

# Which monitoring for patients with shock?



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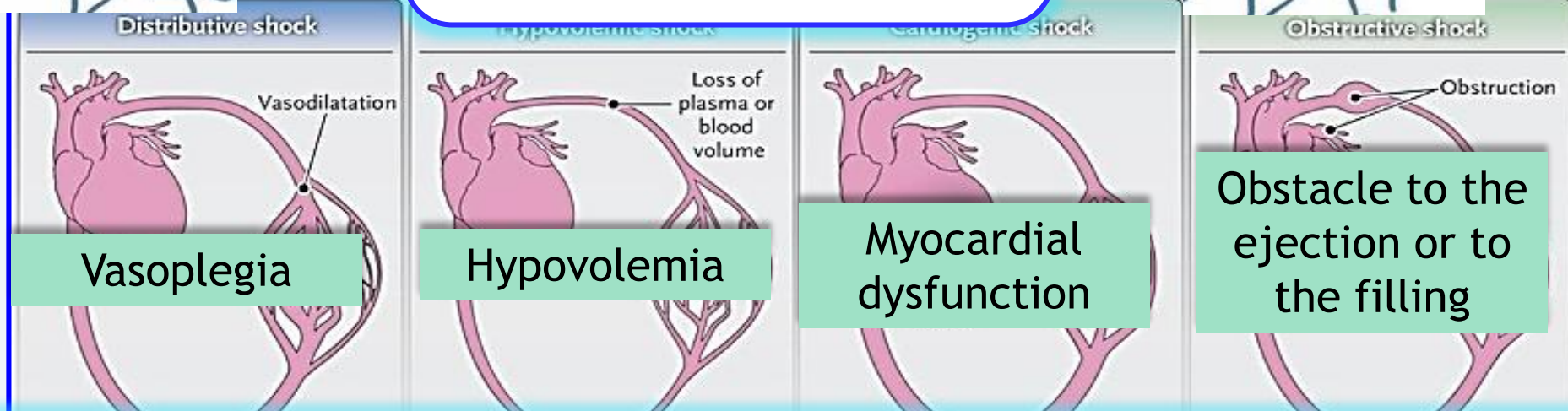
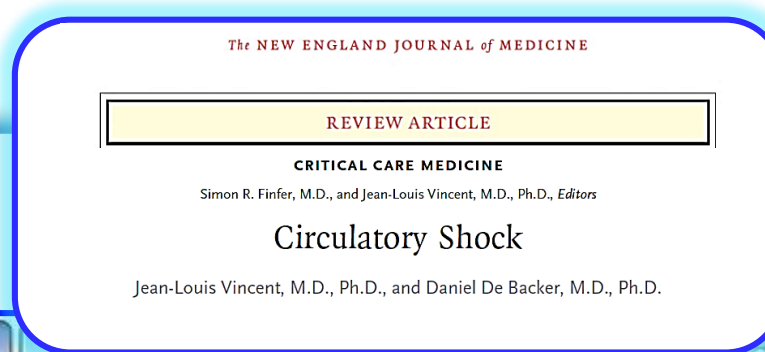
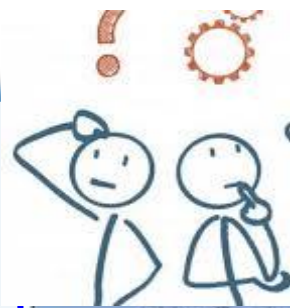
# Conflicts of interest



UNIVERSITÉ  
DE REIMS

- Received Honoraria for Lectures from Baxter
- Received Honoraria From AOP for Consulting
- Member of the scientific board of Vitaris
- Received Honoraria From Gering for Consulting





## Various and intricate mechanisms responsible for hemodynamic instability in critically ill patients

- It is important to **identify** the **type** of shock
- It is important to **assess** the degree of each component
- It is important to **select** the most **appropriate** therapeutic measure
- It is important to **assess** the **response** to treatment

# Il est important de se munir d'outils de monitoring

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**

*Intensive Care Med (2016) 42:1350–1359*

## CONFERENCE REPORTS AND EXPERT PANEL

### **Less invasive hemodynamic monitoring in critically ill patients**



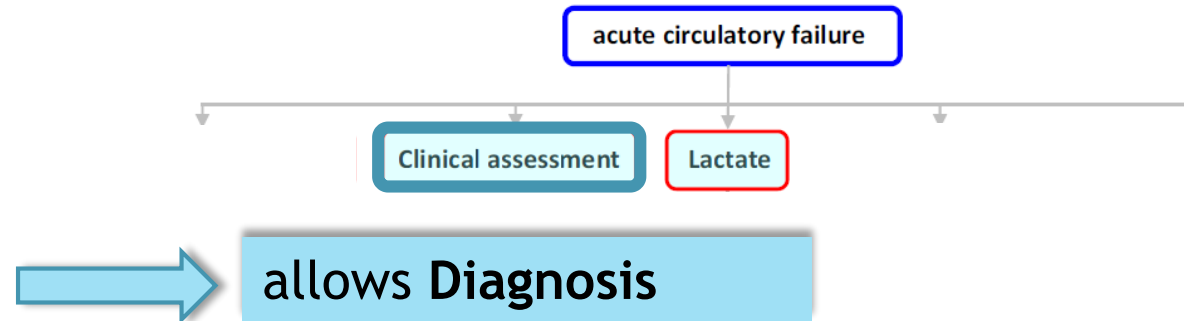
Jean-Louis Teboul<sup>1\*</sup>, Bernd Saugel<sup>2</sup>, Maurizio Cecconi<sup>3</sup>, Daniel De Backer<sup>4</sup>, Christoph K. Hofer<sup>5</sup>, Xavier Monnet<sup>1</sup>, Azriel Perel<sup>6</sup>, Michael R. Pinsky<sup>7</sup>, Daniel A. Reuter<sup>2</sup>, Andrew Rhodes<sup>3</sup>, Pierre Squara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

- **Which monitoring for patients with shock?**
  - **Initial Phase: the first hour**



## Less invasive hemodynamic monitoring in critically ill patients

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





REVIEW ARTICLE

CRITICAL CARE MEDICINE

Simon R. Finfer, M.D., and Jean-Louis Vincent, M.D., Ph.D., *Editors*

## Circulatory Shock

Jean-Louis Vincent, M.D., Ph.D., and Daniel De Backer, M.D., Ph.D.

Arterial hypotension

**Hypotension :**

SAP < 90 mmHg or MAP < 70 mmHg

### Signs of tissue hypoperfusion

#### Brain

Altered mental state

#### Skin

Mottled, clammy

#### Kidney

Oliguria

Tachycardia

Elevated blood lactate

Altered mental status

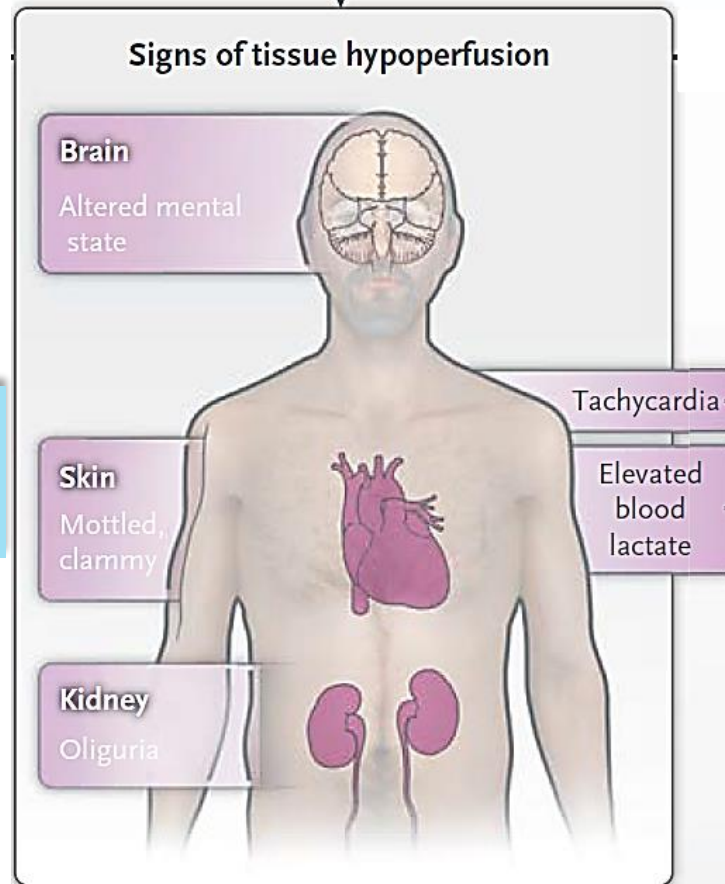
Clinical signs of tissue hypoperfusion

- Mottling
- Increased capillary refill time

Oliguria

**Tachycardia**

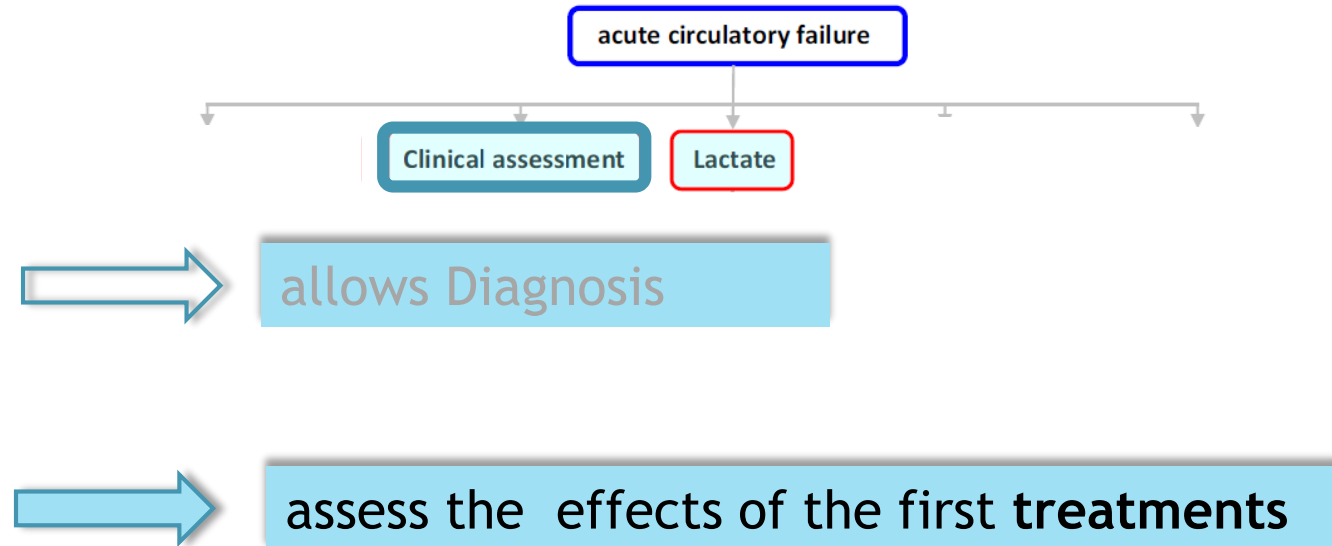
**Hyperlactatemia**





## Less invasive hemodynamic monitoring in critically ill patients

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





- Which monitoring for patients with shock?
  - Initial Phase: the first hour
    - Mottling

