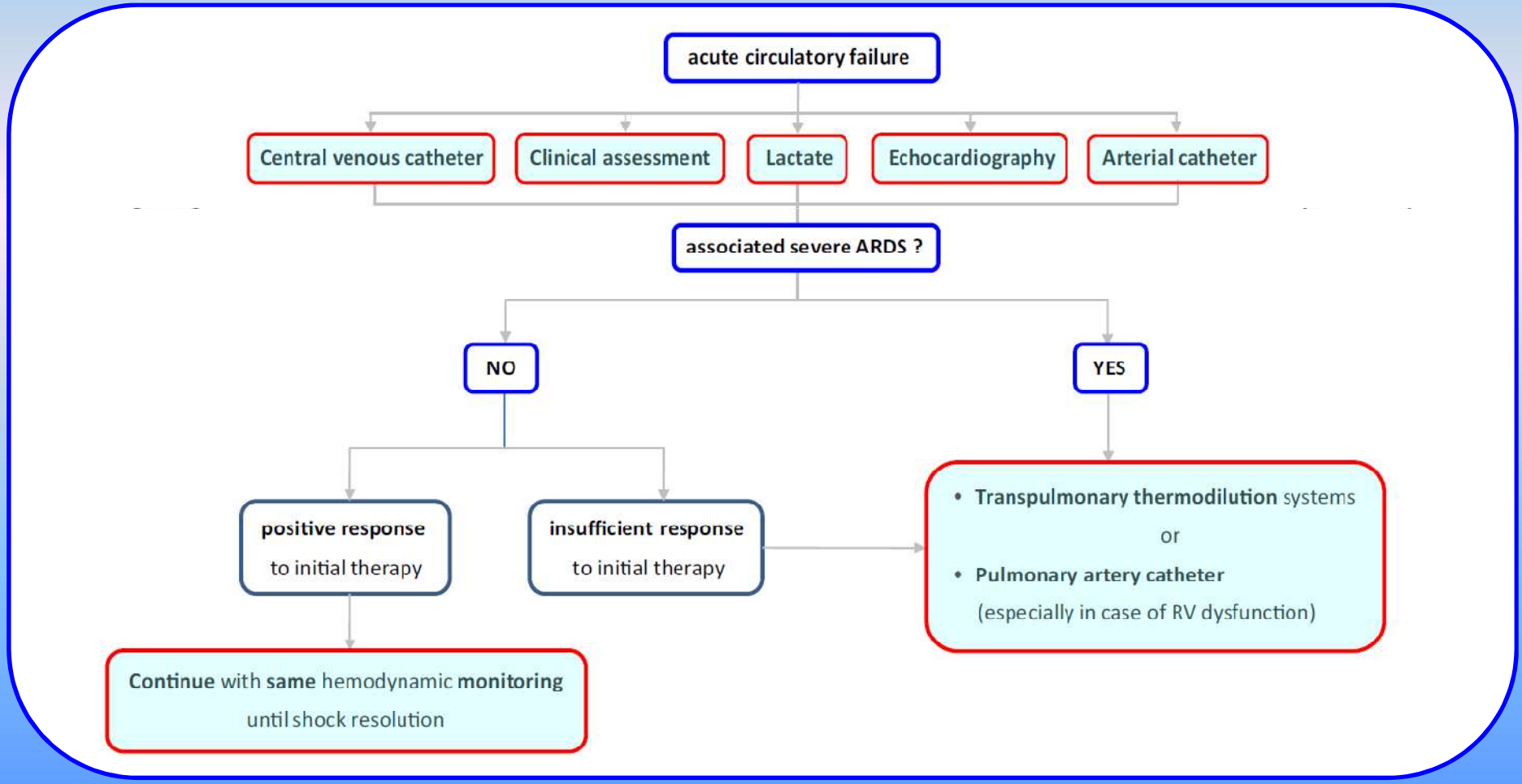
DO_2, VO_2, PCO_2 gap

Intensive Care Med (2016) 42:1350–1

CONFERENCE REPORTS AND EXPERT PANEL

Less invasive hemodynamic monitoring in critically ill patients

[illegible]



Available hemodynamic monitoring devices

- PAC 
- Transpulmonary thermodilution monitors

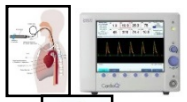
→ PiCCO

non invasive

→ Nexfin/Clearsight 

- **Doppler** methods

non invasive

→ esophageal Doppler 

→ echocardiography 

- Bioreactance 

non invasive

- Pulse wave transit time 

non invasive

Many devices, an abundant **literature** about their **validity**

… but in general **more suitable**

for the **OR** setting than for the ICU

Fluid resuscitation during early sepsis: a need for individualization

Mathieu JOZWIAK [1, 2], Olfa HAMZAOUI [3], Xavier MONNET [1, 2], Jean-Louis TEBOUL [1, 2] *

Minerva Anestesiologica 2018 August;84(8):987-92

Pt presenting with **septic shock**

Decrease infusion rate if:
. Worsening of tachypnea
. Fall in O_2 saturation

Infuse around **10 mL/kg** crystalloids within the **first hour**

Increase infusion rate if:
. Fluid losses
. Abdominal sepsis
. Mottling, ↗ CRT
. Low PP

Importance of **individualization** of the initial **fluid therapy**

Fluid resuscitation during early sepsis: a need for individualization

Mathieu JOZWIAK [1, 2], Olfa HAMZAOUI [3], Xavier MONNET [1, 2], Jean-Louis TEBOUL [1, 2] *

Minerva Anestesiologica 2018 August;84(8):987-92

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←

Infuse around **10 mL/kg** crystalloids within the **first hour**

→

Increase infusion rate if:
. Fluid losses
. Abdominal sepsis
. Mottling, ↗ CRT
. Low PP

