Cardiac ouput Monitoring: Why, When and for which patient?

Olfa Hamzaoui
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Cardiac Output Monitoring: Why, When and for which patient?

Mes liens d'intérêt

- Honoraires pour des conférences invitées par Baxter

Service MIR
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Why measuring cardiac output is important in critically ill patients?

1- CO is a major **determinant** of oxygen delivery to the tissues

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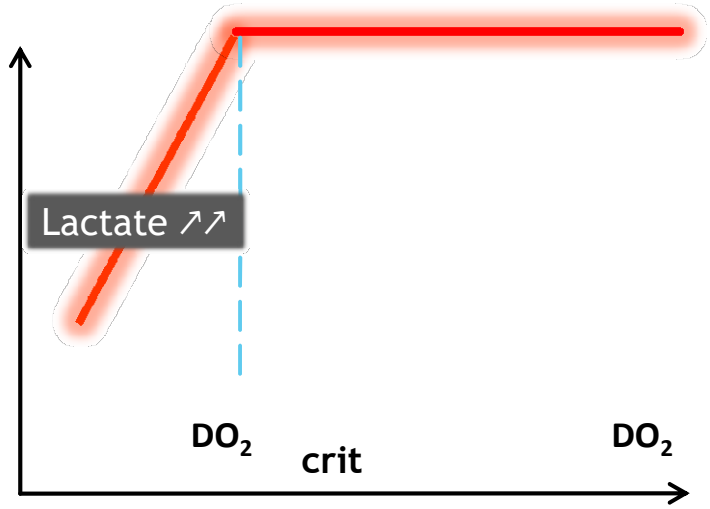
$VO_2 = DO_2 \times O_2$ extraction

↘ O_2 extraction

↘ DO_2 (mainly ↘ SV)

O_2 debt
($VO_2 < O_2$ demand)

Hypotension
(↘ organ **perfusion pressure**)



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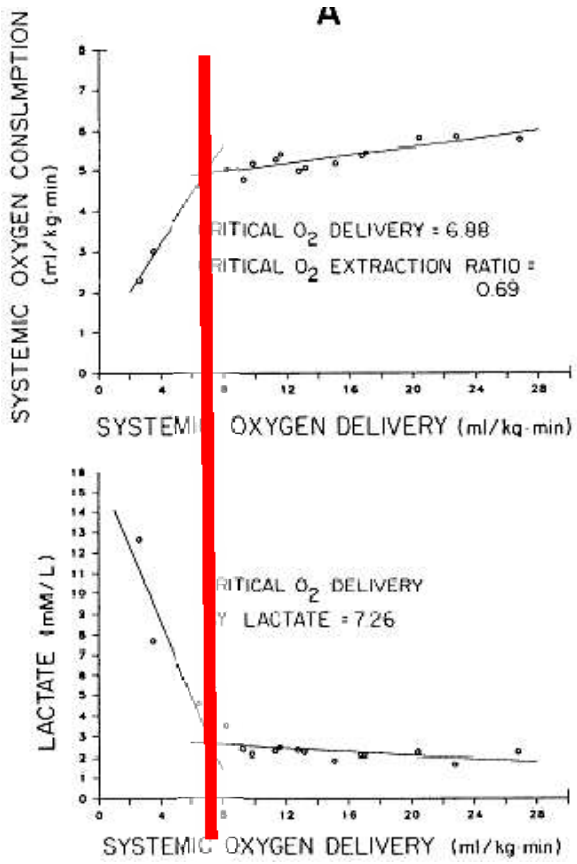

Nelson et al., J Appl Physiol, 1987

Why measuring cardiac output is important in critically ill patients?

1- CO is a major **determinant** of oxygen delivery to the tissues

- There is **no low CO without peripheral hypoperfusion** (in the absence of hypothermia)

- In cases of increase in VO_2, anemia, or low SaO_2, **only** the **elevation** of **CO** allows to prevent of limit tissue hypoxia

Why measuring cardiac output is important in critically ill patients?

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2- In shock states CO is **highly variable** from one patient to another

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	Cardiac index (L/min/m²) before NE administration
• Martin et al Crit Care Med 1999	5.7
• Martin et al Chest 1993	5.3
• Desjars et al Crit Care Med 1987	5.2
• Albanese et al Crit Care Med 2005	5.1
• Albanese et al Chest 2004	4.7
• Ledoux et al Crit Care Med 2000	4.7
• Martin et al Crit Care Med 1999	4.3
• Jhanji et al Crit Care Med 2009	3.9
• Thooft et al Crit Care 2011	3.5
• Deruddre et al Intensive Care Med 2007	3.4
• Hamzaoui et al Crit Care 2010	3.2
• Georger et al Intensive Care Med 2010	3.1
• Dubin et al Crit Care 2009	2.9
• Monnet et al Crit Care Med 2011	2.7

Why measuring cardiac output is important in critically ill patients?

1- CO is a major **determinant** of oxygen delivery to the tissues

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3- **Identifying a low CO** (mostly if low SvO_2) allows identifying the cases where a treatment aimed at **increasing CO** can **reduce** tissue **hypoxia**

Why measuring cardiac output is important in critically ill patients?

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4- Unfortunately, **clinical examination cannot predict** neither the value of CO, nor even its range

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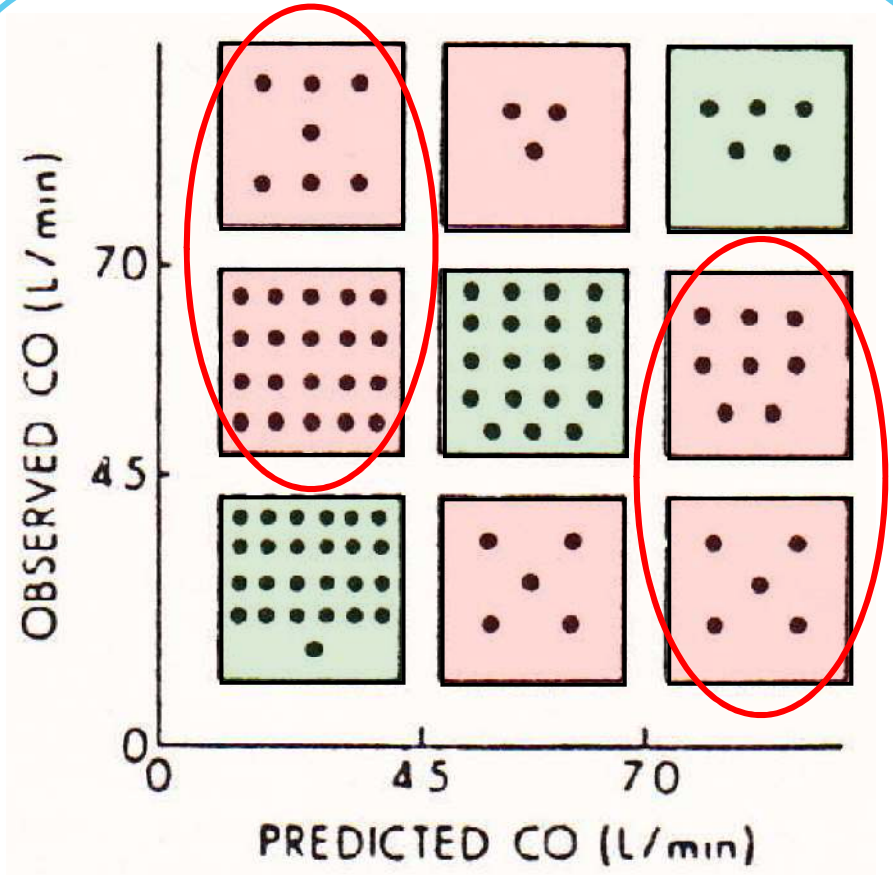

