The hemodynamic triangle: Cardiac output, Preload, EVLW

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What do we want?

I wish for world peace and end of global hunger
What do we want?

And optimal O2 delivery for all critically ill patients
• This will be provided with an adequate CO
• Appropriate oxygenation
• With adequate perfusion pressure
Cardiac Output

Preload
fluid responsiveness

EVLW
Consider this

- A 75 year old man is brought to the ER
- He has had fever for 3-4 days, with nausea and vomiting
- He is confused,
  - BP - 85/40
  - HR - 120
  - Lactate - 4.5
  - ScVO2 - 60%

1. fluids
2. Dopamine
3. Noradrenaline
4. Vasopressin
But what if it is a patient in your ICU

- 65 year old man post abdominal surgery
- Develops high fever, increase in WBC
  - BP 90/40
  - HR 110
  - CVP 10
  - Lactate 4.0
  - ScVO2 78%

What’s his cardiac output?
1. Fluids
2. Dopamine
3. Noradrenaline
4. Vasopressin
ScVO2

- Used as a surrogate marker for CO depending on O2 consumption
Measurement is critical
Why measure CO?

- Surrogate markers can be misleading
  - Blood pressure
  - ScVO2

- Cardiac output is the basis for calculations of oxygen delivery and consumption
The PiCCO and $\text{CO}$

- **Thermodilution**
  - Arterial thermodilution
  - Volume measurement

- **Pulse contour $\text{CO}$**
  - SVV
Comparison of cardiac output measurements by arterial trans-cardiopulmonary and pulmonary arterial thermodilution with direct Fick in septic shock

G. Marx*, T. Schuerholz*, R. Sümpelmann†, T. Simon*, M. Leuwer*
Cardiac output monitoring: aortic transpulmonary thermodilution and pulse contour analysis agree with standard thermodilution methods in patients undergoing lung transplantation

[Le monitorage du débit cardiaque : la thermodilution aortique transpulmonaire et l’analyse de la conformation du pouls concordent avec les méthodes de thermodilution normalisées chez des patients qui subissent une greffe pulmonaire]

Giorgio Della Rocca MD,* Maria Gabriella Costa MD,* Cecilia Coccia MD,* Livia Pompei MD,* Pierangelo Di Marco MD,† Vincenzo Vilardi MD,‡ Paolo Pietropaoli MD†
Why measure CO?

• Surrogate markers can be misleading
  - Blood pressure
  - ScVO2

• Cardiac output is the basis for calculations of oxygen delivery and consumption

• The behavior of CO can indicate response to therapy
<table>
<thead>
<tr>
<th>Variable</th>
<th>Value 1</th>
<th>Value 2</th>
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**Time ST**

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<th>Time</th>
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**Time ST**

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Cardioversion
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<th>Time</th>
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<th>음성 비도</th>
<th>معهد</th>
<th>بدكت</th>
<th>أمود</th>
<th>نولمان</th>
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- **amiodarone**
- **Cardioversion**
But even when we know the cardiac output....

- A 56 year old man develops sepsis following 4 days after admission due to trauma
- BP – 100/60
- HR – 120
- CVP – 11 mmhg
- CI – 2.8 L/M/M2
- Lactate – 4.0

- We want to increase his CO and O2 delivery.... But how?
  - Fluids?
  - Inotropes?
Which is the appropriate approach?
You must measure Preload
(And pay attention to fluid responsiveness)
• When there is hypotension with a low cardiac output
• What is the mechanism of low cardiac output?
• Preload is important
• Fluid responsiveness is the key
ITBV vs. CVP and PAOP in a model of graded hemorrhage in pigs

<table>
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<tr>
<th>Parameter</th>
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<tr>
<td>ITBV</td>
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<td>CVP</td>
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<td>PAOP</td>
<td>0.90</td>
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(*) correlation between the parameter and the degree of volume change

Volumetric preload measurement by thermodilution: a comparison with transoesophageal echocardiography

- Twenty patients undergoing elective cardiac surgery with preserved left-right ventricular function were studied after induction of anesthesia.
- Conventional hemodynamic variables, were recorded before and 20 and 40 min after fluid replacement therapy.

Hofer et al
BJA 2005
When we know the CO

- A patient in the ICU with sepsis due to a pneumonia
- Patient has known severe CHF EF - 18%
- Is now hypotensive, tachycardic and a CI of 1.8 L/M/M2
- CVP is 18

1. His preload is fine - the CVP indicates this
2. His preload may not be adequate - we know he has CHF
3. His preload may be high - diurese him
Changed compliance and size confound assessment of preload
Will the patient respond to our therapy?

Can we predict his response?

A high SVV, SPV and PPV indicate a fluid responsive patient who will increase stroke volume and cardiac output in response to fluid bolus.
Stroke Volume and Pulse Pressure Variation for Prediction of Fluid Responsiveness in Patients Undergoing Off-Pump Coronary Artery Bypass Grafting

Hofer
Chest, 2005
These results primarily demonstrate the ability of SVV to predict fluid responsiveness in mechanically ventilated patients with reduced myocardial function.

With continuous measurement of CO, on-line monitoring of SVV might help to guide and optimize fluid therapy to avoid unnecessary and potentially harmful volume overloading in high-risk patients after cardiac surgery.
Will this patient respond to a fluid challenge with an increase in his CO?

- A 76 year old man with pneumonia is in the ICU
- His vital signs are
  - BP - 100/45
  - HR - 110
  - CVP - 14
  - CI - 2.0 L/M/M2
  - SVV - 18% (normal 10-12%)

Yes, Yes, Yes !!!!
• 60 year old patient with severe IHD after CABG with poor LV function
• BP - 100/60
• HR - 90
• CI - 2.2 L/M/M2
• CVP 16
• SVV - 8%

That’s not gonna happen Doctor, Low SVV
Limitations

- Arrhythmia
- High intrathoracic pressures
- Spontaneous ventilation
EVLW

- The final point of the triangle is the degree of pulmonary edema
Effect on decision making

• Patients with significant pulmonary edema should not be fluid overloaded
• Fluid restriction therefore will depend on the assessment degree of pulmonary edema
• Usually quantified by looking at the CXR
The CXR is a poor tool for quantifying EVLW

• 18 year old girl injured in a bus bomb
• Burns to face chest and hands
• Hypotensive
  - pO2/FiO2 - 85
21 year old girl injured by a car bomb

- Burns to face, torso
- Amputation of both legs

EVLWI – 19ml/kg

EVLWI – 7ml/kg
Summary of CXR assessment by 5 clinicians

Classification of PE by 5 clinicians

EVLW ml/Kg

- normal
- moderate
- severe
CXR interpretation

- Normal Vs. Moderate: p > 0.05
- Normal Vs. Severe: p < 0.001
- Moderate Vs. Severe: p < 0.05
Hypotension?

Cardiac output

Preload

Fluid responsiveness

Extravascular lung water
Thank you for your attention