+

Norepinephrine
if **DAP** is **low**

1) Does **shock persist**? → **clinical signs**, **lactate**

2) If **yes**, try to **optimize** the **macrocirculation**

Check if **MAP adequate**

If **MAP – CVP adequate**

yes **no**

DAP

Check if **DO_2** adequate to **VO_2**

1) Does **shock persist**? → **clinical signs**, **lactate**

2) If **yes**, try to **optimize** the **macrocirculation**

Check if **MAP adequate**

If **MAP – CVP adequate**

yes **no**

DAP

low **not low**

depressed Insufficient

arterial tone **CO**

Vasopressors

Check if **DO_2** adequate to **VO_2**

$ScvO_2$

1) Does **shock persist**? → **clinical signs, lactate**

2) If **yes**, try to **optimize** the **macrocirculation**

Check if **MAP adequate**

If **MAP – CVP adequate**

yes **no**

DAP

low **not low**

depressed **arterial tone**

Vasopressors

Insufficient **CO**

Check if **DO_2** adequate to **VO_2**

$ScvO_2$

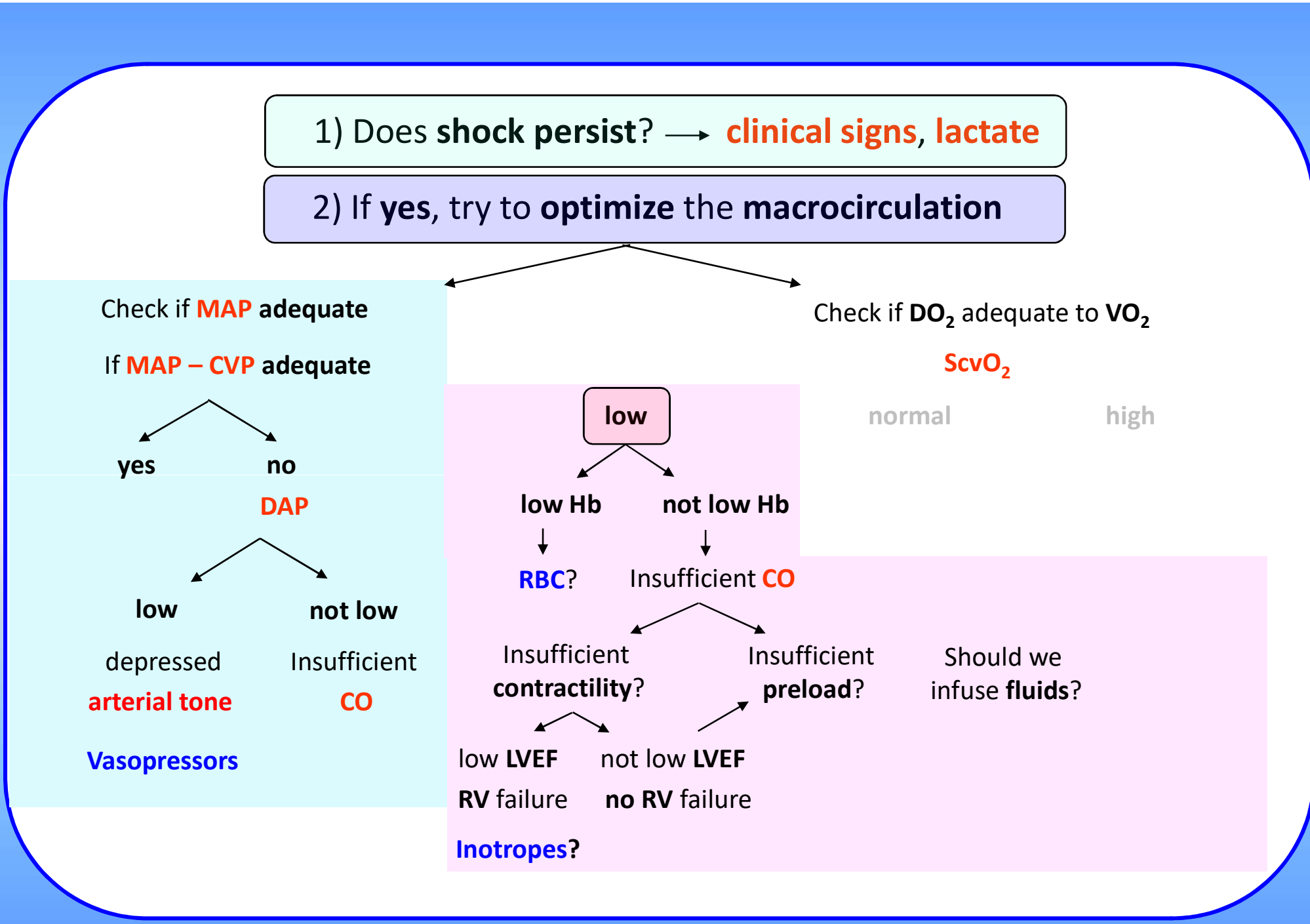
low **normal** **high**

Intensive Care Med (2016) 42:1350–1

CONFERENCE REPORTS AND EXPERT PANEL

Less invasive hemodynamic monitoring in critically ill patients

$ScvO_2$ is used as a surrogate of mixed venous blood oxygen saturation (SvO_2), which reflects in real time the balance between oxygen consumption and oxygen delivery. Hence, a low $ScvO_2$ may indicate insufficient global oxygen delivery in case of shock and incite one to increase it. However, there are situations where absolute values as well as dynamic changes of $ScvO_2$ and SvO_2 differ [65].


1) Does shock persist? → clinical signs, lactate
2) If yes, try to optimize the macrocirculation
Check if MAP adequate
If MAP – CVP adequate
yes
no
DAP
low
not low
depressed arterial tone
Vasopressors
Insufficient CO
Check if DO2 adequate to VO2
ScvO2
normal
high
low
low Hb
not low Hb
RBC?
Insufficient CO
Insufficient contractility?
Insufficient preload?
Should we infuse fluids?
low LVEF
RV failure
not low LVEF
no RV failure
Inotropes?

1) Does **shock persist**? → **clinical signs, lactate**

2) If **yes**, try to **optimize** the **macrocirculation**

Check if **MAP adequate**

If **MAP – CVP adequate**

yes **no**

DAP

low **not low**

depressed **arterial tone**

Vasopressors

Insufficient **CO**

Check if **DO_2** adequate to **VO_2**

$ScvO_2$

normal high

low

low Hb **not low Hb**

RBC?

Insufficient **CO**

Insufficient **contractility**?

low **LVEF**

RV failure

Insufficient **preload**?

not low **LVEF**

no RV failure

Inotropes?

preload responsiveness

dynamic variables

Intensive Care Med (2014) 40:1795–1815

CONFERENCE REPORTS AND EXPERT PANEL

Maurizio Cecconi
Daniel De Backer
Massimo Antonelli
Richard Beale
Jan Bakker
Christoph Hofer
Roman Jaeschke
Alexandre Mebazaa
Michael R. Pinsky
Jean Louis Teboul
Jean Louis Vincent
Andrew Rhodes

Consensus on circulatory shock and hemodynamic monitoring. Task force of the European Society of Intensive Care Medicine

We recommend using **dynamic** over static variables to predict **fluid responsiveness**, when applicable

CONFERENCE REPORTS AND EXPERT PANEL

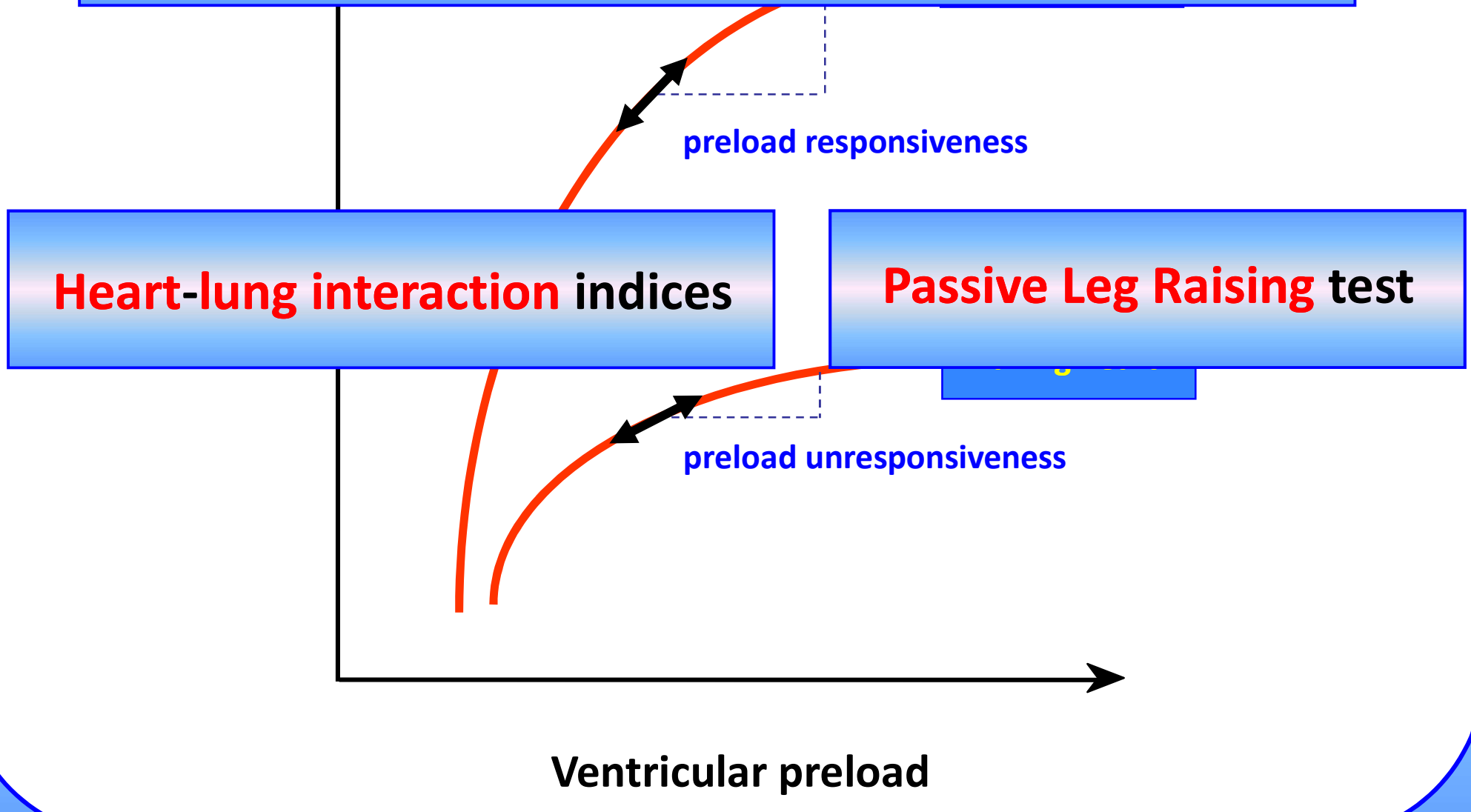
Surviving Sepsis Campaign: International Guidelines for Management of Sepsis and Septic Shock: 2016