RESEARCH

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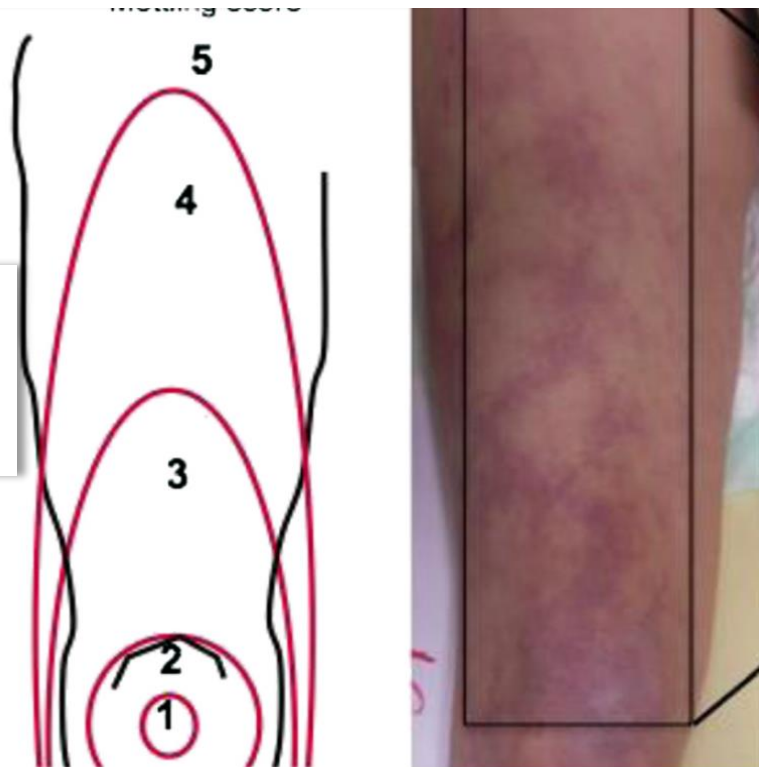
## Alteration of skin perfusion in mottling area during septic shock

Hafid Ait-Oufella<sup>1,2,3\*</sup>, Simon Bourcier<sup>1</sup>, Mikael Alves<sup>1,3</sup>, Arnaud Galbois<sup>1</sup>, Jean-Luc Baudel<sup>1</sup>, Dimitri Margetis<sup>1</sup>, Naïke Bige<sup>1,3</sup>, Georges Offenstadt<sup>1,3,4</sup>, Eric Maury<sup>1,3,4</sup> and Bertrand Guidet<sup>1,3,4</sup>

The skin is an accessible organ that allows a non invasive assesement of tissue perfusion at the bedside

### Motling score:

based on the extension of mottling around the knee

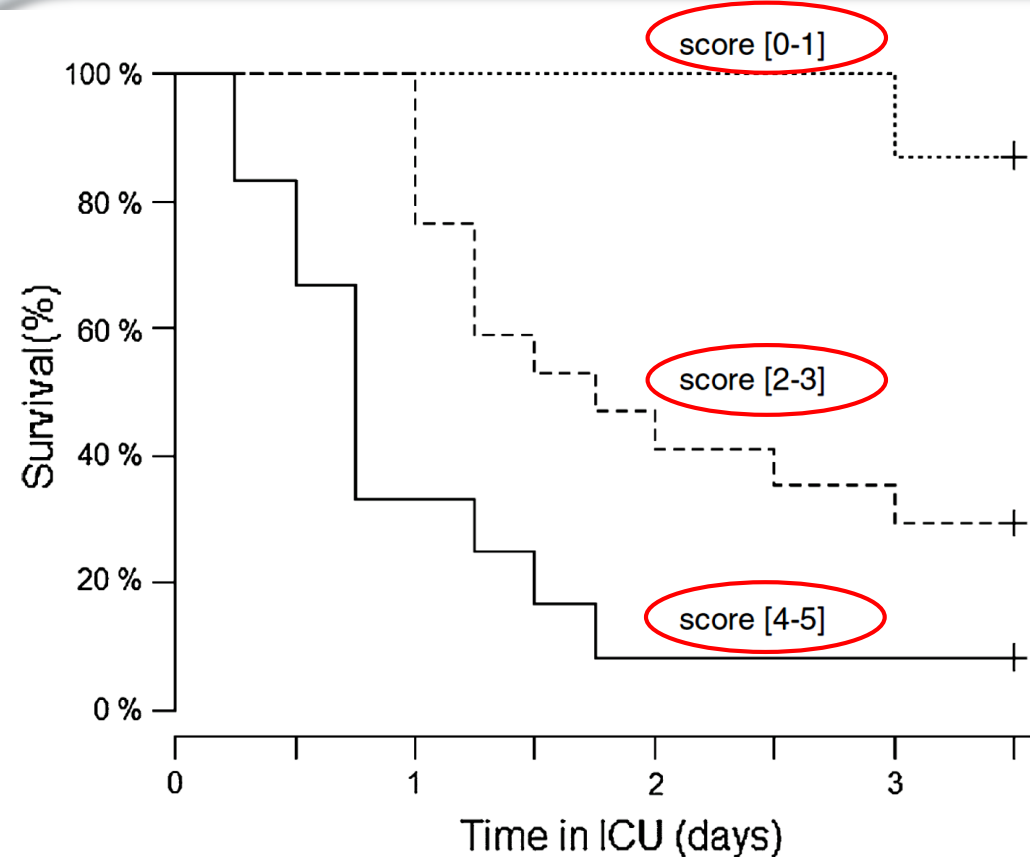


H. Ait-Oufella  
S. Lemoine  
P. Y. Boelle  
A. Galbois  
J. L. Baudel  
J. Lemant  
J. Joffre  
D. Margetis  
B. Guidet  
E. Maury  
G. Offenstadt

## Mottling score predicts survival in septic shock

### Mottling score at H<sub>6</sub>

The higher **the mottling score** at H<sub>6</sub>, the **higher** was **the mortality** rate



- Which monitoring for patients with shock?
  - Initial Phase: the first hour
    - Mottling
    - Capillary Refill Time

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

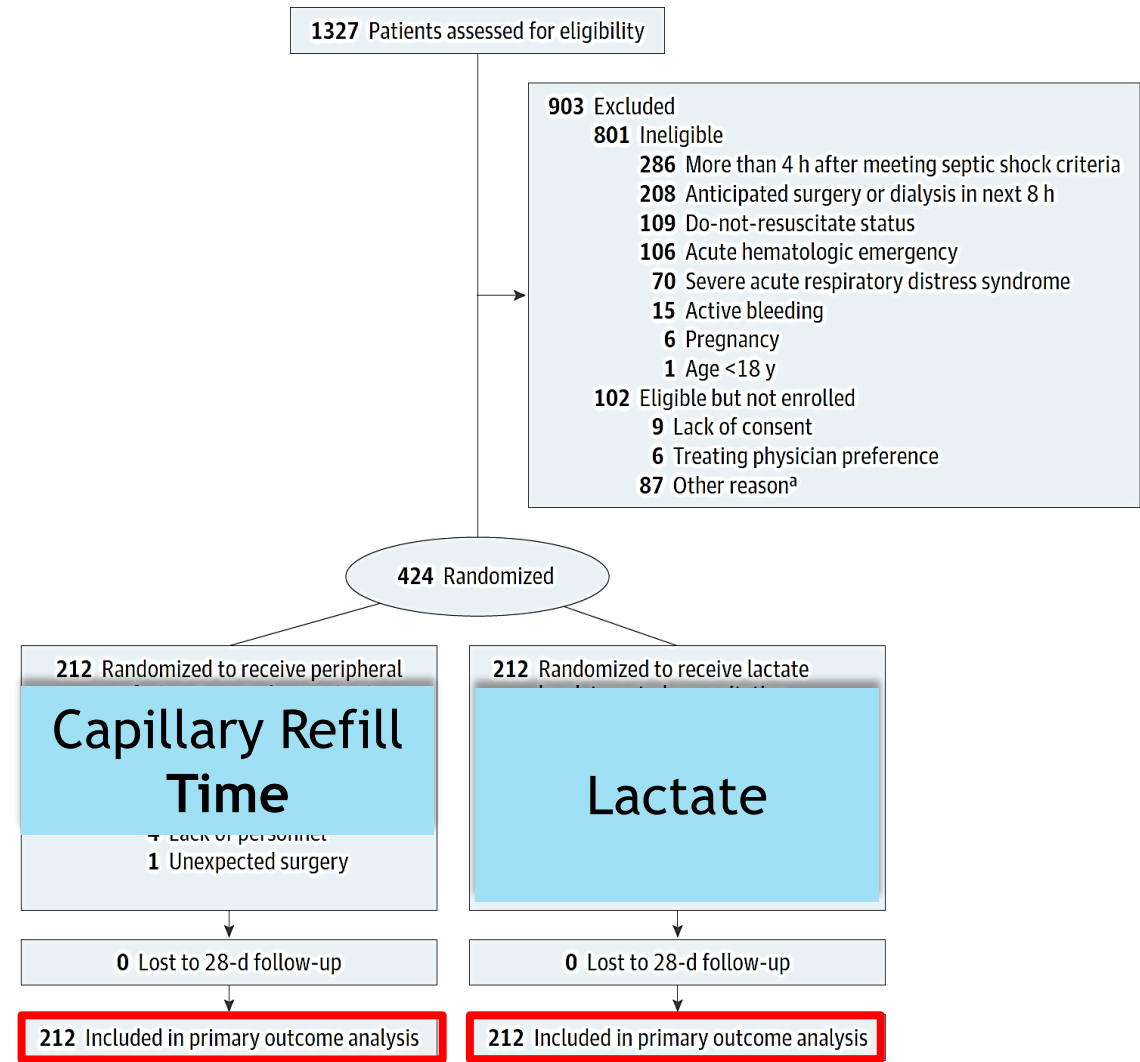
## The ANDROMEDA-SHOCK Randomized Clinical Trial

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 Alegria, 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. 2019;321(7):654-664.



Figure 1. Flow of Participants Through the Study



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

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JAMA. 2019;321(7):654-664.