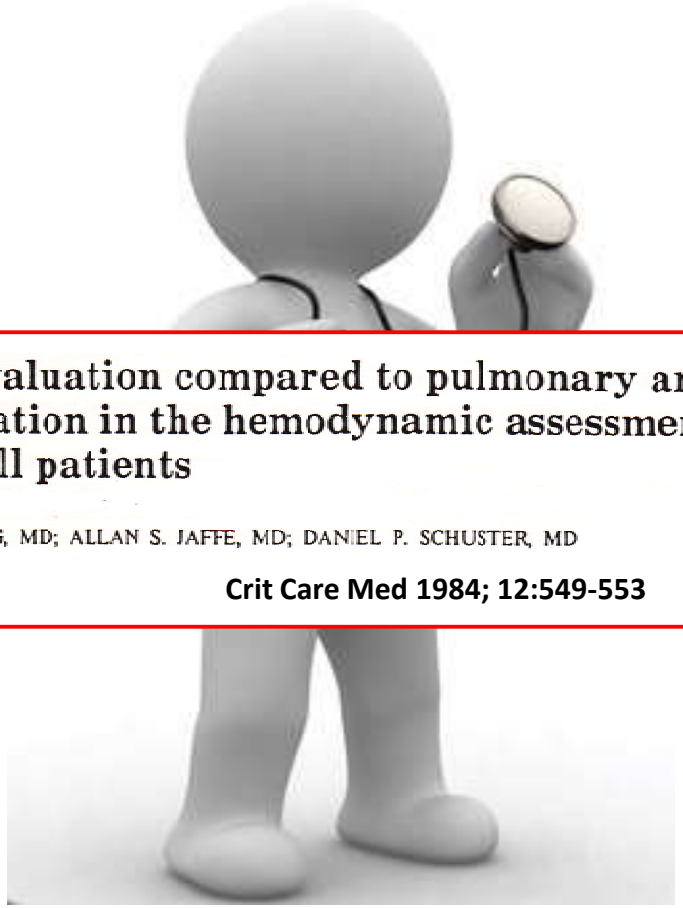

Clinical evaluation compared to pulmonary artery catheterization in the hemodynamic assessment of critically ill patients

PAUL R. EISENBERG, MD; ALLAN S. JAFFE, MD; DANIEL P. SCHUSTER, MD

Crit Care Med 1984; 12:549-553

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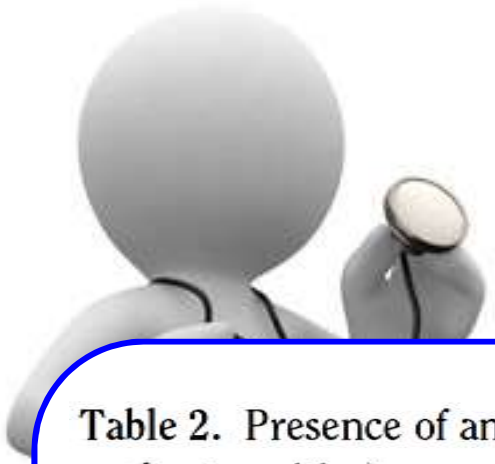

Association of physical examination with pulmonary artery catheter parameters in acute lung injury*

Colin K. Grissom, MD; Alan H. Morris, MD; Paul N. Lanken, MD; Marek Ancukiewicz, PhD; James F. Orme, Jr., MD; David A. Schoenfeld, PhD; B. Taylor Thompson, MD; for the National Institutes of Health/National Heart, Lung and Blood Institute Acute Respiratory Distress Syndrome Network

Crit Care Med 2009; 37:2720–2726

Table 2. Presence of any one physical examination finding (capillary refill >2 secs, knee mottling, or cool extremities) as predictive of CI <2.5

N = 405	CI <2.5	CI ≥2.5
Any 1 physical examination finding present	17	83
No physical examination findings present	16	289
	Sensitivity = 52%	Specificity = 78%

In Which patient we need to monitor CO?

1- Patients with severe shock : are very hemodynamically unstable

In Which patient we need to monitor CO?

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2- Unfortunately, **changes** in **Arterial Pressure cannot predict changes** in **CO**

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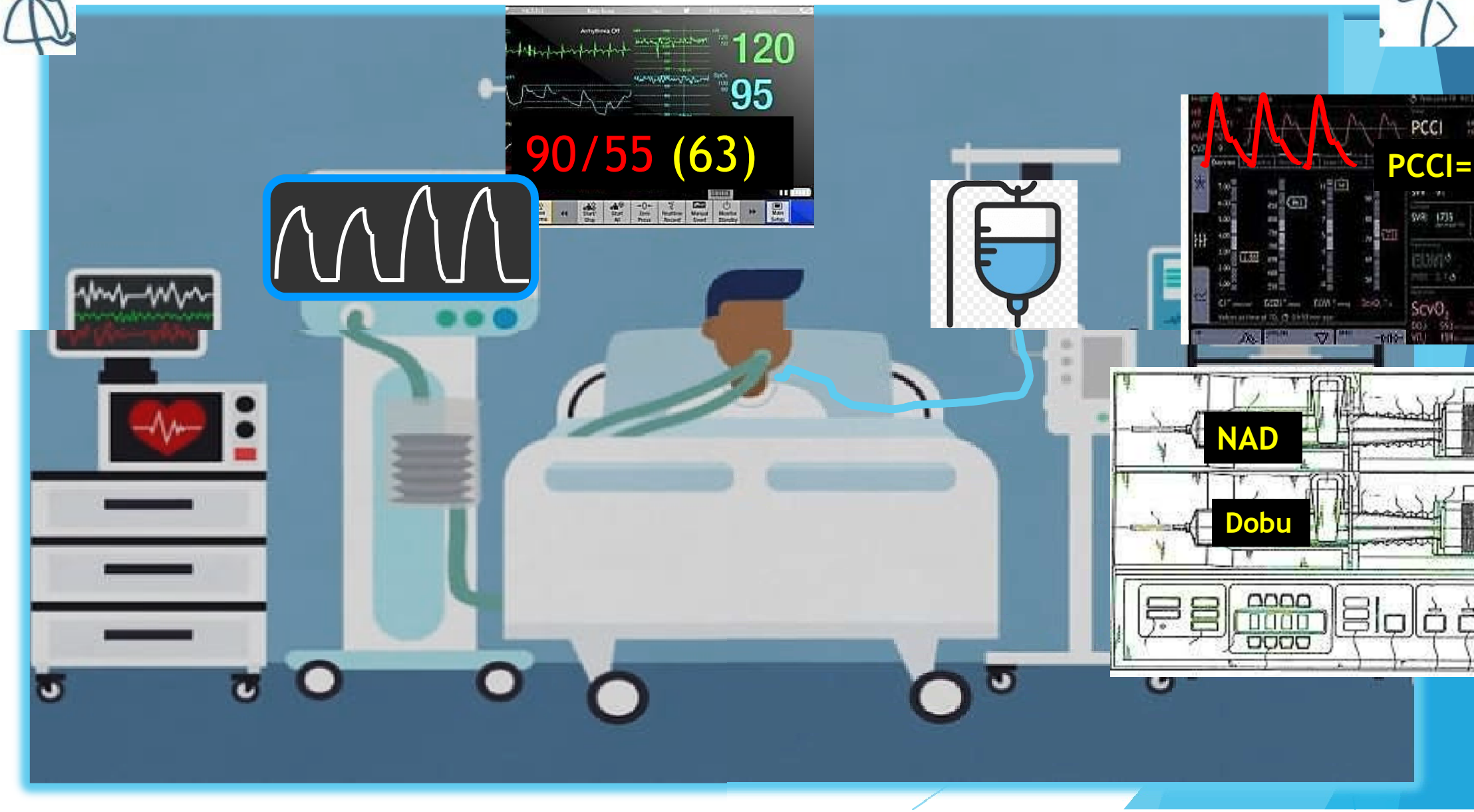
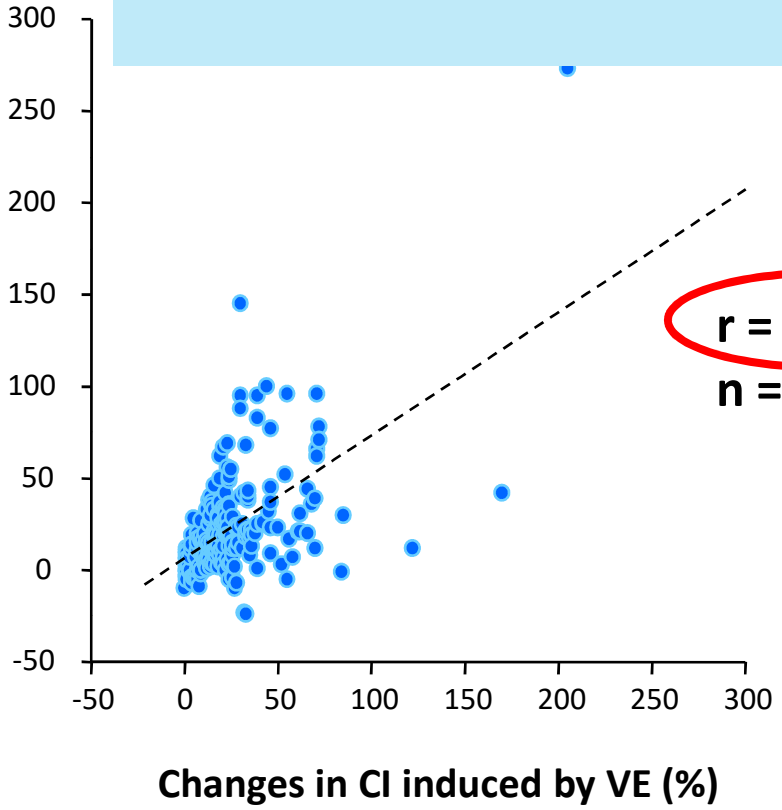


