Hemodynamic Monitoring and Management in the ICU

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Roadmap

• Basics
• Hemodynamic parameters for monitoring and management
• A sensible approach to choosing the right monitoring
• Algorithms for hemodynamic management
• Take home messages

What this lecture is not about:

The various techniques and modalities of hemodynamic monitoring

The scientific evidence for specific treatment protocols; e.g. GDT
What really matters and where it’s happening

Microcirculation and tissue oxygenation
Basics...

Getting The Full Hemodynamic Picture

Blood Pressure (MAP) → Systemic Vascular Resistance (SVR)

Cardiac Output (CO) → Stroke Volume (SV)

Tissue Fluids (TFC) → Heart Rate (HR)

Preload (SVV, FT) → Contractility (ICON, STR)

Afterload (SVR) → + or – Vascular Tone

Diuretics → + or – Chronotropy

MAP = CO x SVR

DO₂ = CO x Hb x 1.34 x SaO₂

VO₂ = CO x (CₐO₂ – CᵥO₂)

CᵥO₂ = CₐO₂ – VO₂ / CO
Blood Pressure

Caveat:

$MAP = CO \times SVR$

$\Rightarrow \text{‘Normal’ } MAP \text{ due to high } SVR \text{ despite low } CO \text{ and } DO_2$ !!!
Fluids

Stroke volume

Hypovolaemia
Low blood volume
Poor perfusion
Poor oxygenation

Normovolaemia
Tissue edema
Poor perfusion
Poor oxygenation

Hypervolaemia

Significant response

No response

Cardiac preload

Normal ventricular systolic function

Poor ventricular systolic function

Diagnostic accuracy of passive leg raising for prediction of fluid responsiveness in adults: systematic review and meta-analysis of clinical studies

Fabio Cavallaro
Claudio Sandroni
Cristina Marnas
Giuseppe La Torre
Alice Mannocci
Chiara De Warre
Giuseppe Bello
Riccardo Masigna
Massimo Antonelli

Intensive Care Med (2010), 36:1475-1483
DOI 10.1007/s00134-010-2129-y

Vor allem Gesundheit

Oliver Herden-Kirchhof. 11-й Британо-Український Симпозіум. Київ, 2019
Hemodynamic monitoring and management in patients undergoing high risk surgery: a survey among North American and European anesthesiologists

Maxime Cannesson¹, Gunther Pestel², Cameron Ricks¹, Andreas Hoeft³ and Azriel Perel⁴
### Table 1 Hemodynamic monitoring used for the management of high-risk surgery patients.

<table>
<thead>
<tr>
<th>Answer options</th>
<th>ASA respondents (n = 237)</th>
<th>ESA respondents (n = 195)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Invasive arterial pressure</td>
<td>95.4%</td>
<td>89.7%</td>
</tr>
<tr>
<td>Central venous pressure</td>
<td>72.6%</td>
<td>83.6%</td>
</tr>
<tr>
<td>Non-invasive arterial pressure</td>
<td>51.9%</td>
<td>53.9%</td>
</tr>
<tr>
<td>Cardiac output</td>
<td>35.4%</td>
<td>34.5%</td>
</tr>
<tr>
<td>Pulmonary capillary wedge pressure</td>
<td>30.8%</td>
<td>14.4%</td>
</tr>
<tr>
<td>Transthoracic echocardiography</td>
<td>28.3%</td>
<td>19.0%</td>
</tr>
<tr>
<td>Systolic pressure variation</td>
<td>20.3%</td>
<td>23.6%</td>
</tr>
<tr>
<td>Plethysmographic waveform variation</td>
<td>17.3%</td>
<td>17.9%</td>
</tr>
<tr>
<td>Pulse pressure variation</td>
<td>15.2%</td>
<td>25.6%</td>
</tr>
<tr>
<td>Mixed venous saturation (SvO2)</td>
<td>14.3%</td>
<td>15.9%</td>
</tr>
<tr>
<td>Central venous saturation (SvO2)</td>
<td>12.7%</td>
<td>33.3%</td>
</tr>
<tr>
<td>Oxygen delivery (DO2)</td>
<td>6.3%</td>
<td>14.4%</td>
</tr>
<tr>
<td>Stroke volume variation</td>
<td>6.3%</td>
<td>21.5%</td>
</tr>
<tr>
<td>Near infrared spectroscopy</td>
<td>4.6%</td>
<td>5.1%</td>
</tr>
<tr>
<td>Global end diastolic volume</td>
<td>2.1%</td>
<td>8.2%</td>
</tr>
</tbody>
</table>

ASA, American Society of Anesthesiology respondents; ESA, European Society of Anaesthesiology respondents.

### Table 3 What are your indicators for volume expansion in this setting (diagnostic tools)?

<table>
<thead>
<tr>
<th>Answer Options</th>
<th>ASA Respondents (n = 209)</th>
<th>ESA Respondents (n = 165)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood pressure</td>
<td>88.9%</td>
<td>77.6%</td>
</tr>
<tr>
<td>Urate output</td>
<td>83.3%</td>
<td>77.1%</td>
</tr>
<tr>
<td>Clinical experience</td>
<td>77.5%</td>
<td>64.8%</td>
</tr>
<tr>
<td>Central venous pressure</td>
<td>70.8%</td>
<td>64.2%</td>
</tr>
<tr>
<td>Cardiac output</td>
<td>49.3%</td>
<td>53.3%</td>
</tr>
<tr>
<td>Pulse Pressure Variation or Systolic Pressure Variation</td>
<td>45.0%</td>
<td>55.8%</td>
</tr>
<tr>
<td>Transthoracic echocardiography</td>
<td>43.5%</td>
<td>28.5%</td>
</tr>
<tr>
<td>Pulmonary capillary wedge pressure</td>
<td>38.8%</td>
<td>24.2%</td>
</tr>
<tr>
<td>Plethysmographic Waveform Variation</td>
<td>25.4%</td>
<td>25.5%</td>
</tr>
<tr>
<td>Stroke Volume Variation</td>
<td>19.1%</td>
<td>36.4%</td>
</tr>
<tr>
<td>Mixed venous saturation (SvO2)</td>
<td>18.7%</td>
<td>21.8%</td>
</tr>
<tr>
<td>Global end diastolic volume</td>
<td>10.5%</td>
<td>17.0%</td>
</tr>
<tr>
<td>Central venous saturation (SvO2)</td>
<td>10.0%</td>
<td>34.5%</td>
</tr>
</tbody>
</table>