Table 2. Main Outcomes of the Study of Resuscitation Strategies in Septic Shock

Outcome	Peripheral Perfusion-Targeted Resuscitation (n = 212)	Lactate Level-Targeted Resuscitation (n = 212)	Unadjusted Absolute Difference (95% CI)	Adjusted Relative Measure (95% CI)	P Value
Primary Outcome					
Death within 28 d, No. (%)	74 (34.9)	92 (43.4)	−8.5 (−18.2 to 1.2) <sup>b</sup>	HR, 0.75 (0.55 to 1.02) <sup>a</sup>	.06 <sup>a</sup>
Secondary Outcomes					
Death within 90 d, No. (%)	87 (41.0)	99 (46.7)	−5.7 (−15.6 to 4.2) <sup>b</sup>	HR, 0.82 (0.61 to 1.09) <sup>a</sup>	.17 <sup>a</sup>
Mechanical ventilation-free days within 28 d, mean (SD) <sup>c</sup>	14.6 (12.1)	12.7 (12.2)	1.9 (−0.6 to 4.3)		.14
Renal replacement therapy-free days within 28 d, mean (SD) <sup>c</sup>	18.5 (12.1)	16.9 (12.1)	1.7 (−1.5 to 4.8)		.31
Vasopressor-free days within 28 d, mean (SD) <sup>c</sup>	16.7 (12.0)	15.1 (12.3)	1.6 (−0.7 to 3.9)		.18
SOFA at 72 h, No. <sup>d</sup>	165	166			.045
Mean (SD)	5.6 (4.3)	6.6 (4.7)	−1.00 (−1.97 to −0.02)		



RESEARCH

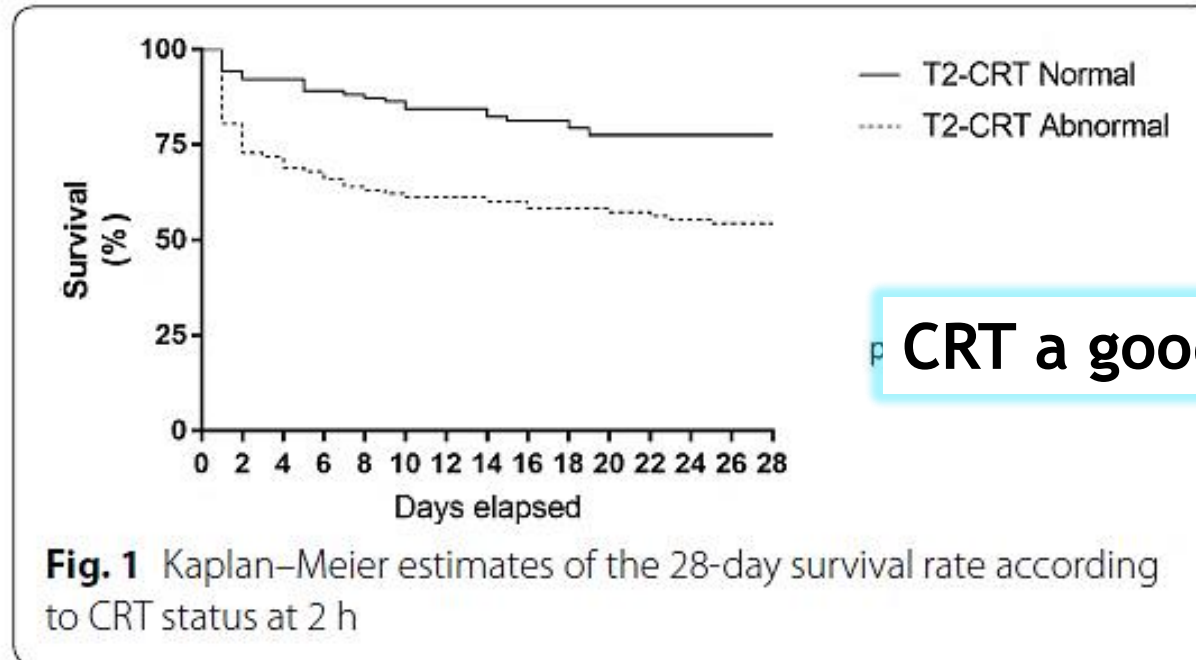
Open Access



# A lactate-targeted resuscitation strategy may be associated with higher mortality in patients with septic shock and normal capillary refill time: a post hoc analysis of the ANDROMEDA-SHOCK study

Eduardo Kattan<sup>1</sup>, Glenn Hernández<sup>1</sup>, Gustavo Ospina Tascón<sup>2</sup>, Emilio Daniel Valenzuela<sup>1</sup>, Jan Bakker<sup>1,3,4,5</sup>, Ricardo Castro<sup>1\*</sup> and The ANDROMEDA-SHOCK Study Investigators and the Latin America Intensive Care Network (LIVEN)

- The **ANDROMEDA-SHOCK trial** compared CRT- vs. lactate-targeted resuscitation in early SS
- ANDROMEDA-SHOCK study included 424 patients
- 378 patients had available data at 2 h



CRT a good parameter to target


Regardless of the study group allocation, patients with normal CRT at 2 Hours, had a **lower mortality** at **D28** compared to patients with abnormal CRT at T2

They received less **resuscitative interventions** and evolved with **lower SOFA** at 24h

## GUIDELINES

# Surviving sepsis campaign: international guidelines for management of sepsis and septic shock 2021



Laura Evans<sup>1\*</sup> , Andrew Rhodes<sup>2</sup>, Waleed Alhazzani<sup>3</sup>, Massimo Antonelli<sup>4</sup>, Craig M. Coopersmith<sup>5</sup>, Craig French<sup>6</sup>, Flávia R. Machado<sup>7</sup>, Lauralyn McIntyre<sup>8</sup>, Marlies Ostermann<sup>9</sup>, Hallie C. Prescott<sup>10</sup>,

*Intensive Care Med*

8. For adults with septic shock, we **suggest** using capillary refill time to guide resuscitation as an adjunct to other measures of perfusion  
*Weak recommendation, low-quality evidence*

- Which monitoring for patients with shock?

- Initial Phase: the first hour

- Mottling
    - Capillary refill time
    - Lactate

## GUIDELINES

# Surviving sepsis campaign: international guidelines for management of sepsis and septic shock 2021



Laura Evans<sup>1\*</sup>, Andrew Rhodes<sup>2</sup>, Waleed Alhazzani<sup>3</sup>, Massimo Antonelli<sup>4</sup>, Craig M. Coopersmith<sup>5</sup>, Craig French<sup>6</sup>, Flávia R. Machado<sup>7</sup>, Lauralyn McIntyre<sup>8</sup>, Marlies Ostermann<sup>9</sup>, Hallie C. Prescott<sup>10</sup>,

*Intensive Care Med*

7. For adults with sepsis or septic shock, we **suggest** guiding resuscitation to decrease serum lactate in patients with elevated lactate level, over not using serum lactate

*Weak recommendation, low-quality evidence*

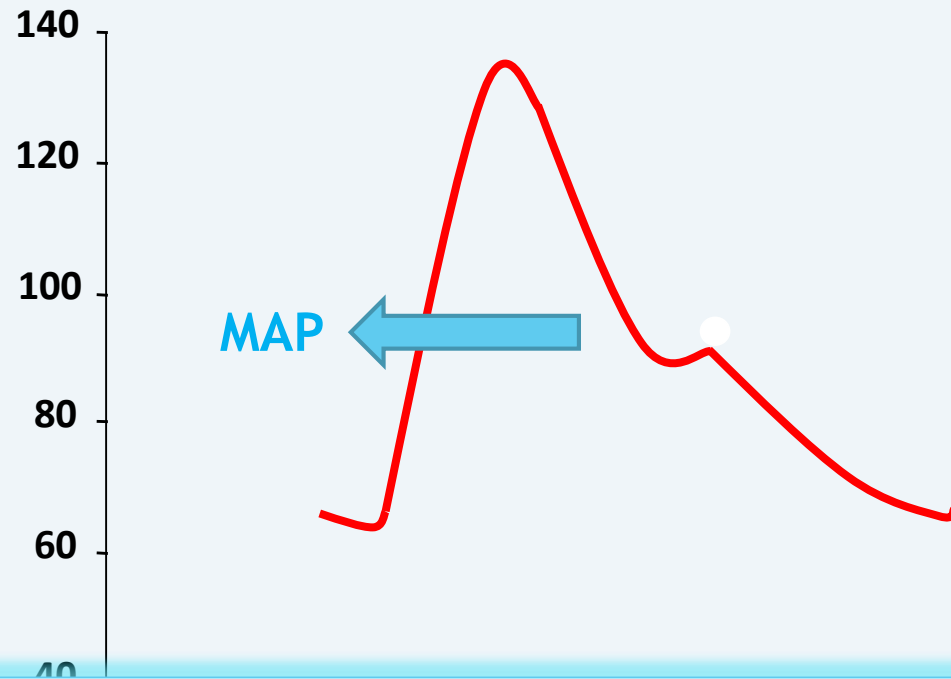
- Which monitoring for patients with shock?