rterial pressure allows monitoring the changes in cardiac output nduced by volume expansion but not by norepinephrine*

vier Monnet, MD, PhD; Alexia Letierce, PhD; Olfa Hamzaoui, MD; Denis Chemla, MD, PhD; adia Anguel, MD; David Osman, MD; Christian Richard, MD; Jean-Louis Teboul, MD, PhD

Crit Care Med 2011; 39:000–000

AP monitoring cannot replace CO monitoring, especially in case of NE use



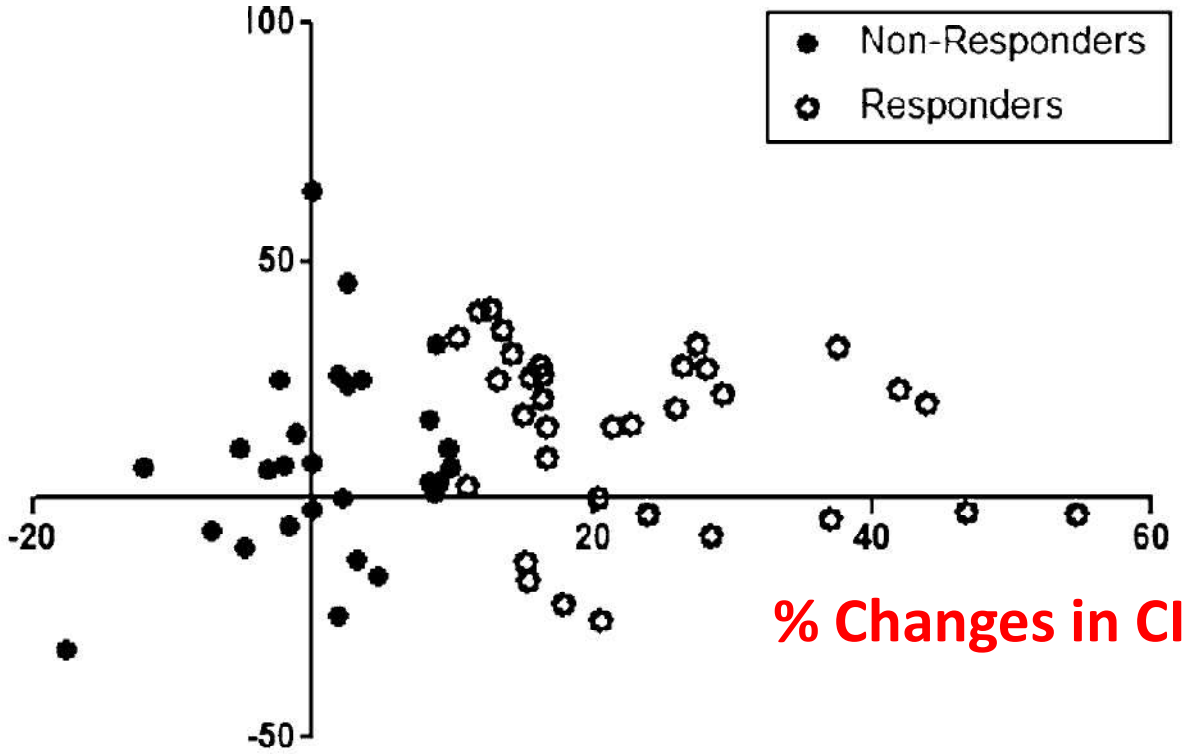
Intensive Care Med (2012) 38:422–428
DOI 10.1007/s00134-011-2457-0

ORIGINAL

Charalampos Pierrakos
Dimitrios Velissaris
Sabino Scolletta
Sarah Heenen
Daniel De Backer
Jean-Louis Vincent

Can changes in arterial pressure be used to detect changes in cardiac index during fluid challenge in patients with septic shock?

% Changes in PP



% Changes in CI

In Which patient we need to monitor CO?

1- Patients with severe shock : are very hemodynamically unstable

2- Unfortunately, changes in Arterial Pressure cannot predict changes in CO

3- Unfortunately, the sole **SvO_2 monitoring cannot predict changes in CO**

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

$ScvO_2$ un reflet acceptable de la **SvO_2**

$ScvO_2$ un indicateur de la balance **VO_2/TaO_2**

Intensive Care Med (2016) 42:1350–1359

CONFERENCE REPORTS AND EXPERT PANEL

Less invasive hemodynamic monitoring in critically ill patients

Jean-Louis Teboul[1*], Bernd Saugel[2], Maurizio Cecconi[3], Daniel De Backer[4], Christoph K. Hofer[5], Xavier Monnet[1], Azriel Perel[6], Michael R. Pinsky[7], Daniel A. Reuter[2], Andrew Rhodes[3], Pierre Squara[8], Jean-Louis Vincent[9] and Thomas W. Scheeren[10]

$ScvO_2$ 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.