Andrew Rhodes[1*], Laura E. Evans[2], Waleed Alhazzani[3], Mitchell M. Levy[4], Massimo Antonelli[5], Ricard Ferrer[6], Anand Kumar[7], Jonathan E. Sevransky[8], Charles L. Sprung[9], Mark E. Nunnally[2], Bram Rochwerg[3], Gordon D. Rubenfeld[10], Derek C. Angus[11], Djillali Annane[12], Richard J. Beale[13], Geoffrey J. Bellinghan[14], Gordon R. Bernard[15], Jean-Daniel Chiche[16], Craig Coopersmith[8], Daniel P. De Backer[17], Craig J. French[18], Seitaro Fujishima[19], Herwig Gerlach[20], Jorge Luis Hidalgo[21], Steven M. Hollenberg[22], Alan E. Jones[23], Dilip R. Karnad[24], Ruth M. Kleinpell[25], Younsuk Koh[26], Thiago Costa Lisboa[27], Flavia R. Machado[28], John J. Marini[29], John C. Marshall[30], John E. Mazuski[31], Lauralyn A. McIntyre[32], Anthony S. McLean[33], Sangeeta Mehta[34], Rui P. Moreno[35], John Myburgh[36], Paolo Navalesi[37], Osamu Nishida[38], Tiffany M. Osborn[31], Anders Perner[39], Colleen M. Plunkett[25], Marco Ranieri[40], Christa A. Schorr[22], Maureen A. Seckel[41], Christopher W. Seymour[42], Lisa Shieh[43], Khalid A. Shukri[44], Steven Q. Simpson[45], Mervyn Singer[46], B. Taylor Thompson[47], Sean R. Townsend[48], Thomas Van der Poll[49], Jean-Louis Vincent[50], W. Joost Wiersinga[49], Janice L. Zimmerman[51] and R. Phillip Dellinger[22]

Intensive Care Med (2017) 43:304–377

We suggest that **dynamic** over static variables be used to predict **fluid responsiveness**, when available

Dynamic indices of preload responsiveness



CONFERENCE REPORTS AND EXPERT PANEL

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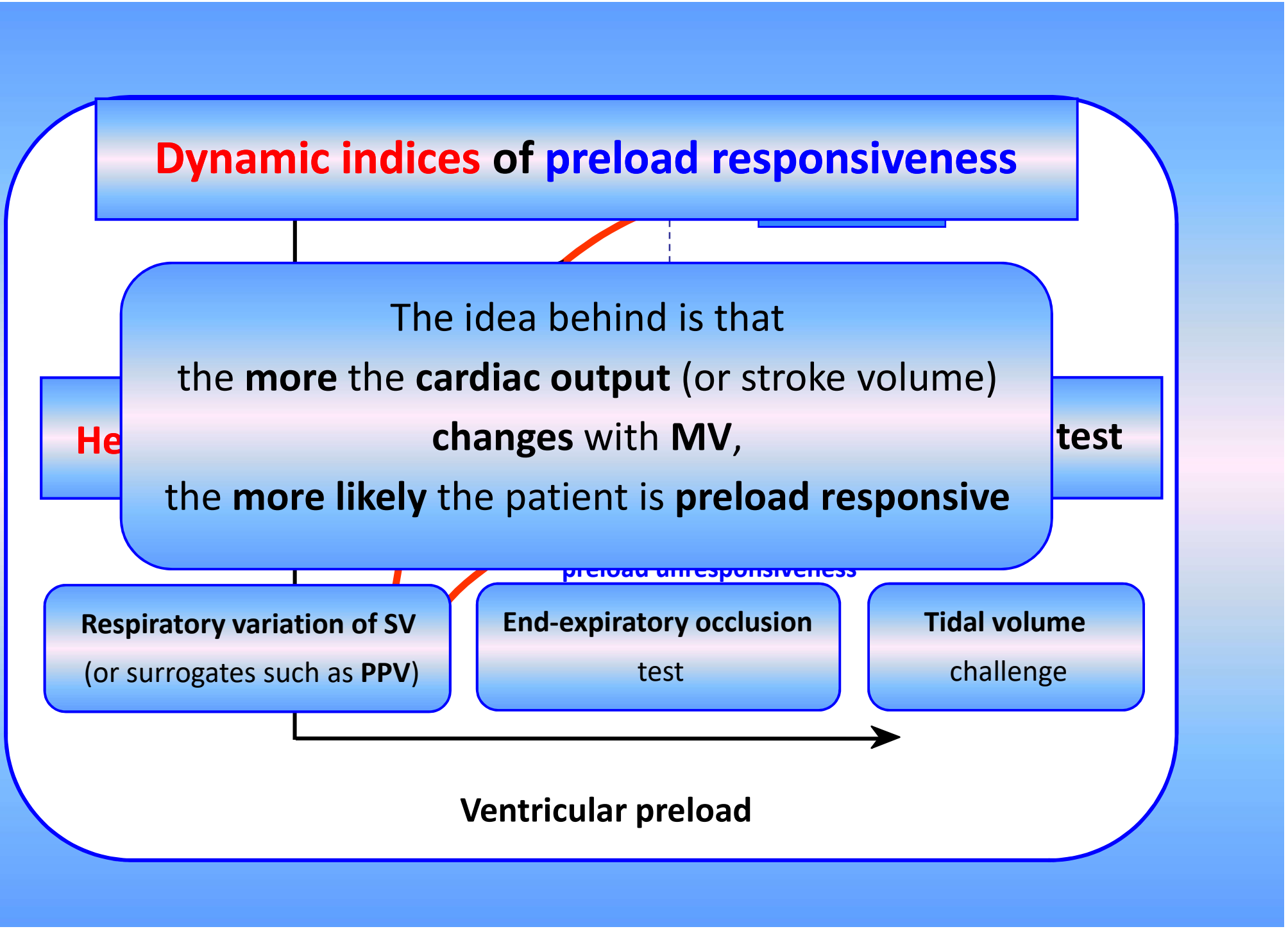
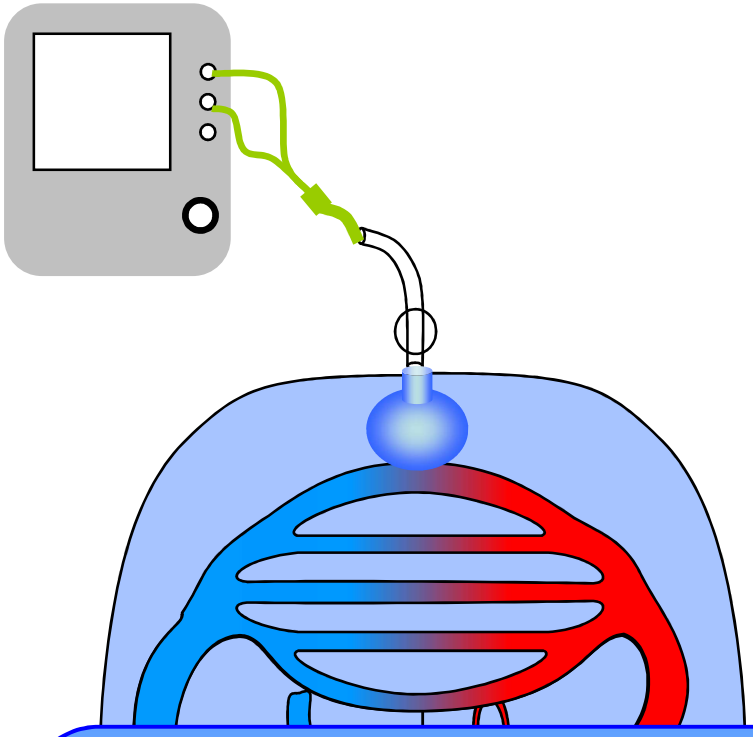
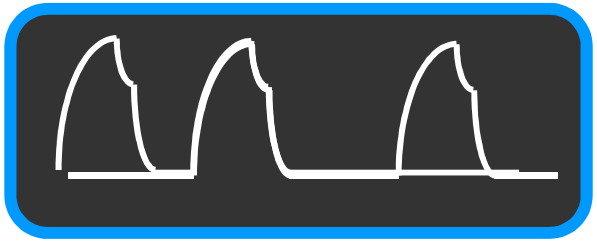
Intensive Care Med (2017) 43:304–377