- Initial Phase: the first hour

- Mottling
    - Capillary refill time
    - Lactate
    - Arterial pressure



## Arterial pressure (mmHg)



**MAP:** upstream pressure for perfusion of most vital organs and a target for shock resuscitation

0

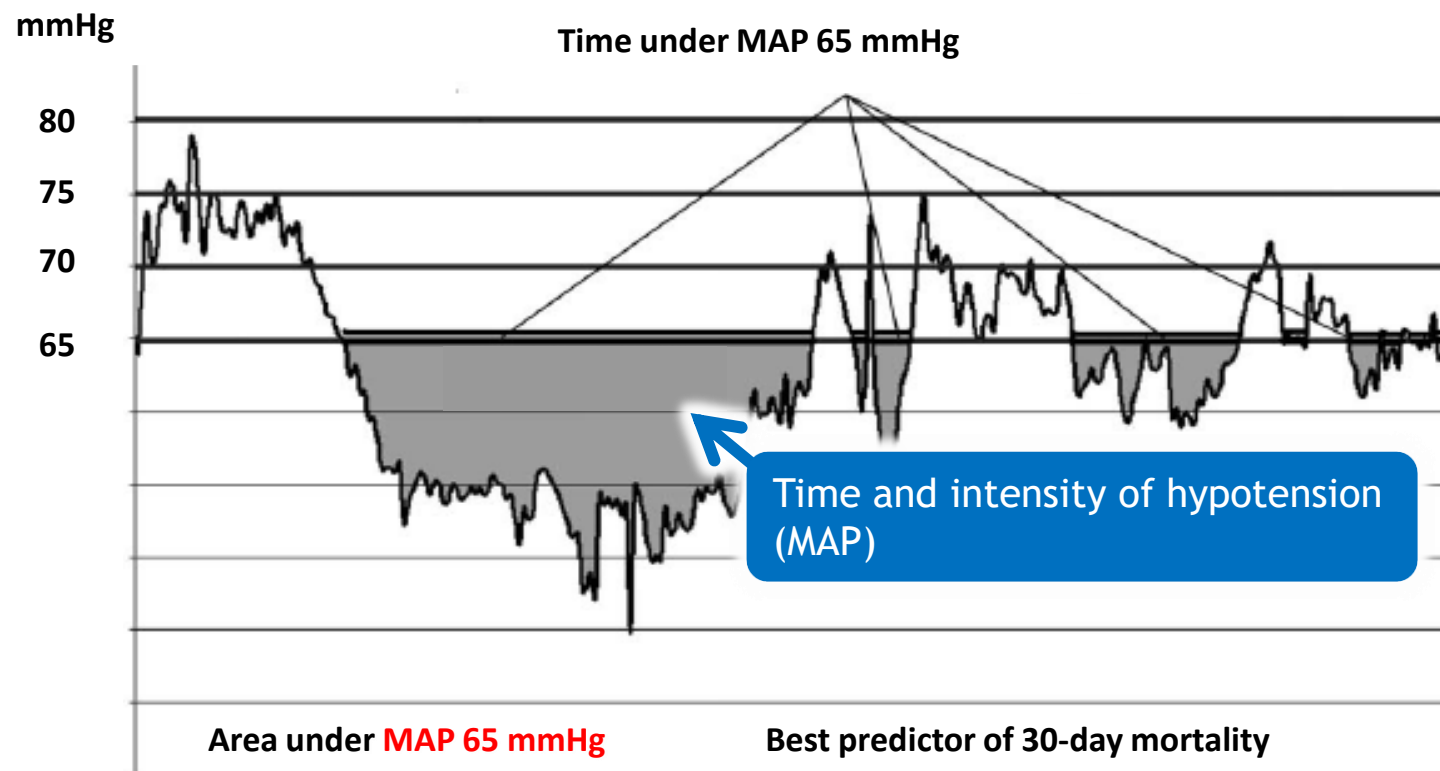
Time



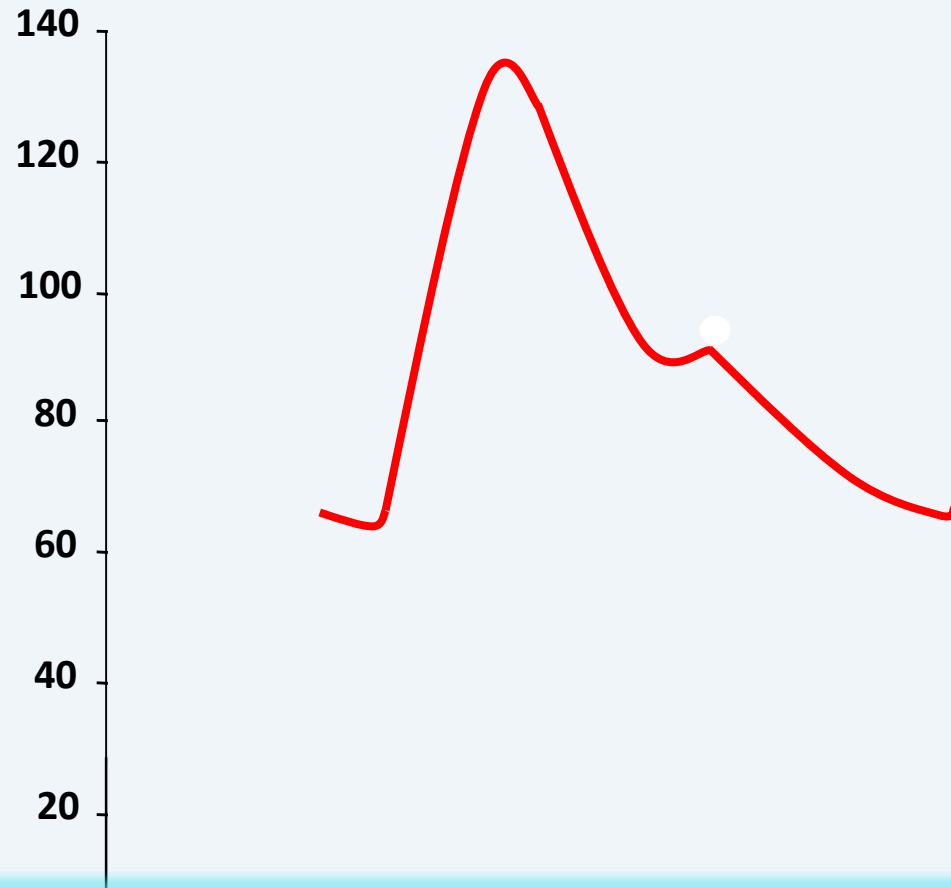
Marjut Varpula  
Minna Tallgren  
Katri Saukkonen  
Liisa-Maria Voipio-Pulkki  
Ville Pettilä

## Hemodynamic variables related to outcome in septic shock

Retrospective cohort  
111 septic shock patients  
30-day mortality



## Arterial pressure (mmHg)



➤ A low **DAP** reflects a low vasomotor tone → introduction of NE

- Which monitoring for patients with shock?

- Initial Phase: the first hour

- Mottling
    - Capillary refill time
    - Lactate
    - Arterial pressure
    - **Echocardiography**



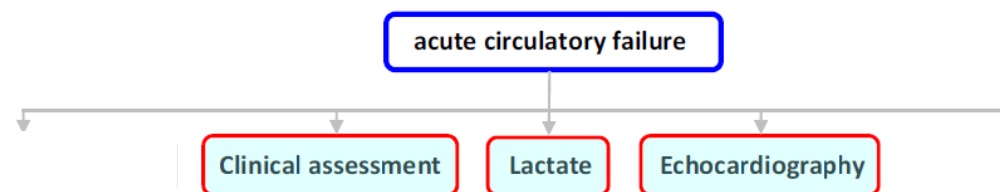
*Intensive Care Med* (2016) 42:1350–1359

CONFERENCE REPORTS AND EXPERT PANEL

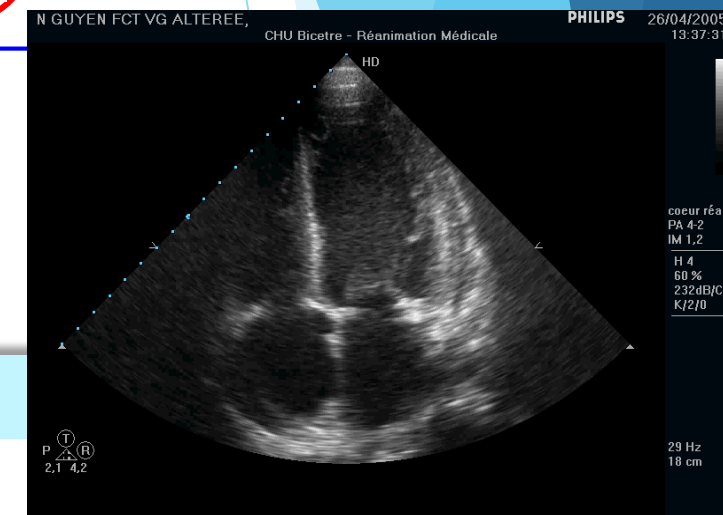


## Less invasive hemodynamic monitoring in critically ill patients

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



Helps for the diagnosis of the **mechanism of shock**





*Intensive Care Med* (2016) 42:1350–1359

## CONFERENCE REPORTS AND EXPERT PANEL



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acute circulatory failure

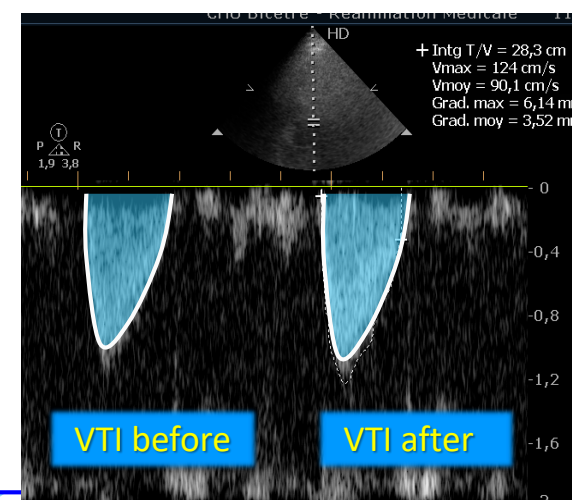
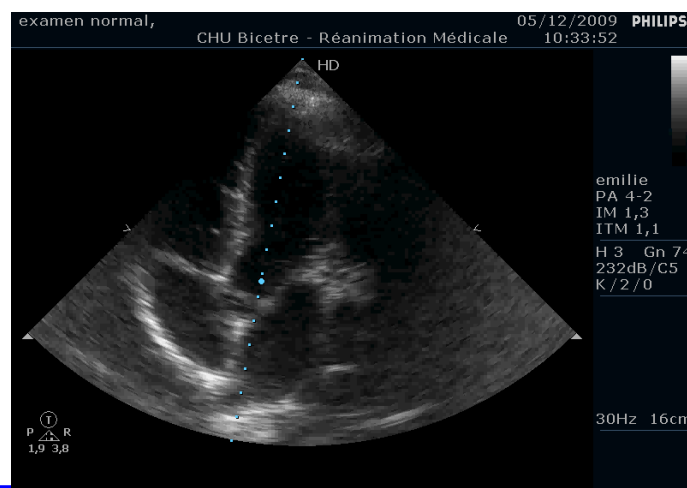
Clinical assessment

Lactate

Echocardiography

Help for the diagnosis of the mechanism of shock

Assess the response to treatment



- Which monitoring for patients with shock?

- Initial Phase: the first hour

- Mottling
    - The capillary refill time
    - Lactate
    - Arterial pressure
    - Echocardiography

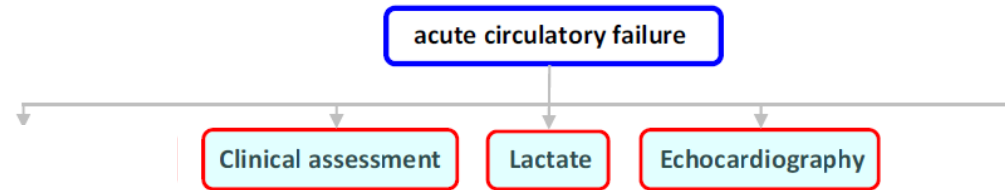
- If shocks **persists** and/or introduction of **catecholamines** :





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- Which monitoring for patients with shock? ?

- Initial Phase: the first hour

- Mottling
    - The capillary refill time
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    - Arterial pressure
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- If shocks **persists** and/or introduction of **catecholamines** :