Une **basse** $ScvO_2$ peut inciter à **augmenter** TaO_2

(surtout par augmentation du **DC**)

Association of physical examination with pulmonary artery catheter parameters in acute lung injury*

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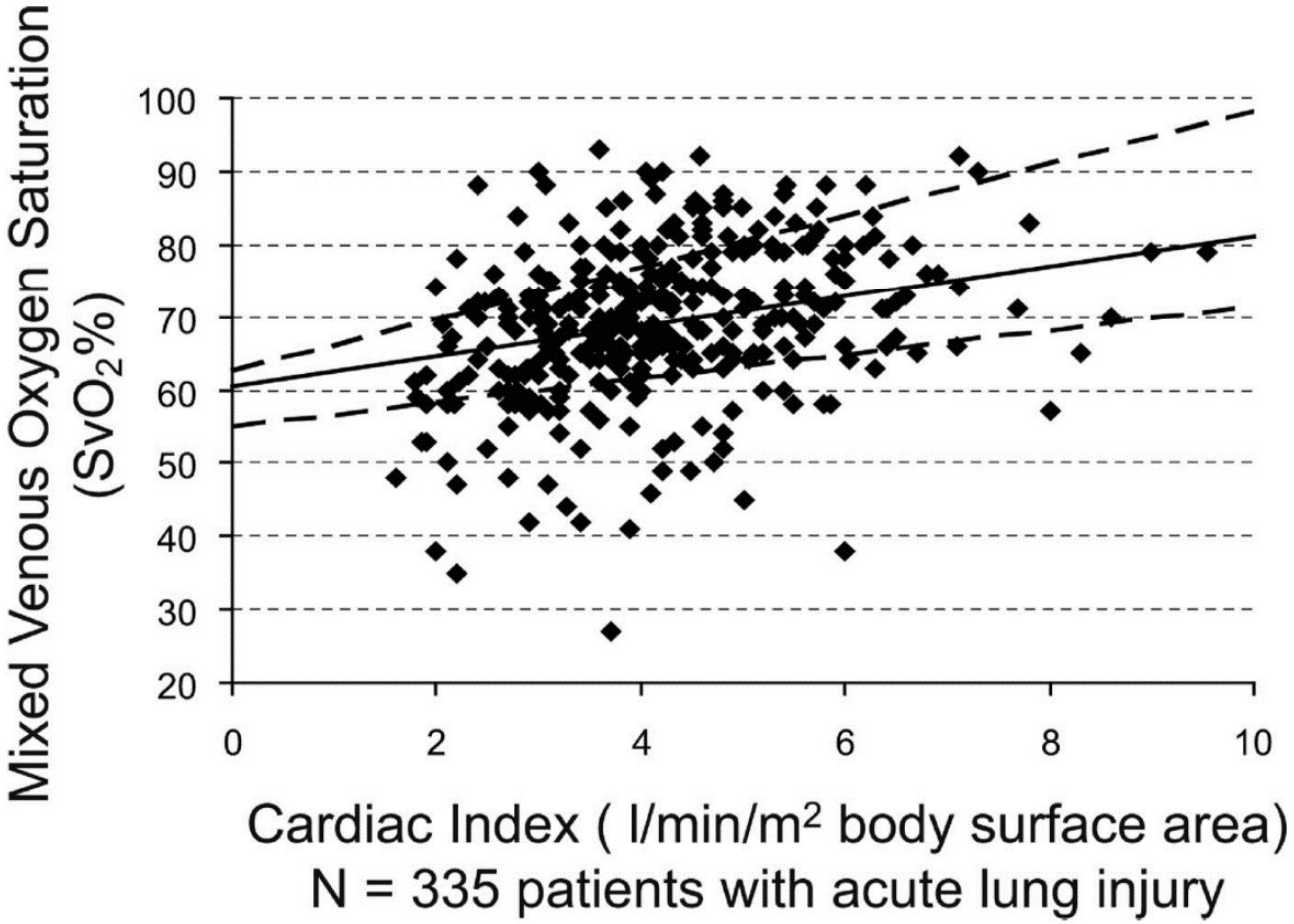


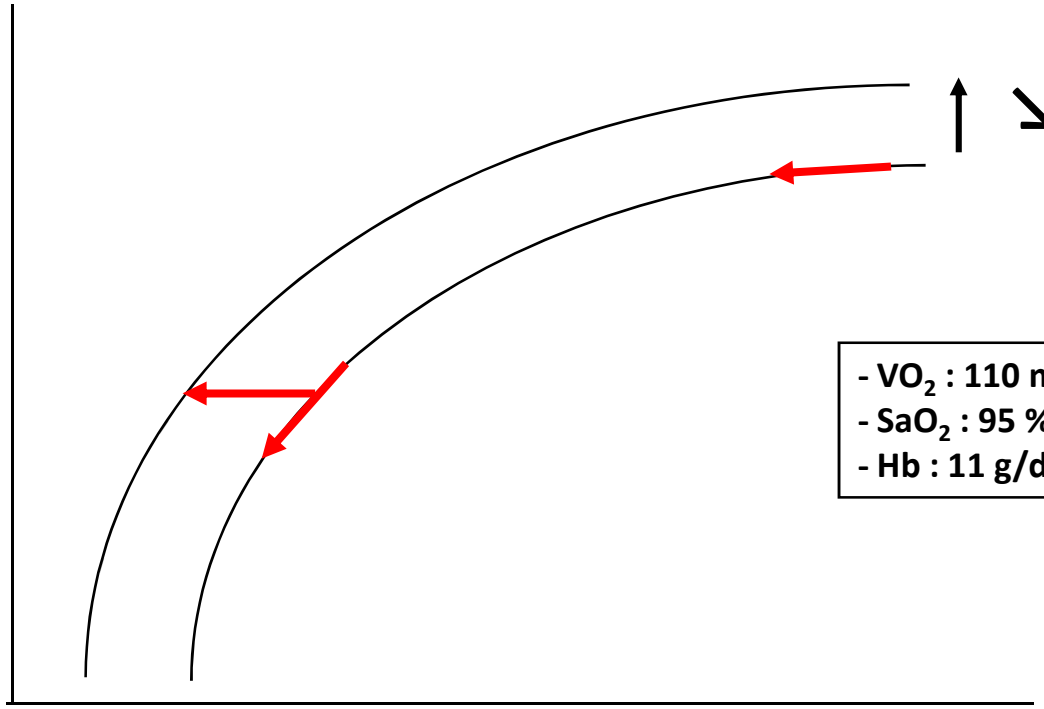
SvO_2 to monitor resuscitation of septic patients: let's just understand the basic physiology

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

Critical Care 2011, **15**:1005

SvO_2

(%)



- **VO_2 : 110 mL/min/m²**
- **SaO_2 : 95 %**
- **Hb : 11 g/dl**

Cardiac Index (L/min/m²)

In Which patient we need to monitor CO?