We suggest that **dynamic** over **static** variables be used **to predict fluid responsiveness**, when available

Dynamic measures of assessing whether a patient requires additional fluid have been proposed in an effort to improve fluid management and have demonstrated better diagnostic accuracy at predicting those patients who are likely to respond to a fluid challenge by increasing stroke volume. These techniques encompass passive leg raises, fluid challenges against stroke volume measurements, or the variations in systolic pressure, pulse pressure, or stroke volume to changes in intrathoracic pressure induced by mechanical ventilation


Dynamic indices of preload responsiveness
The idea behind is that
the more the cardiac output (or stroke volume)
changes with MV,
the more likely the patient is preload responsive
He
test
preload unresponsiveness
Respiratory variation of SV
(or surrogates such as PPV)
End-expiratory occlusion
test
Tidal volume
challenge
Ventricular preload





End-expiratory occlusion

Tran

Fluid responders should be identified

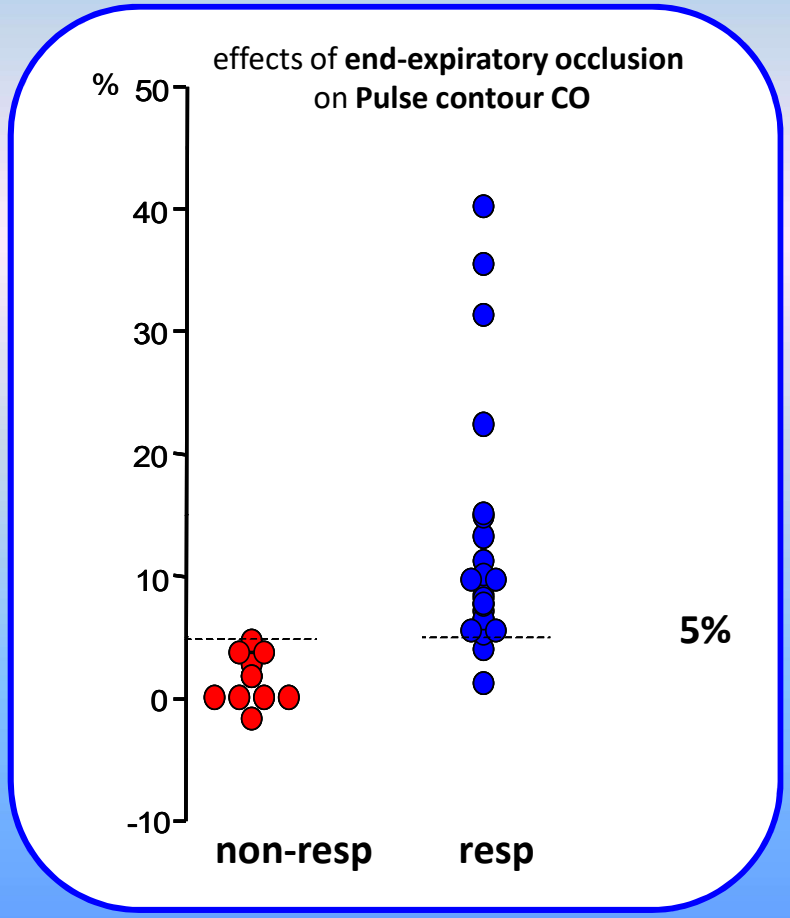
by an **increase** in their **CO**

during the **end-expiration occlusion** test

Predicting volume responsiveness by using the end-expiratory occlusion in mechanically ventilated intensive care unit patients

Xavier Monnet, MD, PhD; David Osman, MD; Christophe Ridel, MD; Bouchra Lamia, MD; Christian Richard, MD; Jean-Louis Teboul, MD, PhD

Crit Care Med 2009; 37:951–956



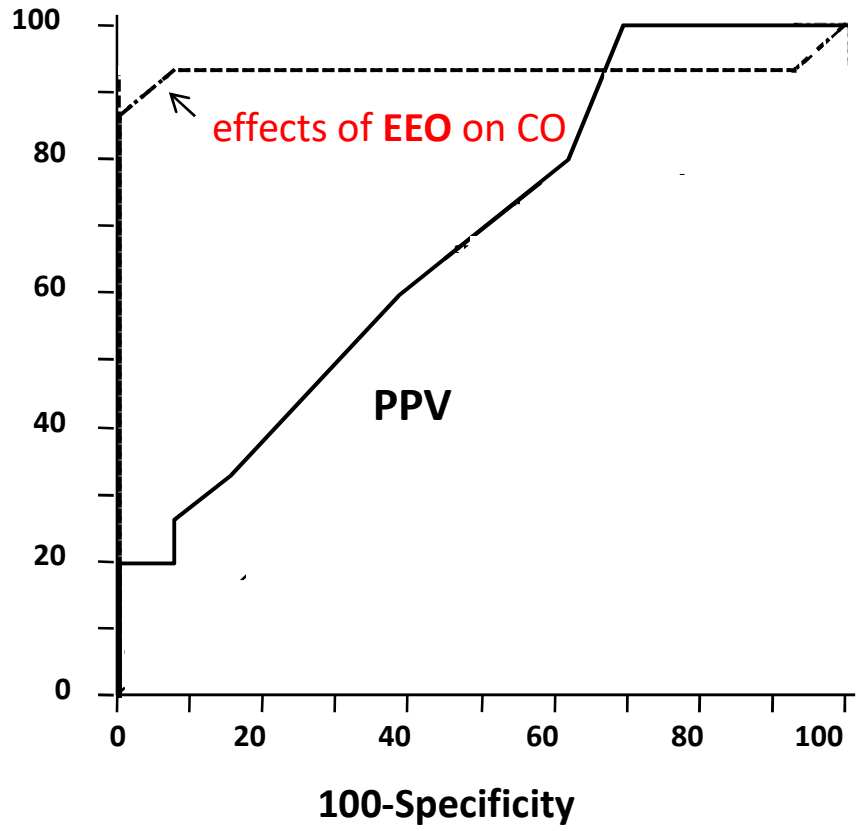
Passive leg-raising and end-expiratory occlusion tests perform better than pulse pressure variation in patients with low respiratory system compliance