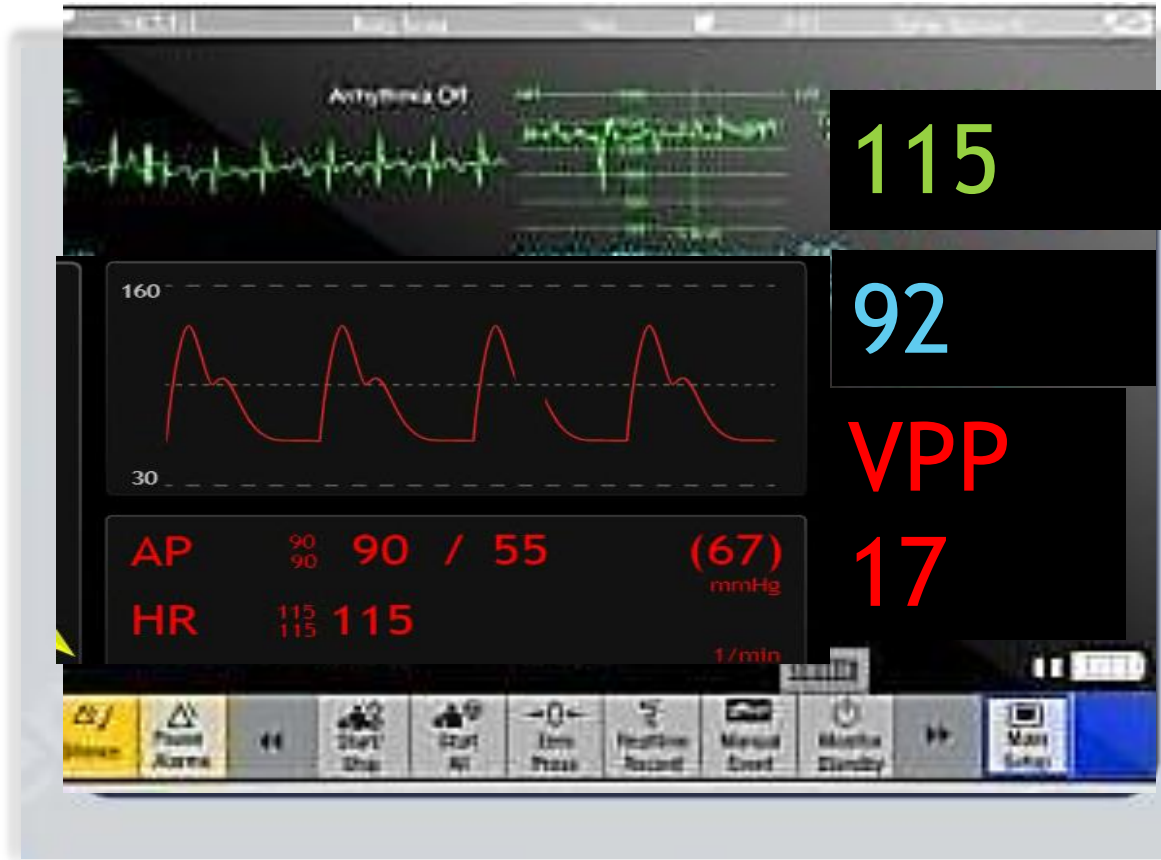
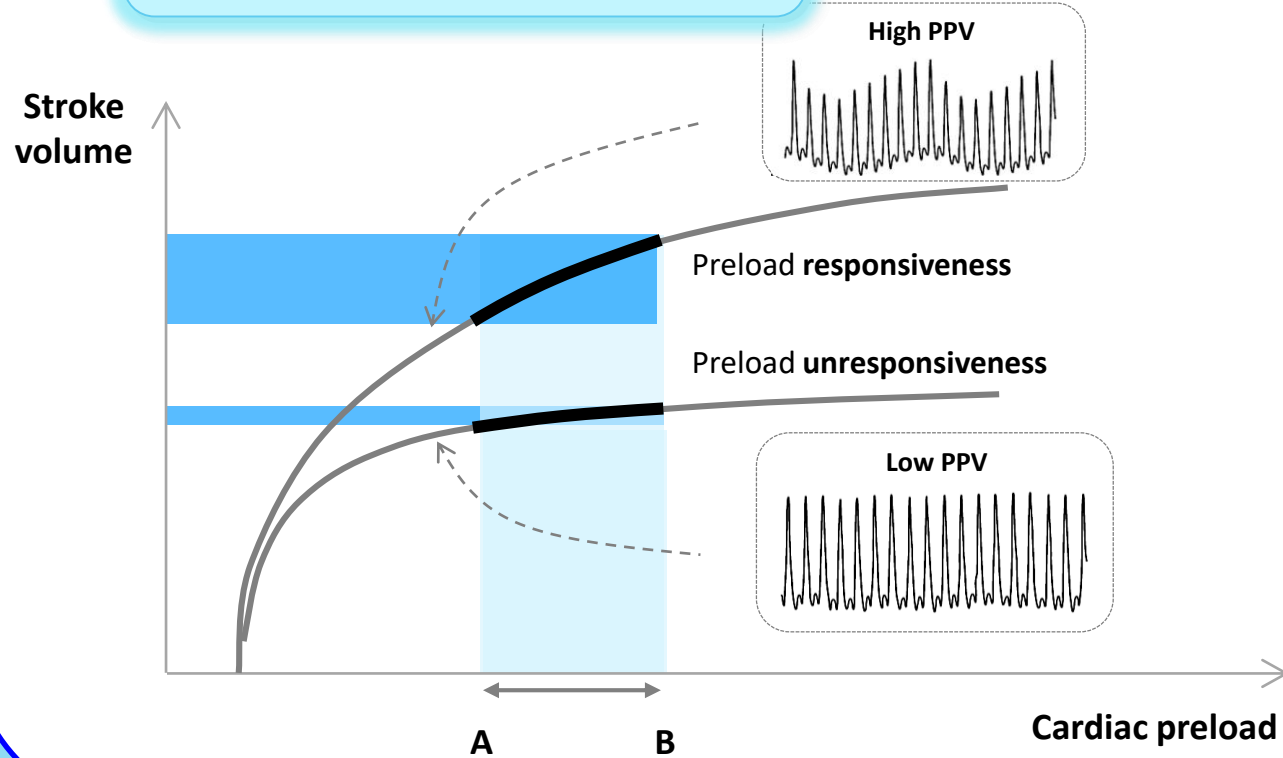
- Arterial Catheter: In addition to the absolute values of AP: PPV

# Arterial Pulse Pressure Variation with Mechanical Ventilation

Jean-Louis Teboul<sup>1</sup>, Xavier Monnet<sup>1</sup>, Denis Chemla<sup>2</sup>, and Frédéric Michard<sup>3</sup>

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

## Applied Physiology



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

Frederic Michard<sup>1\*</sup>, Denis Chemla<sup>2</sup> and Jean-Louis Teboul<sup>3</sup>

*Critical Care* (2015) 19:144

	False positive	False negative
<b>L</b> Low HR/RR ratio (Extreme bradycardia or high frequency ventilation)		✓
<b>I</b> Irregular heart beats	✓	
<b>M</b> Mechanical ventilation with low tidal volume		
<b>I</b> Increased abdominal Pressure (Pneumoperitoneum)	✓	
<b>T</b> Thorax open		✓
<b>S</b> Spontaneous breathing	✓	✓

Limits of applicability

- Which monitoring for patients with shock?

- Initial Phase: the first hour

- Mottling
    - The capillary refill time
    - Lactate
    - Arterial pressure
    - Echocardiography

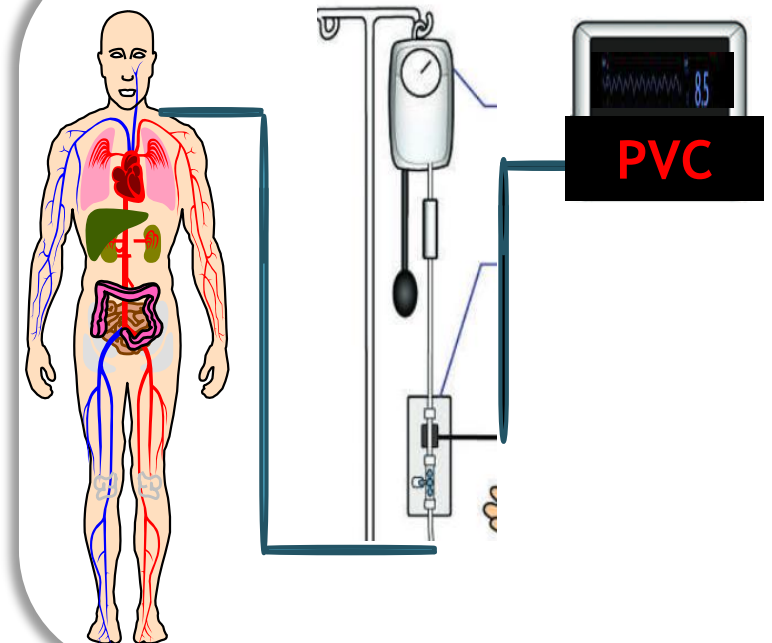
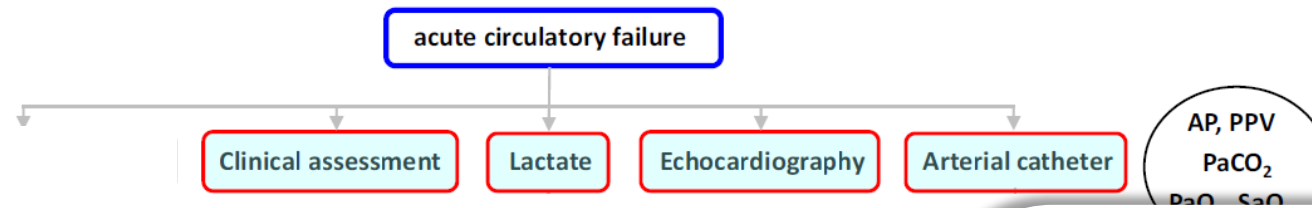
- If shocks **persists** and/or introduction of **catecholamines** :

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



## Less invasive hemodynamic monitoring in critically ill patients


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## SPECIAL ISSUE INSIGHT

# Central venous pressure (CVP)

Olfa Hamzaoui<sup>1\*</sup>  and Jean-Louis Teboul<sup>2,3</sup>

*Intensive Care Med* (2022) 48:1498–1500

## Take-home message

Central venous pressure is a pivotal hemodynamic variable, since it provides important information on the right ventricular function and on the mean organ perfusion pressure.

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

Marlies Ostermann<sup>1\*</sup>, Anna Hall<sup>2</sup> and Siobhan Crichton<sup>3</sup>

*BMC Nephrology* (2017) 18:151


- **Retrospective** analysis of patients admitted to ICU
- **2118 ICU patients: 790 patients (37%) developed AKI**
- **205 underwent** advanced haemodynamic monitoring within 12 h of AKI stage I.

**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.

## SPECIAL ISSUE INSIGHT

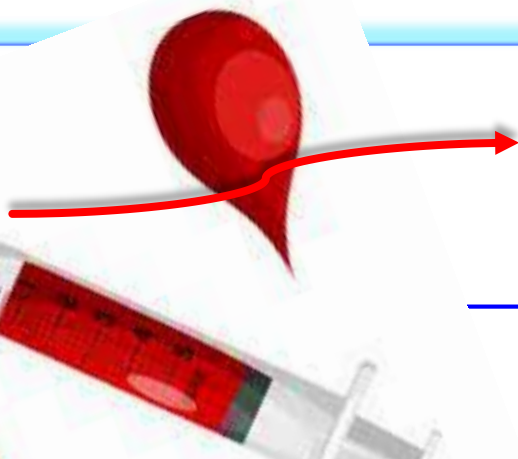
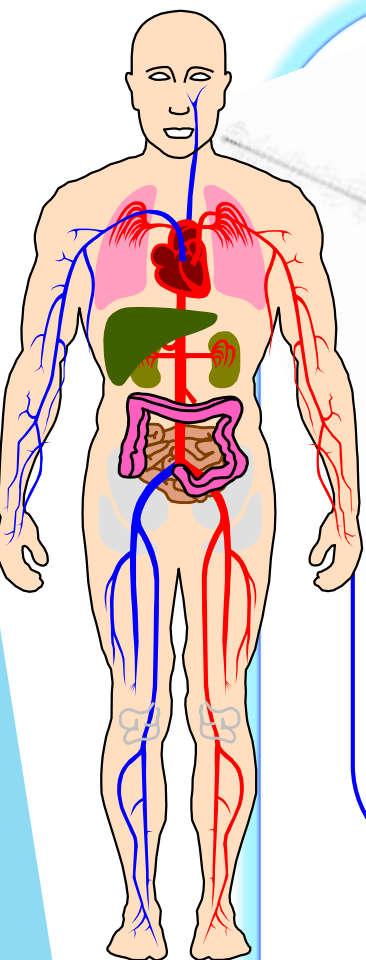
# Central venous pressure (CVP)

Olfa Hamzaoui<sup>1\*</sup>  and Jean-Louis Teboul<sup>2,3</sup>

*Intensive Care Med* (2022) 48:1498–1500

## Take-home message

Central venous pressure is a pivotal hemodynamic variable, since it provides important information on the right ventricular function and on the mean organ perfusion pressure. CVP cannot be used to predict fluid responsiveness.