1- Patients with severe shock : are very hemodynamically unstable

2- Unfortunately, changes in Arterial Pressure cannot predict changes in CO

3- Unfortunately, the sole SvO_2 monitoring cannot predict changes in CO

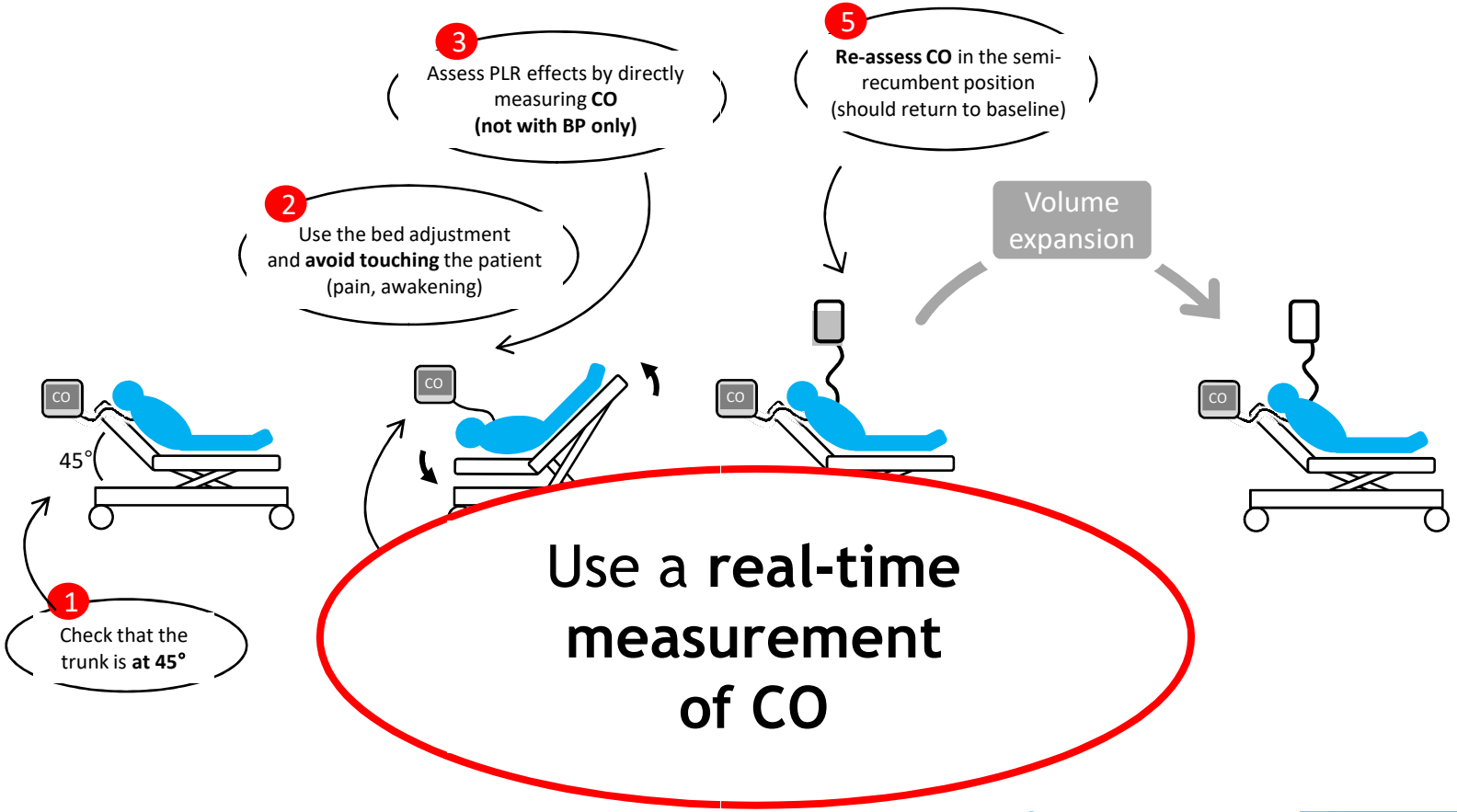
4- **Continuous** (and **real-time**) **CO** enables performance of **preload responsiveness** tests suc
passive leg raising or end-expiratory occlusion