Xavier Monnet, MD, PhD; Alexandre Bleibtreu, MD; Alexis Ferre, MD; Martin Dres, MD; Rim Gharbi, MD; Christian Richard, MD; Jean-Louis Teboul, MD, PhD

Crit Care Med 2012; 40:152–157

Respiratory system compliance

< 30 mL/cmH_2O

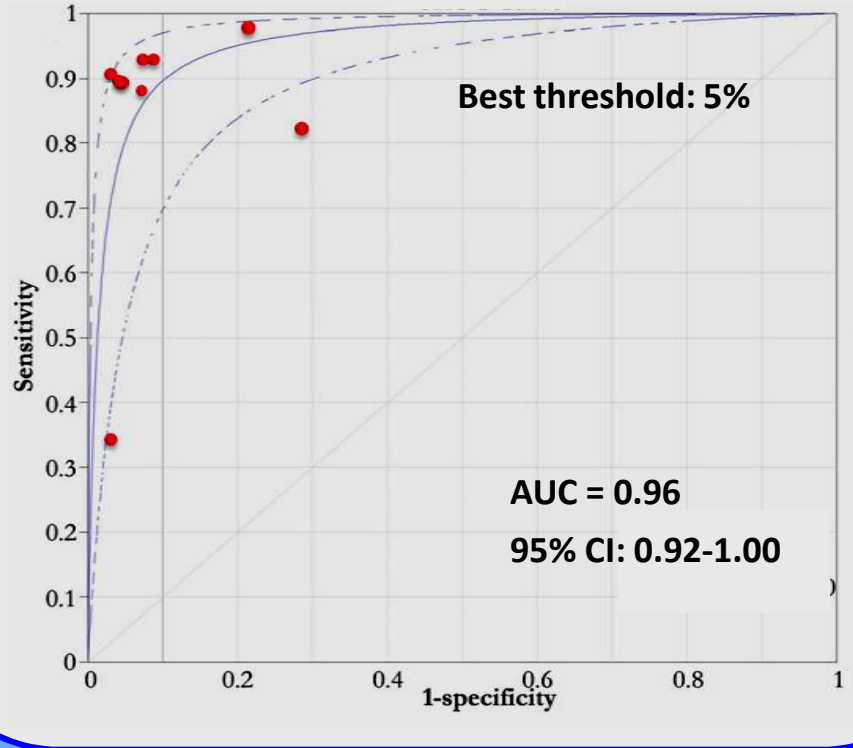


Functional hemodynamic tests: a systematic review and a metanalysis on the reliability of the end-expiratory occlusion test and of the mini-fluid challenge in predicting fluid responsiveness

Antonio Messina[1*], Antonio Dell'Anna[2,3], Marta Baggiani[4], Flavia Torrini[2,3], Gian Marco Maresca[2,3] Victoria Bennett[5], Laura Saderi[6], Giovanni Sotgiu[6], Massimo Antonelli[2,3] and Maurizio Cecconi[1,7]

Critical Care (2019) 23:264

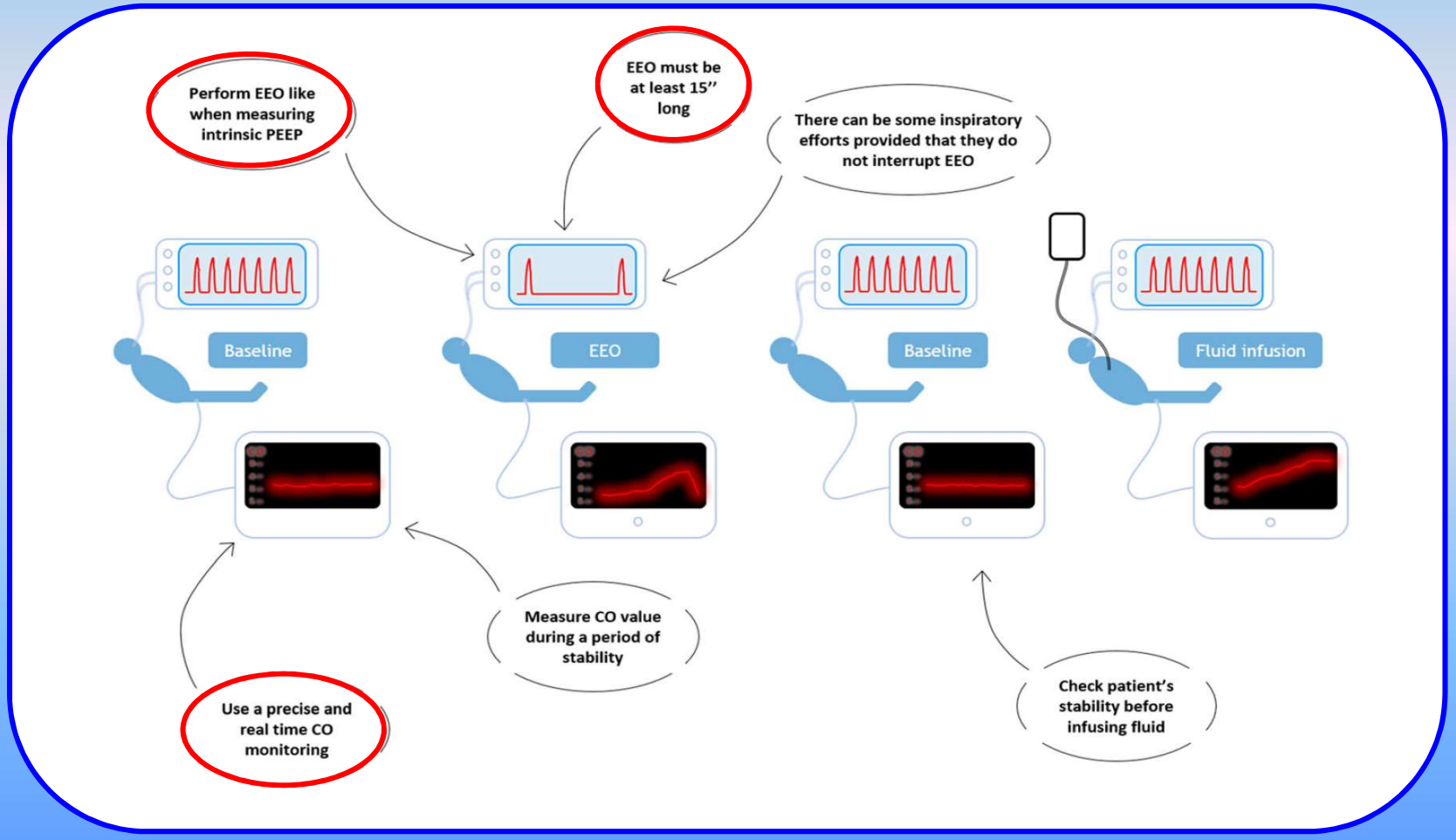
9 studies



The end-expiratory occlusion test: please, let me hold your breath!

Francesco Gavelli[1,2,3*], Jean-Louis Teboul[1,2] and Xavier Monnet[1,2]

Critical Care (2019) 23:274



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Check if **MAP adequate**

If **MAP – CVP adequate**

yes **no**

DAP

low **not low**

depressed **arterial tone**

Vasopressors

Insufficient **CO**

Check if **DO_2** adequate to **VO_2**

$ScvO_2$

normal high

low

low Hb **not low Hb**

RBC?

Insufficient **CO**

Insufficient **contractility**?