Gaz veineux: ScVO<sub>2</sub>



➤ CVP

➤ ScvO<sub>2</sub>

*Intensive Care Med (2016) 42:1350–1359*

CONFERENCE REPORTS AND EXPERT PANEL



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ScvO<sub>2</sub> is an acceptable reflection of SvO<sub>2</sub>

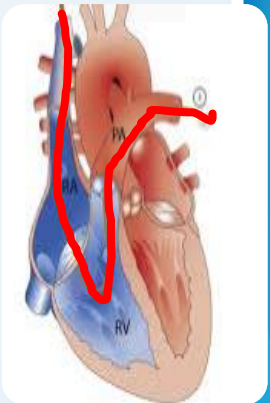
$$\text{ScvO}_2 = \text{SaO}_2 - \frac{\text{VO}_2}{\text{CO} \times \text{Hb} \times 13.4}$$



**ScvO<sub>2</sub>** indicator of the **VO<sub>2</sub> / DO<sub>2</sub>** balance





- A low **ScvO<sub>2</sub>** may encourage to increase **DO<sub>2</sub>**  
(mostly through **an increase in CO**)





## Equilibrating SSC guidelines with individualized care

Jean-Louis Vincent<sup>1\*</sup> , Mervyn Singer<sup>2</sup>, Sharon Einav<sup>3</sup>, Rui Moreno<sup>4</sup> , Julia Wendon<sup>5</sup>, Jean-Louis Teboul<sup>6</sup>, Jan Bakker<sup>7,8,9,10</sup>, Glenn Hernandez<sup>11</sup>, Djillali Annane<sup>12</sup>, Angélique M. E. de Man<sup>13</sup>, Xavier Monnet<sup>14</sup>, V. Marco Ranieri<sup>15</sup>, Olfa Hamzaoui<sup>16</sup>, Jukka Takala<sup>17</sup>, Nicole Juffermans<sup>18,19</sup>, Jean-Daniel Chiche<sup>20</sup>, Sheila N. Myatra<sup>21</sup> and Daniel De Backer<sup>22</sup>

*Critical Care* (2021) 25:397

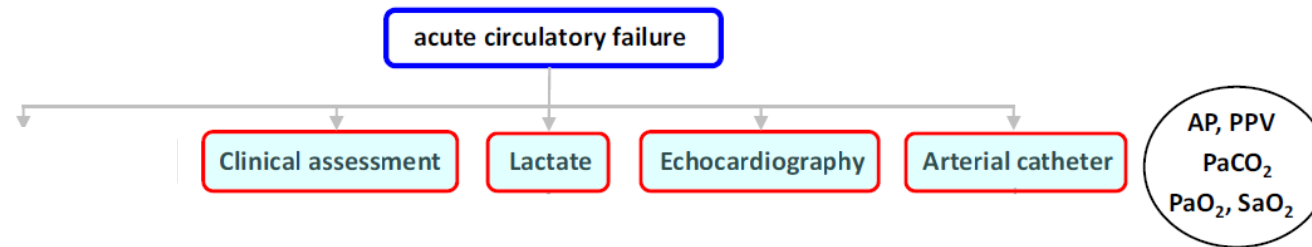
## Hemodynamic management

➡ We recommend **optimizing oxygen delivery**, based on clinical assessment complemented by careful hemodynamic assessment including measurement of **mixed (or central) venous oxygen saturation (SvO<sub>2</sub>)** and even carbon dioxide-derived variables