EDITORIAL

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

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

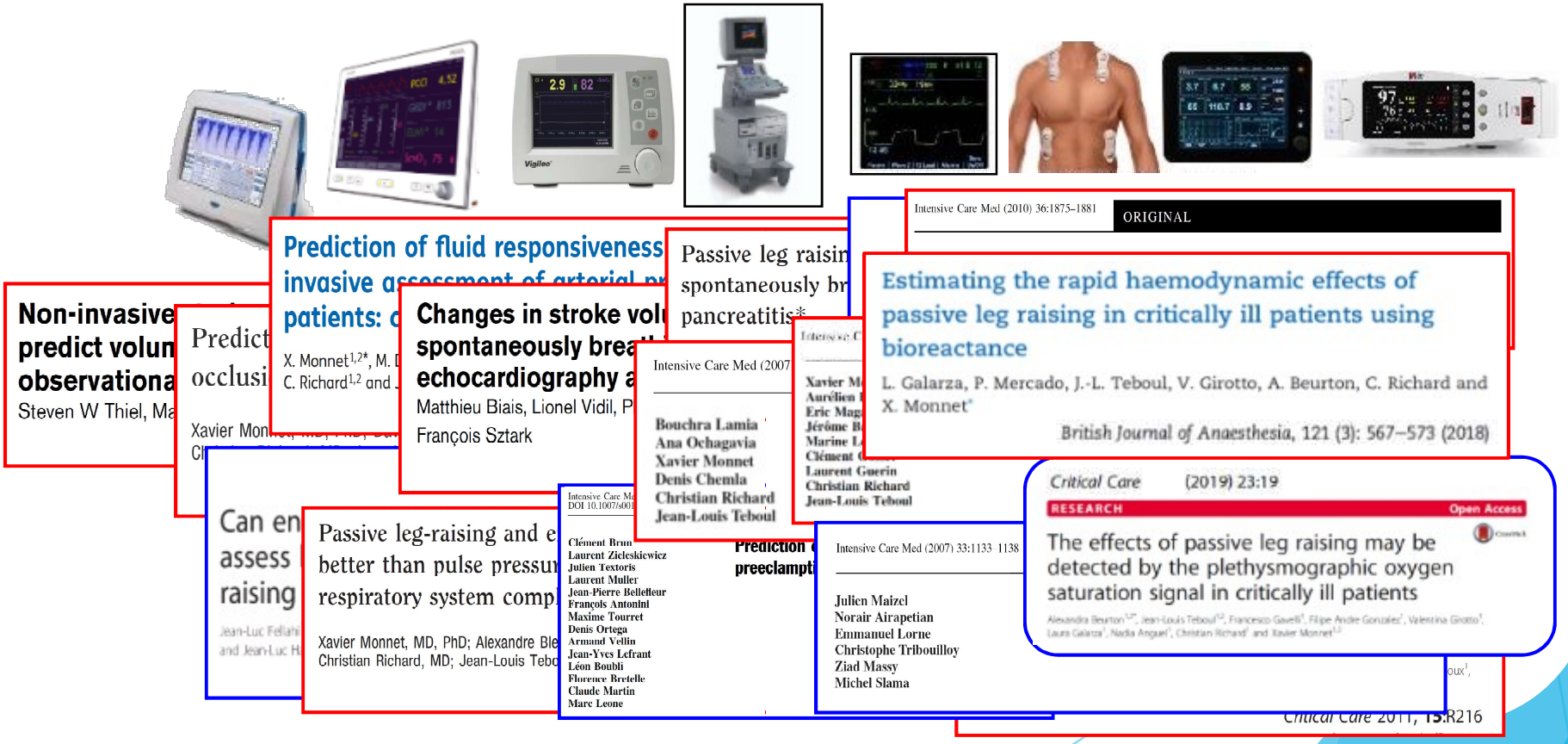
Crit Care 2015, 19:18



The **hemodynamic response** to **PLR**

can predict the **hemodynamic response** to **fluid infusion**

Real-time CO (or surrogate) response to PLR

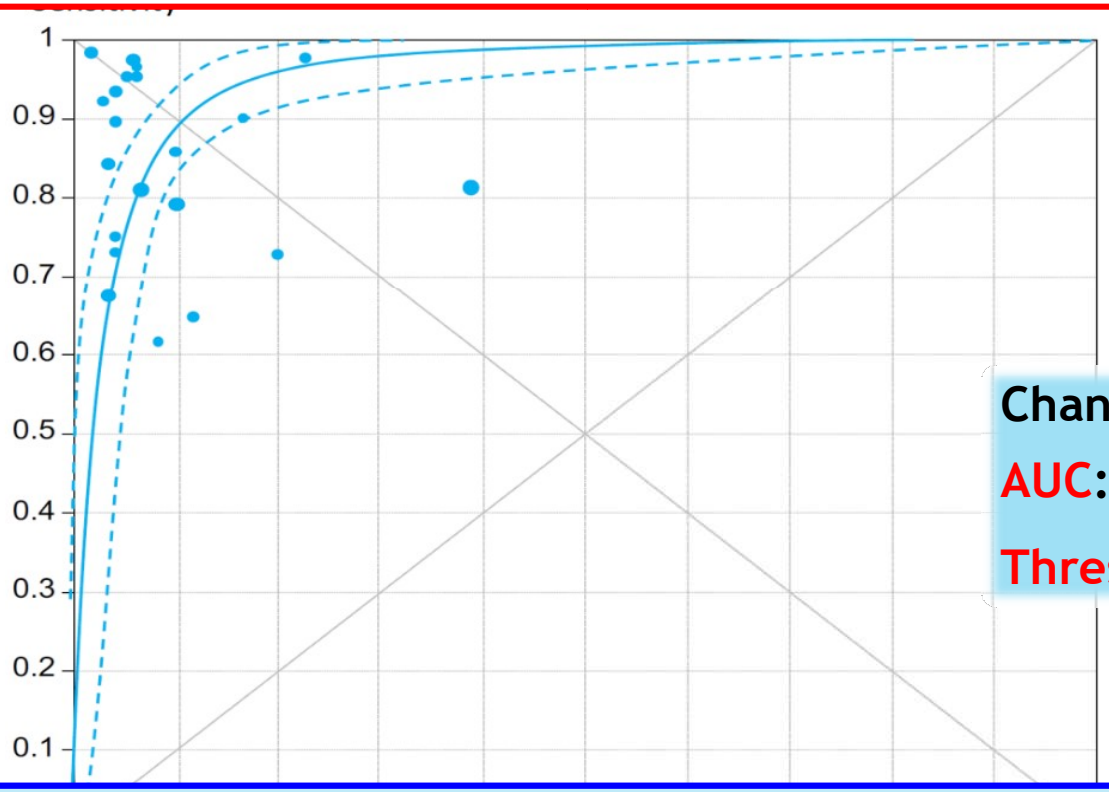


Intensive Care Med (2016) 42:1935–1947

ORIGINAL

Xavier Monnet
Paul Marik
Jean-Louis Teboul

Passive leg raising for predicting fluid responsiveness: a systematic review and meta-analysis



21 ***clinical studies***

995 ***pts***

Changes in CO

AUC: 0.95±0.01

Threshold: 10%

- **PLR** provides a good **prediction** of **fluid responsiveness**

When do we need to measure cardiac output?

e Care Med (2014) 40:1795–1815

CONFERENCE REPORTS AND EXPERT PANEL

io Cecconi
De Backer
o Antonelli
d Beale
kker
ph Hofer
Jaeschke
dre Mebazaa
l R. Pinsky
ouis Teboul
ouis Vincent
y Rhodes

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

Intensive Care Med (2016) 42:1350–1359

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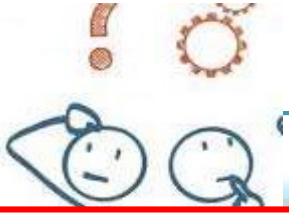
When do we need to measure cardiac output?



tensive Care Med (2014) 40:1795–1815

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aurizio Cecconi
niel De Backer
assimo Antonelli
chard Beale
n Bakker
ristoph Hofer
man Jaeschke
exandre Mebazaa
chael R. Pinsky
an Louis Teboul
an Louis Vincent
drew Rhodes

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

- We **do not recommend routine** measurement of **CO** for pts with shock **responding** to the **initial therapy**

  Level 1; QoE low (C)

- We **recommend** measurements of **CO** and **stroke volume** to evaluate the **response** to fluids or inotropes in pts that are **not responding** to **initial therapy**

  Level 1; QoE low (C)

When de we need to measure cardiac output?

tensive Care Med (2016) 42:1350–1359

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CrossMark

ess invasive hemodynamic monitoring
critically ill patients

n-Louis Teboul[1*], Bernd Saugel[2], Maurizio Cecconi[3], Daniel De Backer[4], Christoph K. Hofer[5], Xavier Monnet[1], el Perel[6], Michael R. Pinsky[7], Daniel A. Reuter[2], Andrew Rhodes[3], Pierre Squara[8], Jean-Louis Vincent[9], Thomas W. Scheeren[10]

acute circulatory failure

- **Clinical assessment**
- **Lactate**
- **Echocardiography**

- **Which monitoring for patients with shock?**
  - **Initial Phase: the first hour**
    - **Mottling**
    - **Capillary refill time**
    - **Lactate**
    - **Arterial pressure**
    - **Echocardiography**

When do we need to measure cardiac output?

tensive Care Med (2016) 42:1350–1359

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Thomas W. Scheeren[10]

acute circulatory failure

- **Clinical assessment**
- **Lactate**
- **Echocardiography**
- **Arterial catheter**

AP, PPV
$PaCO_2$
PaO_2, SaO_2

- **Which monitoring for patients with shock?**

  - Initial Phase: the first hour
  - **If shocks persists and**/or introduction of **catecholamines :**

    - **Arterial Catheter**: In addition to the absolute values of AP: **PPV**

When do we need to measure cardiac output?

tensive Care Med (2016) 42:1350–1359

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critically ill patients

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Thomas W. Scheeren[10]

acute circulatory failure

- **CVP, $ScvO_2$, $PcvCO_2$**
- **Central venous catheter**
- **Clinical assessment**
- **Lactate**
- **Echocardiography**
- **Arterial catheter**
- **AP, PPV, $PaCO_2$, PaO_2, SaO_2**

- **Which monitoring for patients with shock?**

  - Initial Phase: the first hour
  - **If shocks persists and**/or introduction of **catecholamines :**

    - Arterial Catheter: In addition to the absolute values of AP: **PPV**

    - Central **Venous Catheter: CVP**
      ScVO2
      PCO2 Gap

When do we need to measure cardiac output?