Insufficient **preload**?

low **LVEF**
RV failure

not low **LVEF**
no RV failure

Inotropes?

preload responsiveness
dynamic variables

if **ARDS**
PAOP or EVLW
safety parameters

1) Does **shock persist**? → **clinical signs, lactate**

2) If **yes**, try to **optimize** the **macrocirculation**

Check if **MAP adequate**

If **MAP – CVP adequate**

yes **no**

DAP

low **not low**

depressed **arterial tone**

Vasopressors

Insufficient **CO**

Check if **DO_2** adequate to **VO_2**

$ScvO_2$

normal high

low

low Hb **not low Hb**

RBC?

Insufficient **CO**

Insufficient **contractility**?

low **LVEF**

RV failure

Insufficient **preload**?

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Benefit

/

Risk

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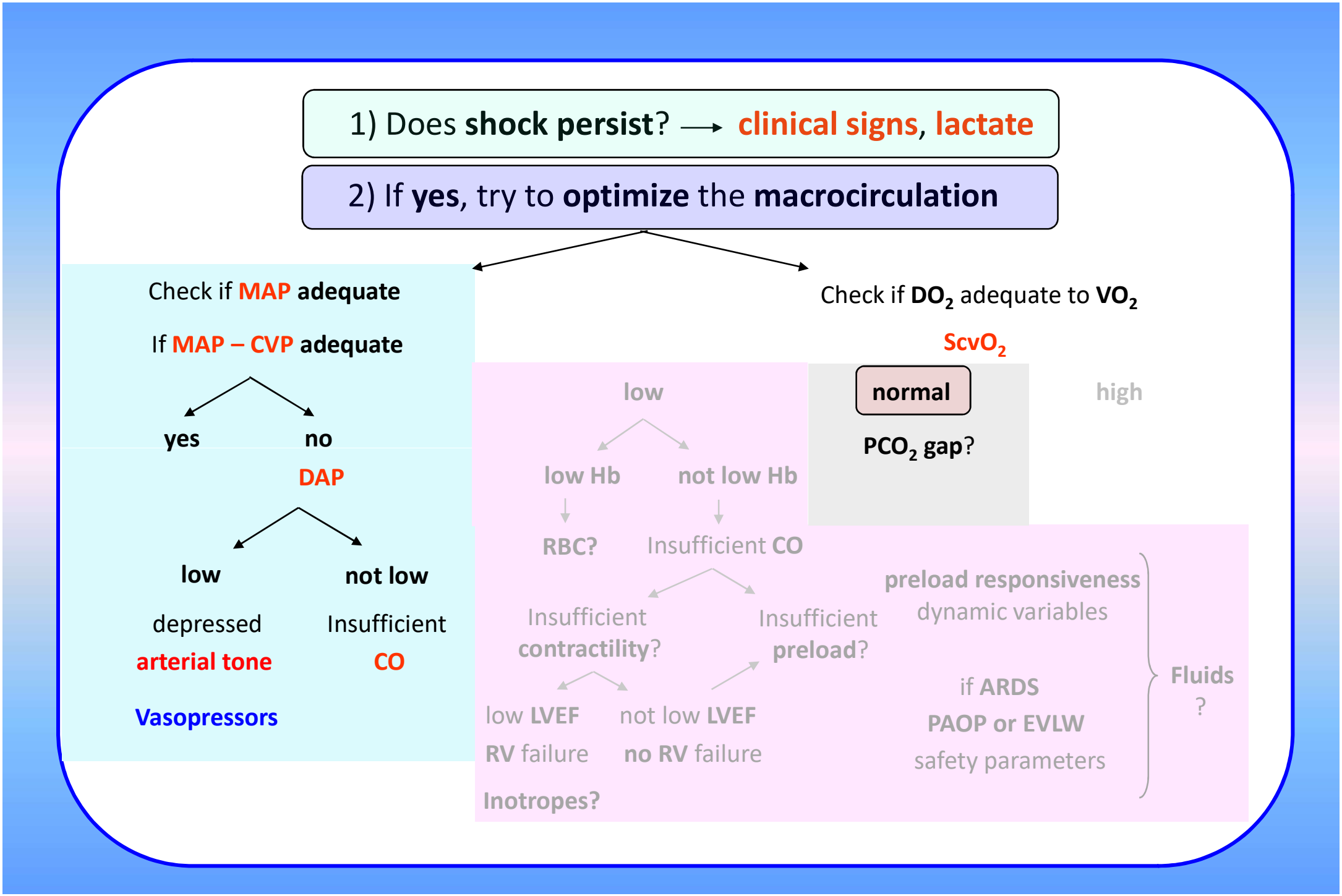
Fluids
?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normal
high
PCO2 gap?
low Hb
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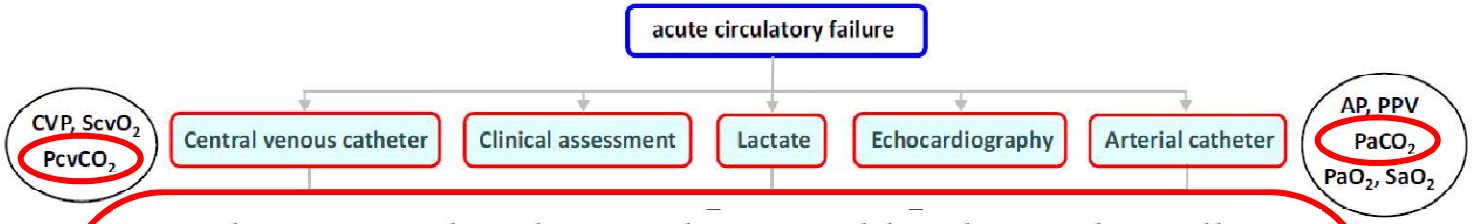
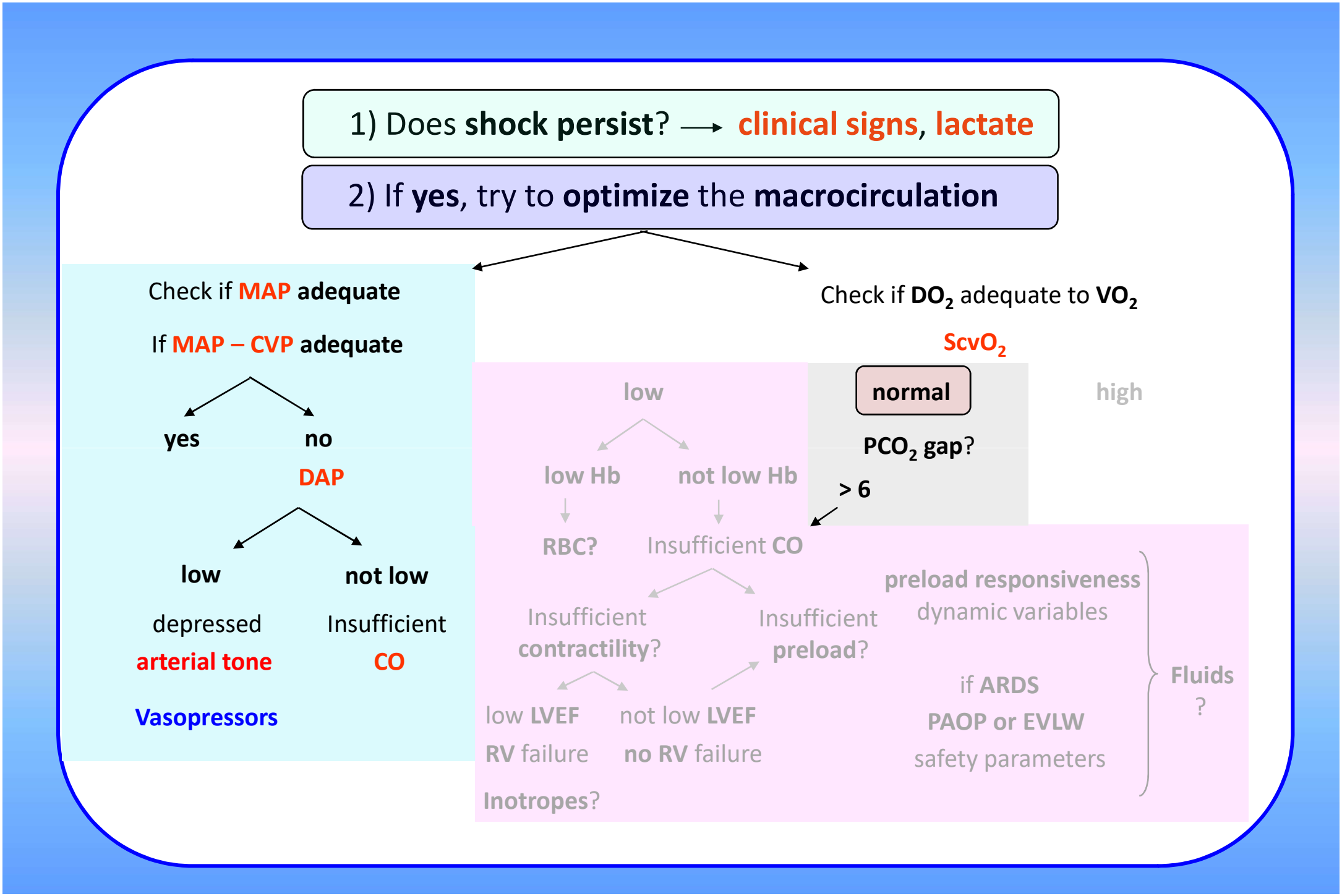
CONFERENCE REPORTS AND EXPERT PANEL