## Less invasive hemodynamic monitoring in critically ill patients

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



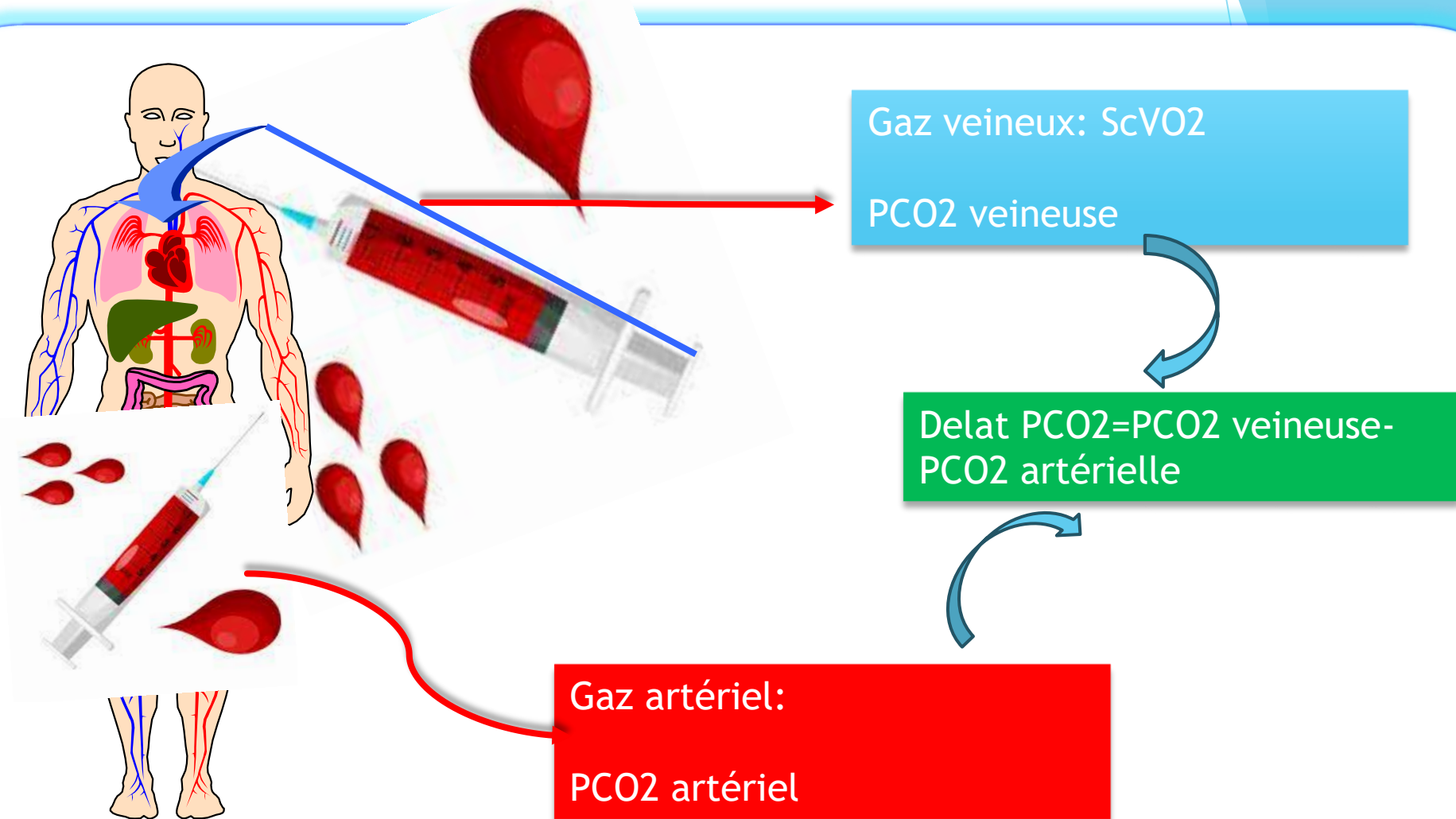
➤ CVP

➤ ScvO<sub>2</sub>

➤ Veno-arterial difference of PCO<sub>2</sub> : PCO<sub>2</sub> gap

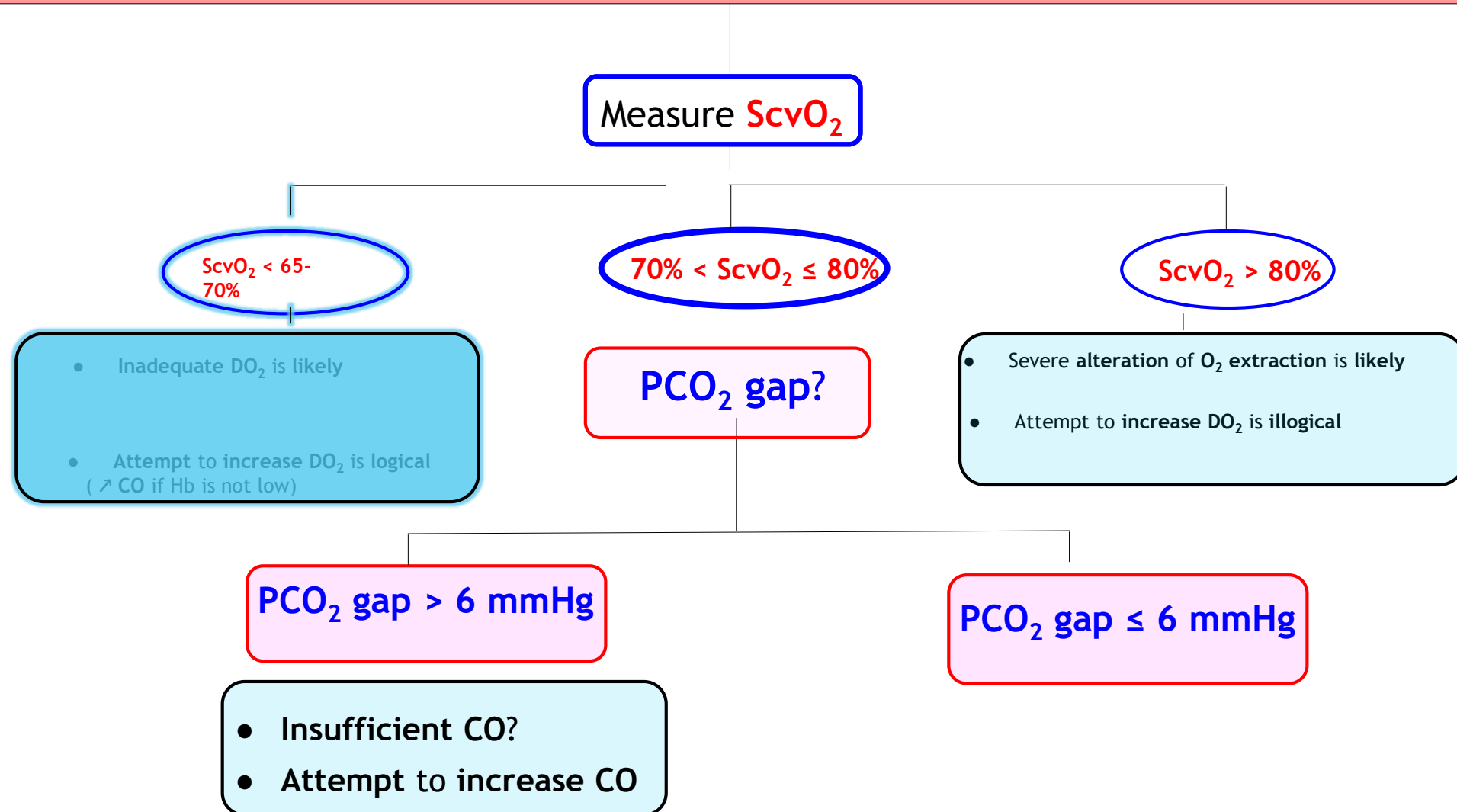


## Cathéter veineux central



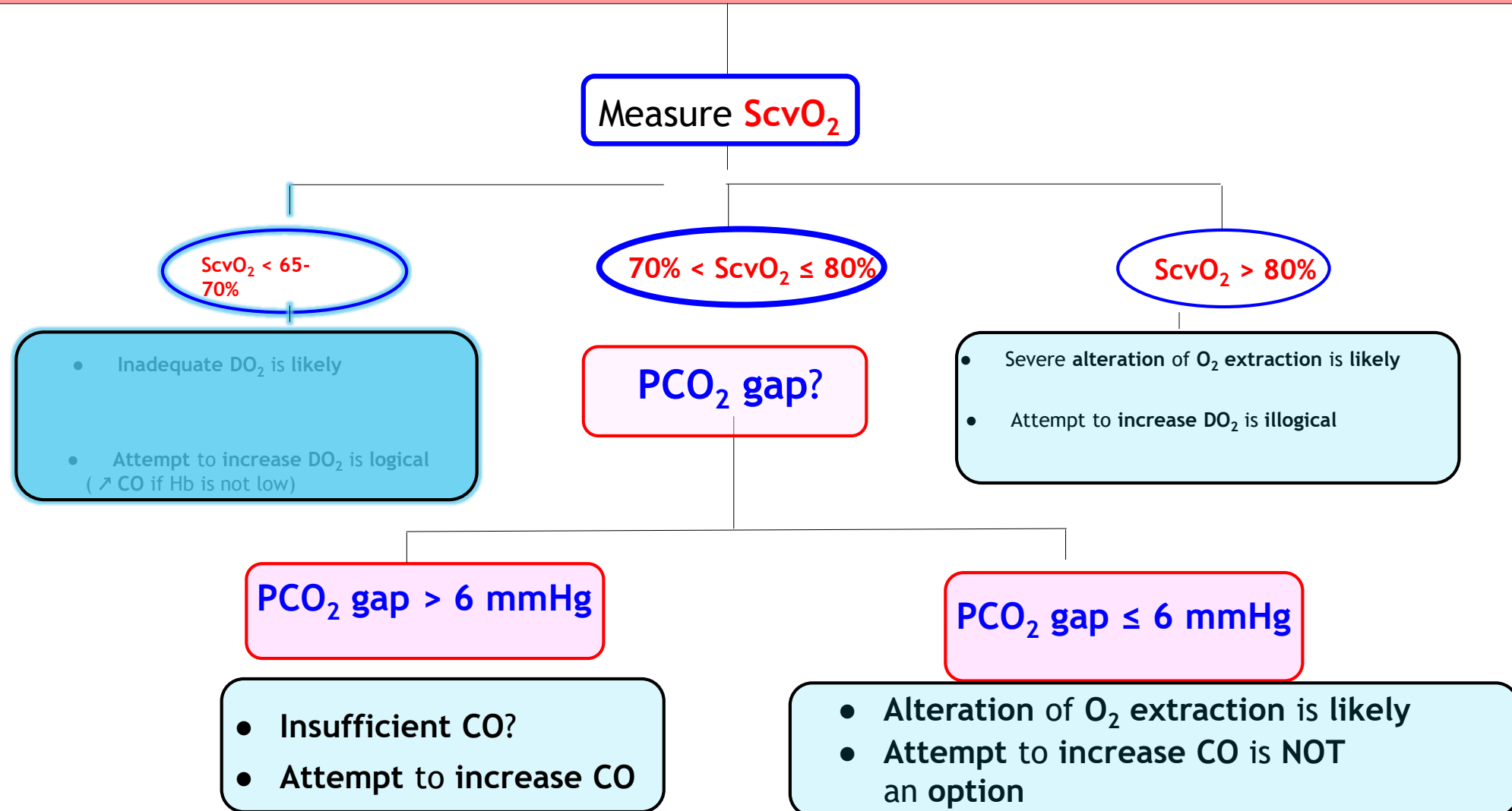
## Patient with septic shock

(hypotension and/or mottling and/or increased capillary refill time and/or hyperlactatemia)



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(hypotension and/or mottling and/or increased capillary refill time and/or hyperlactatemia)



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

- **Initial Phase: the first hour**

- Mottling
    - The capillary refill time
    - Lactate
    - Arterial pressure
    - Echocardiography

- **If shocks persists and/or introduction of catecholamines :**

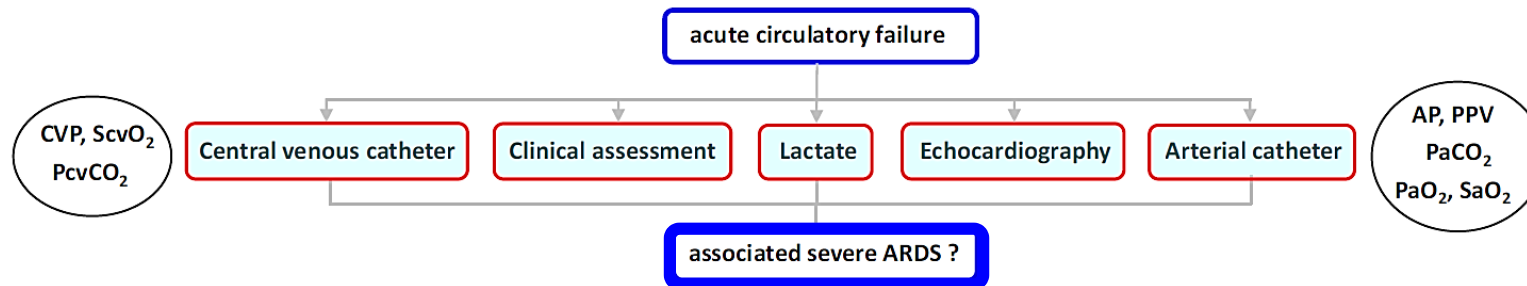
- **Arterial Catheter:** In addition to the absolute values of AP: PPV
    - **Central Venous Catheter**

- **If shock persists and/or if ARDS: discuss an advanced hemodynamic monitoring**

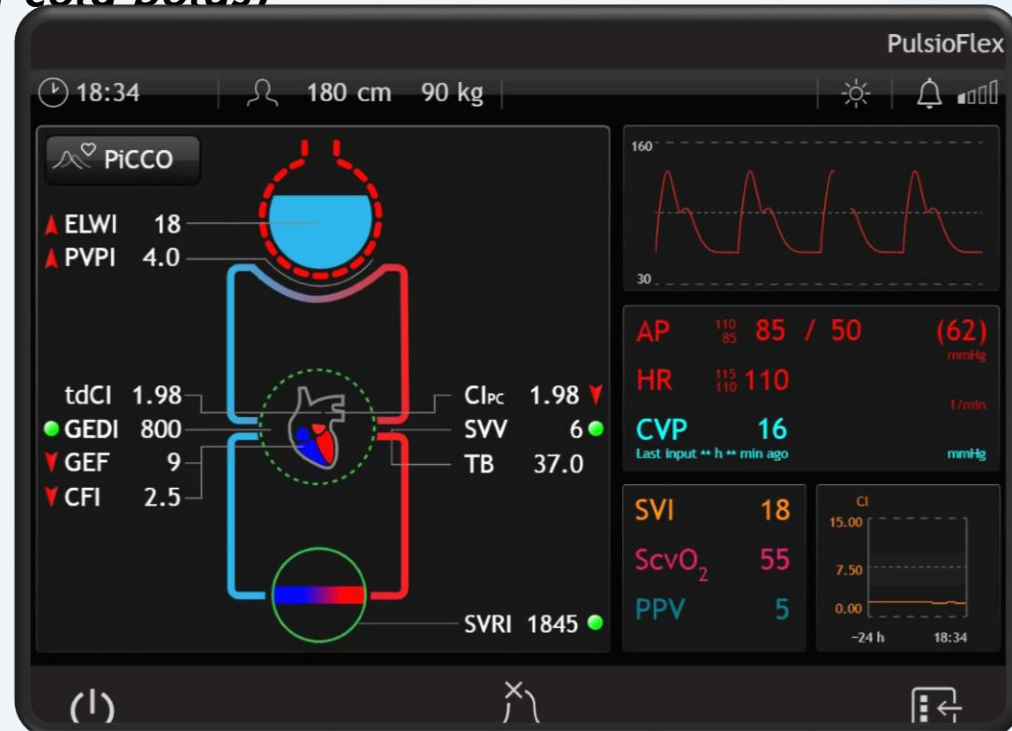
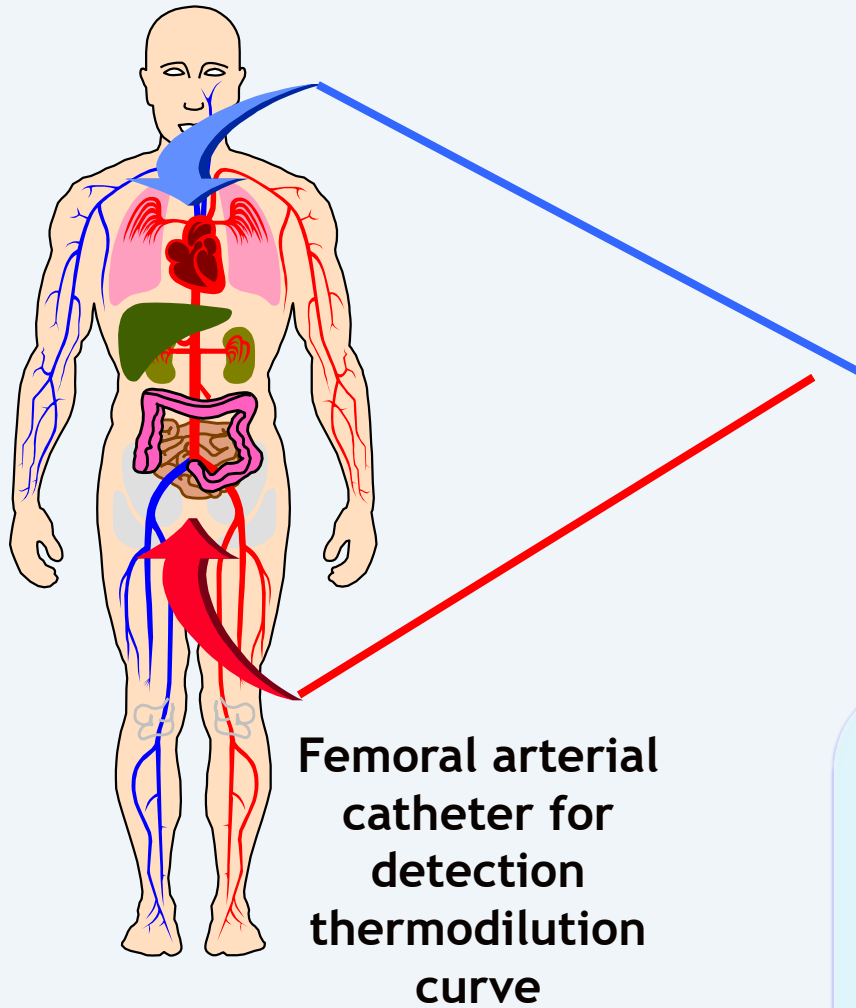


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## Central venous catheter(*injection of cold bolus*)