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acute circulatory failure

- **CVP, $ScvO_2$, $PcvCO_2$**
- **Central venous catheter**
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- **Echocardiography**
- **Arterial catheter**
- **AP, PPV, $PaCO_2$, PaO_2, SaO_2**

- **Which monitoring for patients with shock?**
  - Initial Phase: the first hour
  - **If shocks persists and**/or introduction of **catecholamines :**
    - **Arterial Catheter**: In addition to the absolute values of AP: **PPV**
    - Central **Venous Catheter**
- **If shock persists** and/or if **ARDS**: discuss an **advanced hemodynamic monitoring**

When do we need to measure cardiac output?

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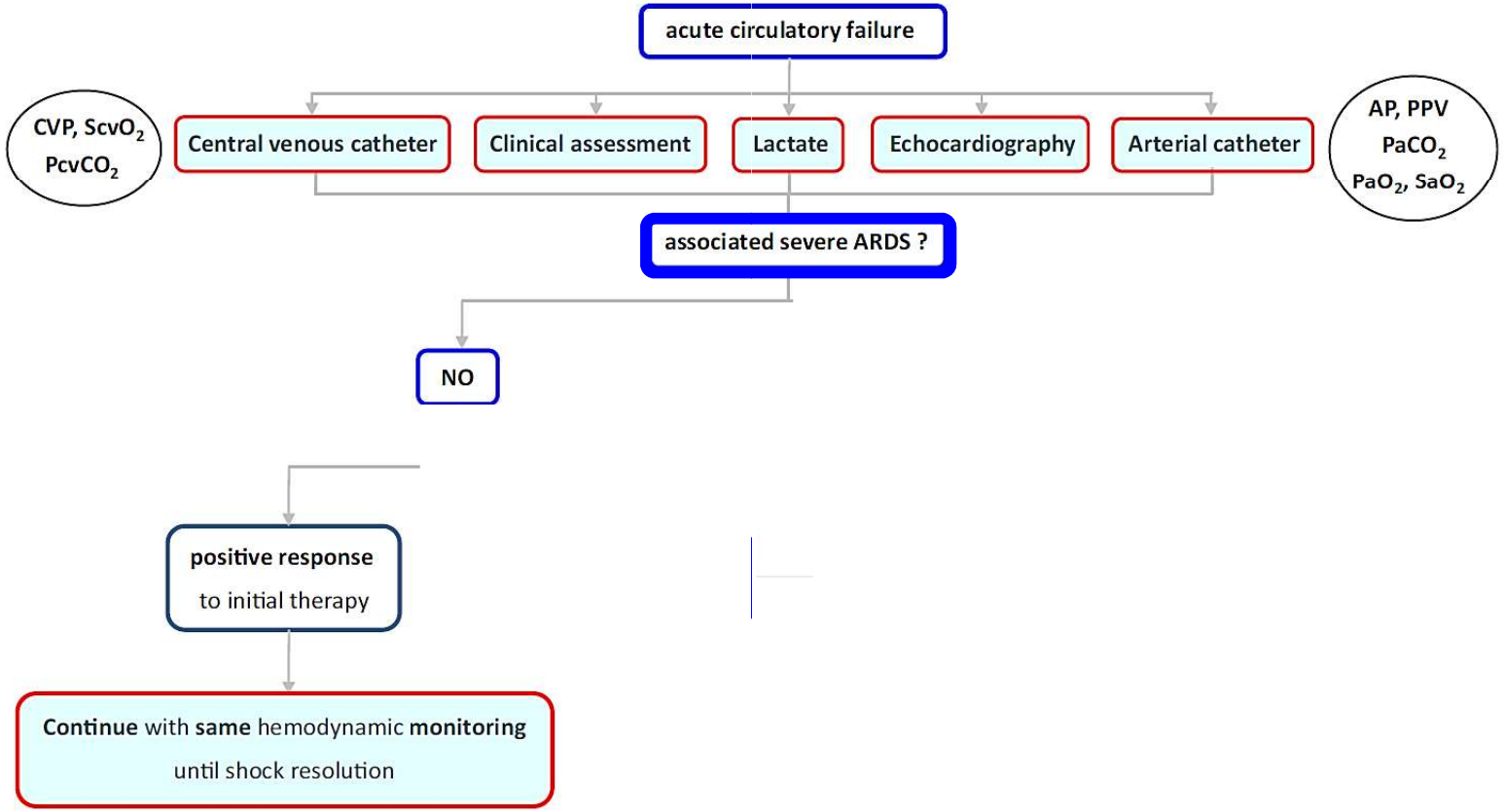
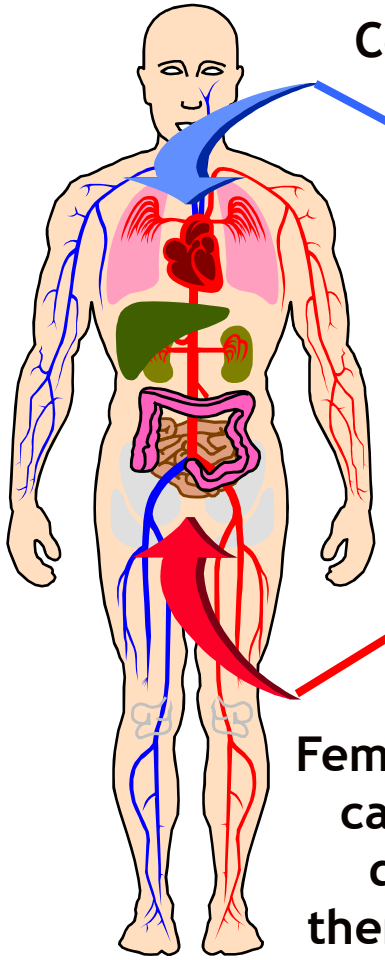




Central venous catheter*(injection of cold bolus)*

Femoral arterial catheter for detection thermodilution curve

Transpulmonary Thermodilution *(TPTD)*

⟶ **Intermittent** Cardiac output

Pulse contour analysis

(after calibration by TPTD)

⟶ **Continuous** cardiac output

Transpulmonary thermodilution :

Useful for guiding fluid management

especially in patients with shock and ARDS

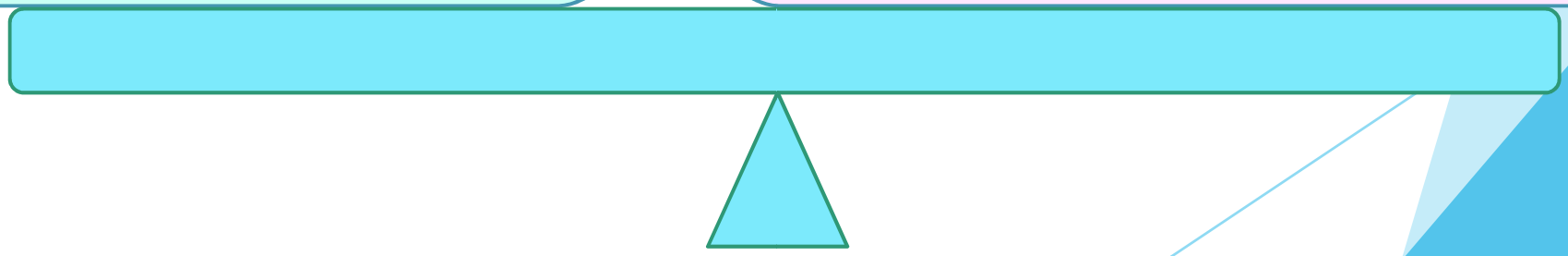
Fluid infusion benefit/risk ratio

Prediction of **fluid responsiveness**

- **PPV** et **SVV**
- **Response** of CO (real time) to PLR

Assessment of **fluid tolerance**

- **Extravascular lung water**
- **Pulmonary Vascular permeability Index**



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- **Response** of CO (real time) after **PLR**