Less invasive hemodynamic monitoring in critically ill patients

[illegible]



coupling arterial and central venous blood sampling allows calculation of the venous-to-arterial carbon dioxide pressure difference (PCO_2 gap), which could be a good indicator of the adequacy of CO relative to the actual global metabolic conditions and could be helpful in conditions where oxygen extraction is altered while $ScvO_2$ is within the normal range. In this particular case, an abnormally high PCO_2 gap (>6 mmHg) could suggest that CO should be elevated to improve tissue oxygenation.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Check if MAP adequate
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yes
no
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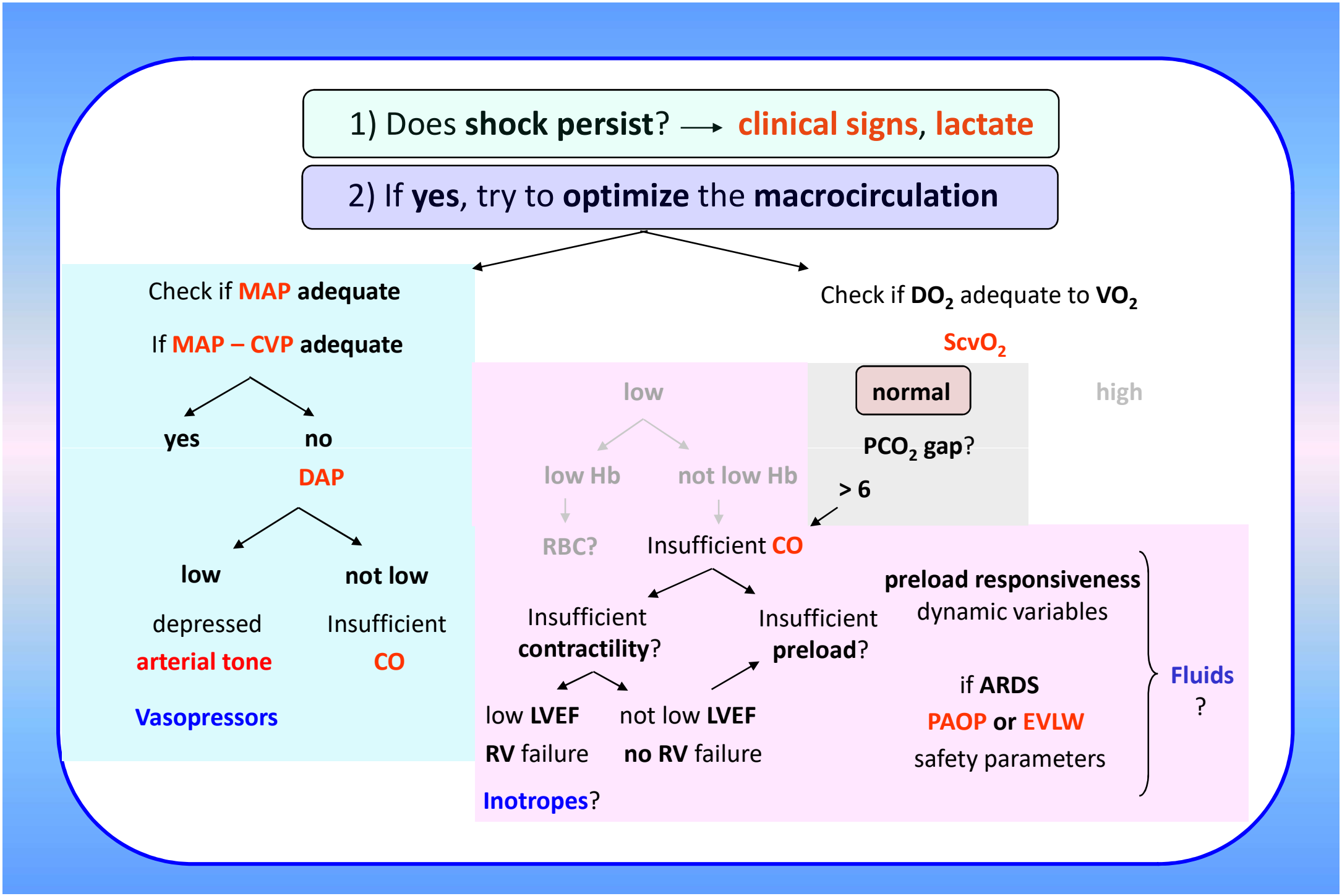
low
not low
depressed
arterial tone
Vasopressors
Insufficient
CO
Check if DO2 adequate to VO2
ScvO2
low
normal
high
PCO2 gap?
> 6
low Hb
not low Hb
RBC?
Insufficient CO
Insufficient
contractility?
Insufficient
preload?
low LVEF
RV failure
not low LVEF
no RV failure
Inotropes?
preload responsiveness
dynamic variables
if ARDS