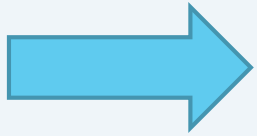
## Transpulmonary Thermodilution (TPTD)

→ Intermittent Cardiac output

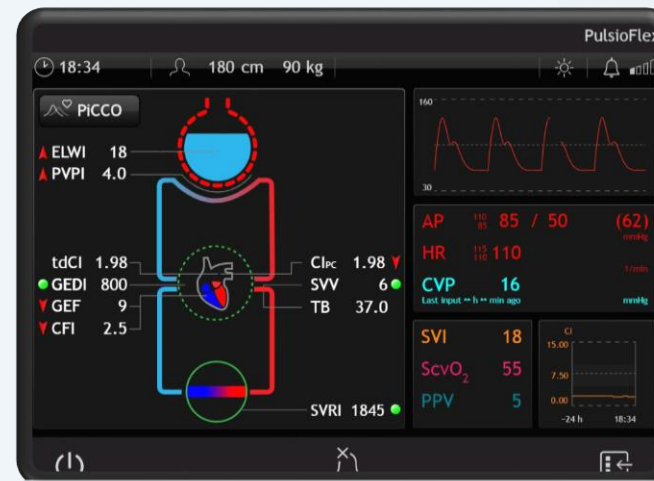
## Pulse contour analysis

(after calibration by TPTD)

→ Continuous cardiac output



# Pas que

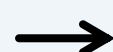


1- Volume télédiastolique global (VTDG) :



marqueur de précharge

2- Eau pulmonaire Extravasculaire (EPEV)



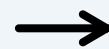
mesure de la quantité d'œdème pulmonaire

3- Indice de perméabilité vasculaire pulmonaire (PVPI)



mesure du degré de fuite capillaire

4- Indice de fonction cardiaque



Index de fonction cardiaque



Transpulmonary thermodilution :  
Useful for **guiding fluid management**  
especially in patients with **shock** and **ARDS**

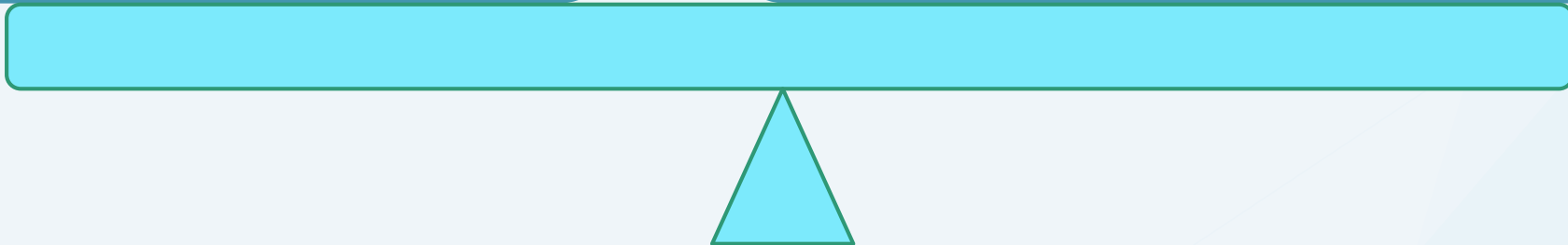
Fluid infusion **benefit** / **risk** ratio

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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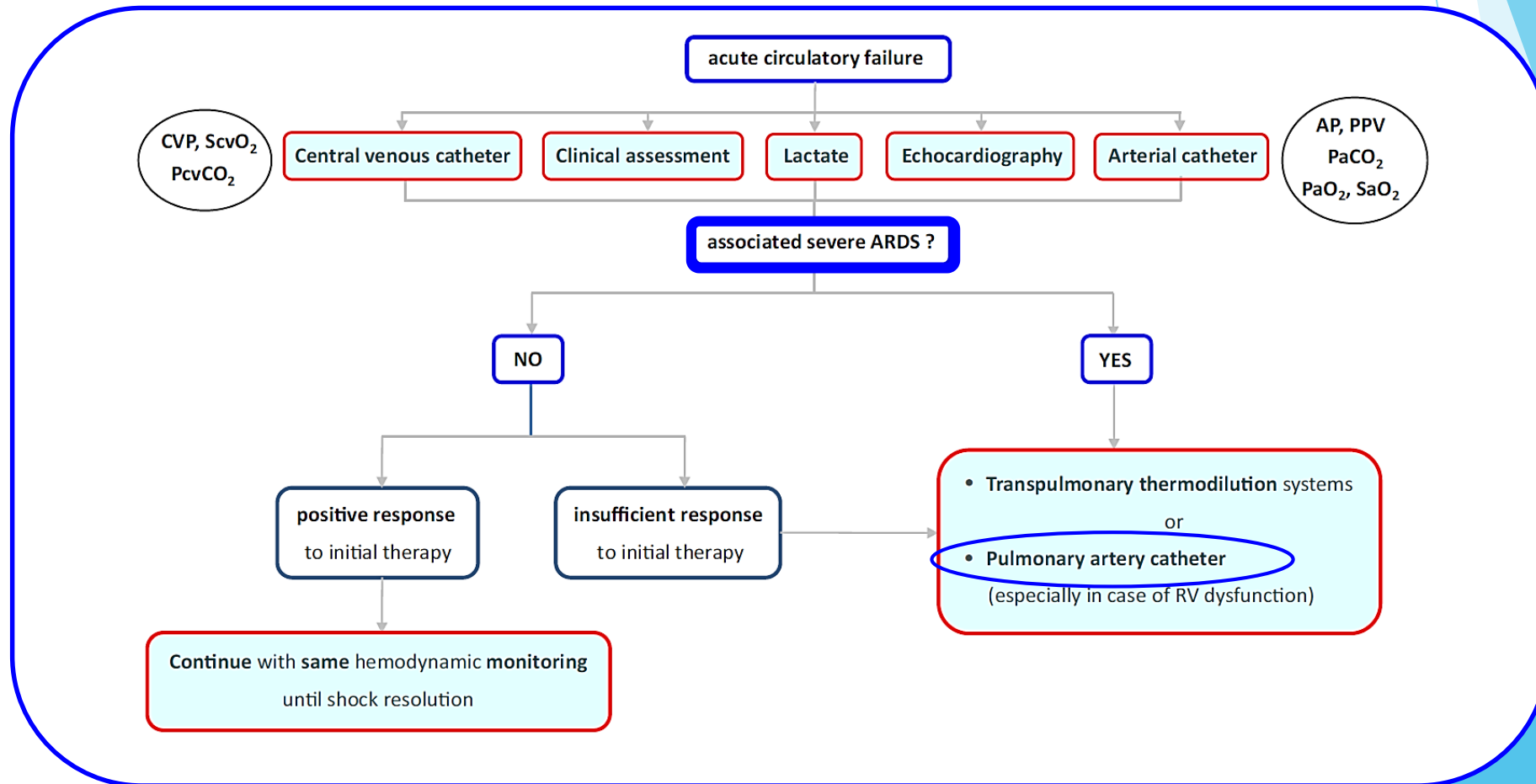
⇒ **decision**

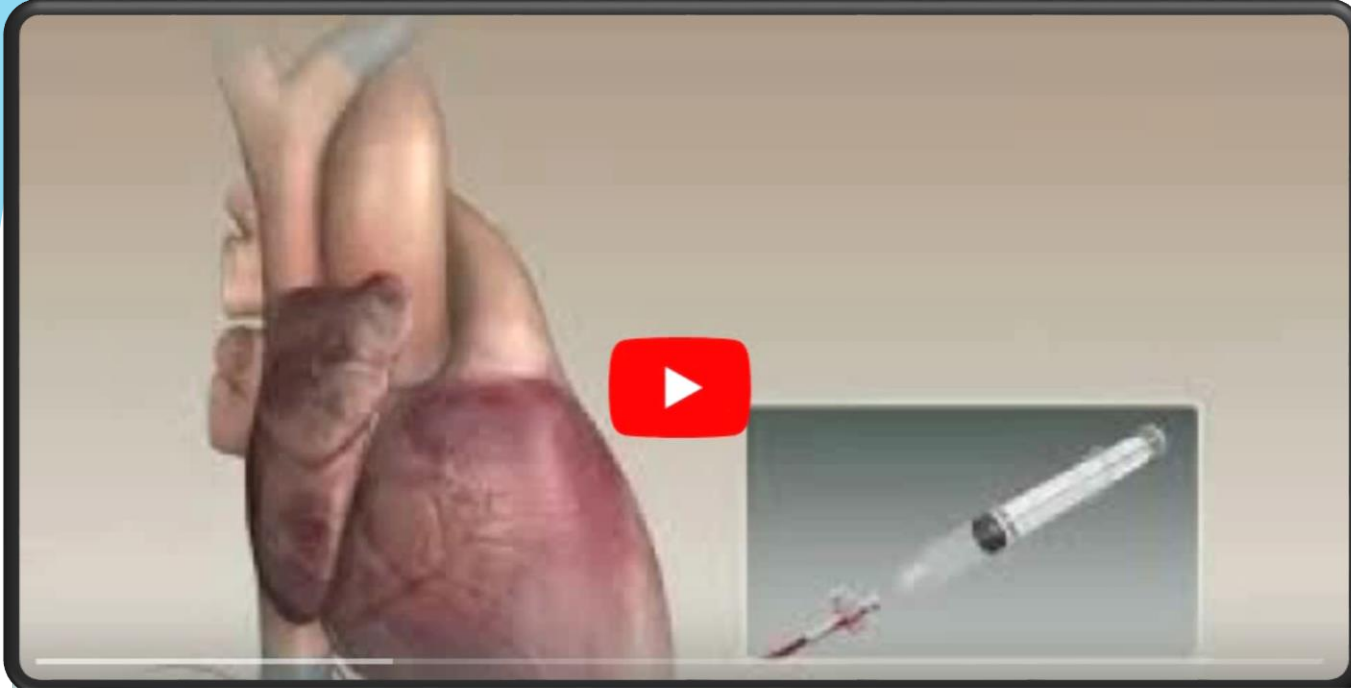
- **to start**
- **to continue** fluid infusion
- **to stop**



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- **Débit cardiaque:** intermittent/temps réel
- **PAP:** pression artérielle pulmonaire
- **PAPO:** pression de remplissage de l'OG
- **SVO2** sang veineux mêlé

# Key messages

Hemodynamic monitoring is essential for an optimal management of shock patients

- Initial Phase: **Clinical examination**, **blood pressure**, **lactate** and **echocardiography** are often sufficient to make the **diagnosis**, elucidate the **mechanisms** of shock and **assess** the **effects** of the first therapies
- If shock persists and/or introduction of catecholamines → arterial catheter and central venous catheter
  - **PPV** to predict fluid responsiveness if MV (limits of applicability)
  - **CVP** to adjust the optimal MAP target and to detect RV dysfunction
  - **ScvO<sub>2</sub>** to detect inadequacy between DO<sub>2</sub> and VO<sub>2</sub>
  - **ΔPCO<sub>2</sub>** to detect inappropriate CO (if normal ScvO<sub>2</sub> in cas of O<sub>2</sub> extraction abnormalities)
- If shock is still persisting and/or associated ARDS, discuss:
  - **Transpulmonary Thermodilution**
  - **Pulmonary artery catheter**