Asesseemnt of fluid tolerance

- **Extravascular lung water**
- **Pulmonary Vascular permeability Index**

⟹ **decision**

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

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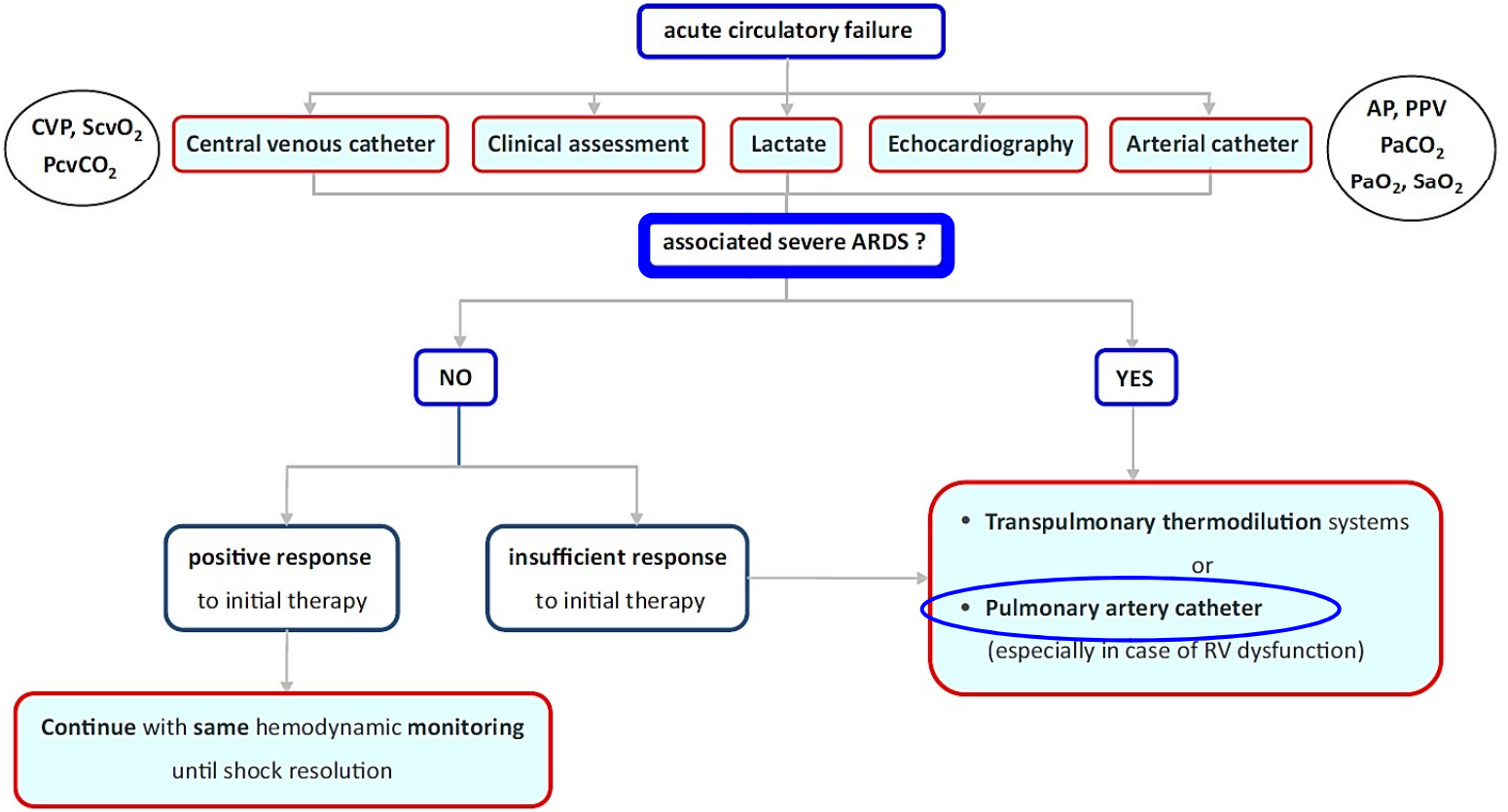

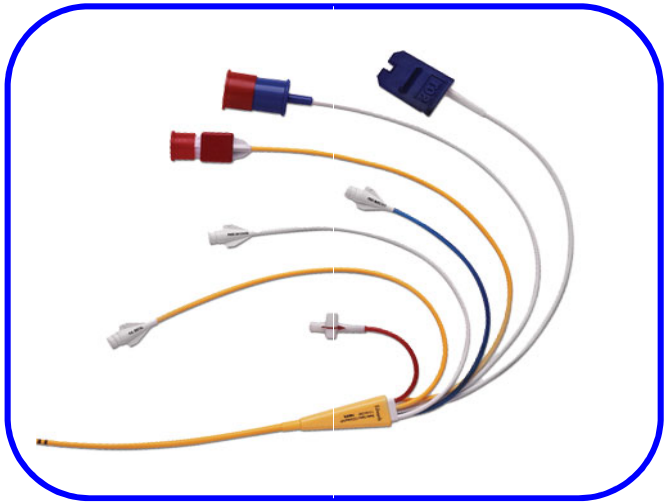

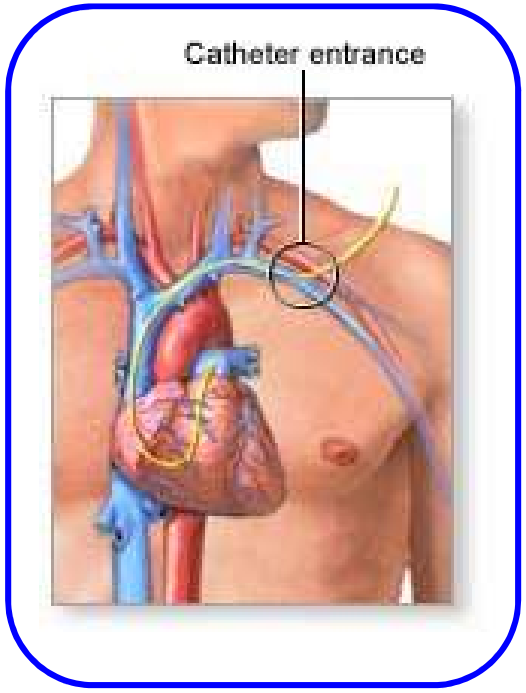

semi-continuous and intermittent **CO**

SvO_2 (continuous and intermittent) + **$PvCO_2$**

Intermittent measurements of **RAP**, **PAP** and **PAOP (wedge Pressure)**

Key messages: Monitoring CO

Why?

1- CO is a major **determinant** of oxygen delivery to the tissues

2- In shock states CO is **highly variable** from one patient to another

3- **Identifying a low CO** (mostly if low SvO_2) allows identifying the cases where a treatment aim at **increasing CO** can **reduce** tissue **hypoxia**

4- Unfortunately, **clinical examination cannot predict** neither the value of CO, nor even its ran

In which patient?

1- Patients very hemodynamically unstable

2-Need to test the response to the treatments: Fluids and catecolamines

Key messages: Monitoring CO

When?

1- Patients not responding to the initial treatment

2-Patients with associated ARDS

Merci!