PAOP or EVLW
safety parameters
Fluids
?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DAP
low
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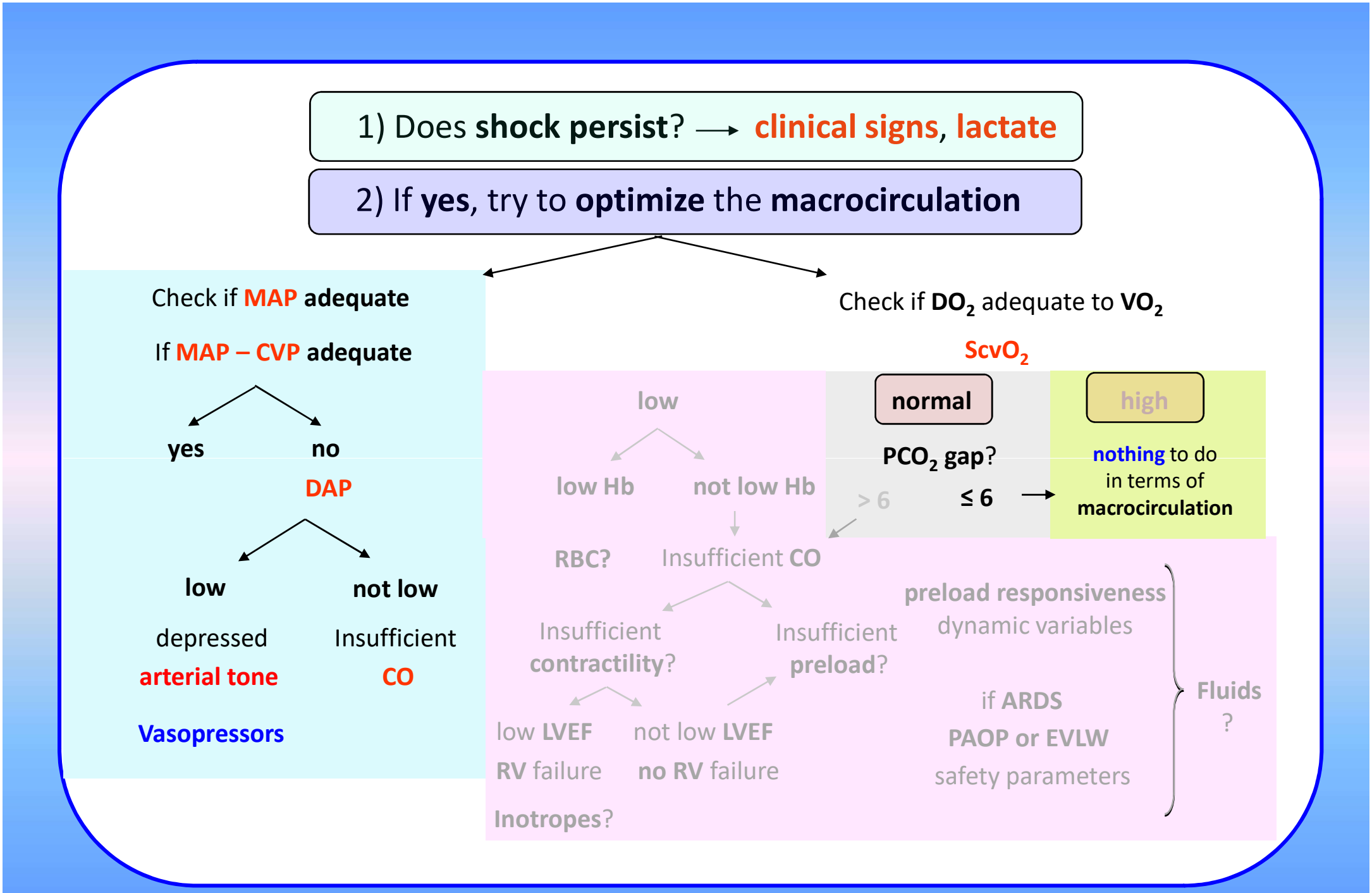
depressed arterial tone
Insufficient CO
Vasopressors
Check if DO2 adequate to VO2
ScvO2
low
normal
high
PCO2 gap?
> 6
low Hb
not low Hb
RBC?
Insufficient CO
Insufficient contractility?
Insufficient preload?
low LVEF
RV failure
not low LVEF
no RV failure
Inotropes?
preload responsiveness
dynamic variables
if ARDS
PAOP or EVLW
safety parameters
Fluids
?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ScvO2
low
normal
high
low Hb
not low Hb
PCO2 gap?
> 6
≤ 6
nothing to do
in terms of
macrocirculation
RBC?
Insufficient CO
Insufficient
contractility?
Insufficient
preload?
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Fluids
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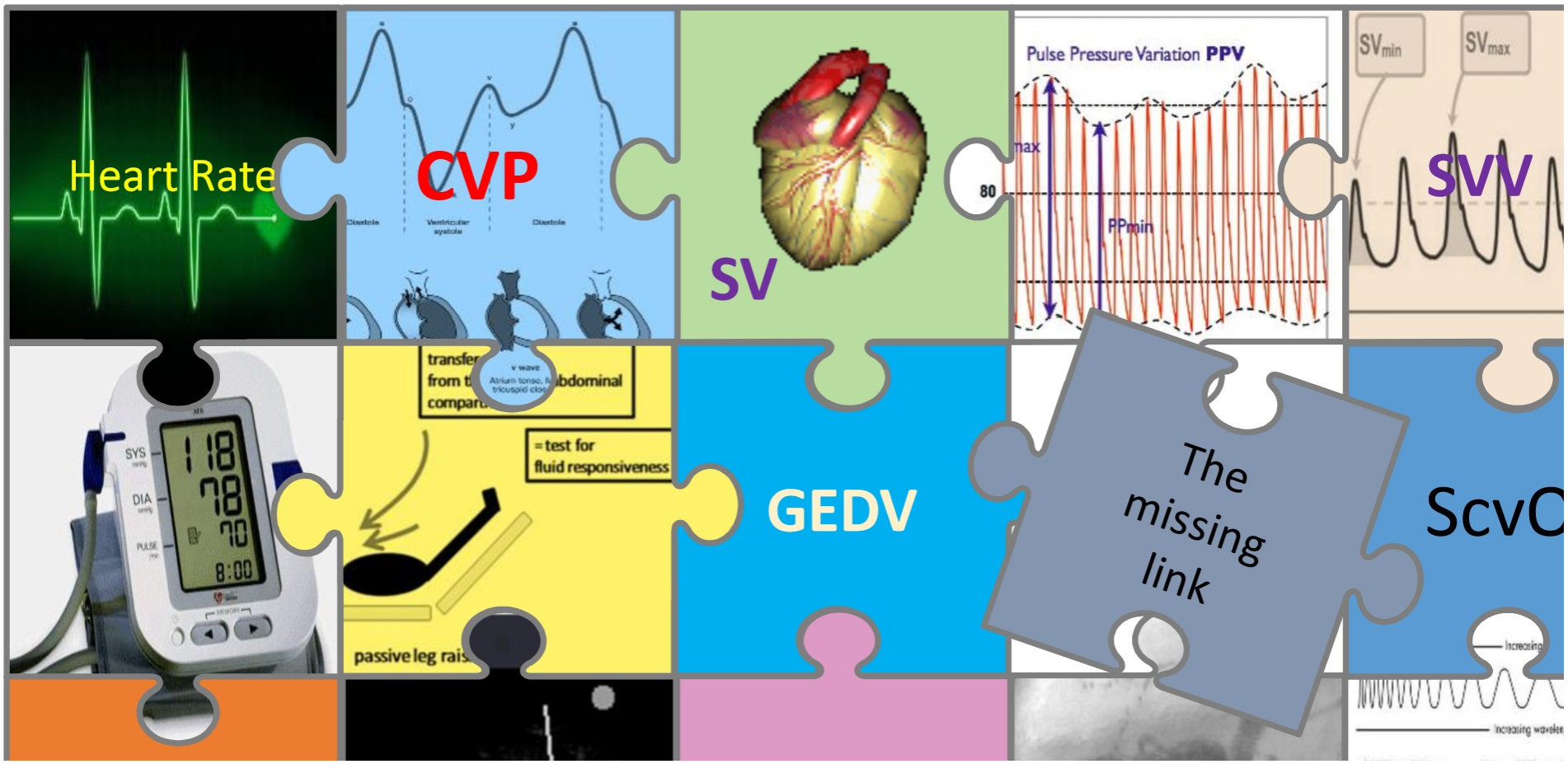
Heart Rate
CVP
SV
Pulse Pressure Variation PPV
max
80
PPmin
SVmin
SVmax
SVV
SYS
DIA
PULSE
118
78
70
8:00
=test for
fluid responsiveness
passive leg rais
GEDV
The
missing
link
ScvO

شكرا

Thank you

Merci