ASA, American Society of Anesthesiology respondents; ESA, European Society of Anaesthesiology respondents.
Table 4 How do you routinely assess the hemodynamic effects of volume expansion?

<table>
<thead>
<tr>
<th>Answer options</th>
<th>ASA respondents (n = 203)</th>
<th>ESA respondents (n = 162)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase in blood pressure</td>
<td>92.1%</td>
<td>75.3%</td>
</tr>
<tr>
<td>Increase in urine output</td>
<td>84.7%</td>
<td>73.5%</td>
</tr>
<tr>
<td>Decrease in heart rate</td>
<td>74.4%</td>
<td>75.3%</td>
</tr>
<tr>
<td>Increase in cardiac output</td>
<td>59.1%</td>
<td>54.3%</td>
</tr>
<tr>
<td>Decrease in pulse pressure variation or systolic pressure variation</td>
<td>56.7%</td>
<td>54.9%</td>
</tr>
<tr>
<td>Decrease in plethysmographic waveform variation</td>
<td>28.6%</td>
<td>25.9%</td>
</tr>
<tr>
<td>Increase in mixed venous saturation (SV02)</td>
<td>22.2%</td>
<td>18.5%</td>
</tr>
<tr>
<td>Decrease in stroke volume variation</td>
<td>21.7%</td>
<td>35.2%</td>
</tr>
<tr>
<td>Increase in central venous saturation (SV02)</td>
<td>19.2%</td>
<td>27.8%</td>
</tr>
</tbody>
</table>

ASA, American society of anesthesiology respondents; ESA, European society of anaesthesiology respondents.

Figure 2 Incidence of institutional guidelines concerning hemodynamic management in this setting.

Does your institution or group have a written protocol, care guide, or statement concerning hemodynamic management in this setting?

- No
- Yes
- Unsure or don’t know

ASA Respondents

ESA Respondents
All respondents agree that oxygen delivery is of major importance for patients undergoing high-risk surgery, with more than 90% exhibiting the knowledge that CO is a major determinant of oxygen delivery:

Table 2: If you do not monitor cardiac output routinely in these patients, what are the main reasons for not monitoring it? (Please, mark all that apply)

<table>
<thead>
<tr>
<th>Answer Options</th>
<th>ASA Respondents (n = 157)</th>
<th>Response Percent</th>
<th>ESA Respondents (n = 142)</th>
<th>Response Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>I use dynamic parameters of fluid responsiveness (Pulse Pressure Variations,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic Pressure Variations, Plethysmographic Waveform Variations) as</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>surrogates for cardiac output monitoring</td>
<td></td>
<td>54.1%</td>
<td></td>
<td>60.6%</td>
</tr>
<tr>
<td>Available cardiac output monitoring solutions are too invasive</td>
<td></td>
<td>48.4%</td>
<td></td>
<td>26.8%</td>
</tr>
<tr>
<td>Cardiac output monitoring does not provide any additional clinically relevant</td>
<td></td>
<td>24.2%</td>
<td></td>
<td>14.1%</td>
</tr>
<tr>
<td>information in this setting</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I use Svo2 and/or ScVO2 as surrogates for cardiac output monitoring</td>
<td></td>
<td>13.4%</td>
<td></td>
<td>26.1%</td>
</tr>
</tbody>
</table>
Monitoring options – Mix and Match

• Arterial pressure – estimation of tissue perfusion pressure

• Flow based monitoring – cardiac output: calibrated / uncalibrated

• Static parameters of preload – pressure: CVP; PAOP / volumetric: GEDV; ITBV

• Dynamic parameters of preload – fluid responsiveness: PLR; SVV; PPV

• Tissue perfusion markers – oxygen-supply-and-demand balance: SvO₂, Lactate, ΔPCO₂

• Echocardiography – evaluation of contractility
Oxygen supply and demand balance

Figure 5. The relationship between oxygen delivery and lactate level and $\text{SvO}_2$

Research

Multicentre study on peri- and postoperative central venous oxygen saturation in high-risk surgical patients

Collaborative Study Group on Perioperative $\text{ScVO}_2$ Monitoring


Critical Care 2006, 10(R158) (doi:10.1186/cc5094)
The new kid on the Block

Central venous-to-arterial carbon dioxide difference as a prognostic tool in high-risk surgical patients

- $\Delta$PCO$_2$ is inversely correlated with both: 
  - systemic perfusion and 
  - microcirculation
- Elevated $\Delta$PCO$_2$ = defect in CO$_2$ clearance
- Threshold of 6 mmHg
- Biomarker of hypoperfusion and tissue hypoxia
Central venous-to-arterial $PCO_2$ difference, arteriovenous oxygen content and outcome after adult cardiac surgery with cardiopulmonary bypass

*Vor allem Gesundheit*  
_Eur J Anaesthesiol_ 2019; 36:279–289
See what’s going on:

- Chamber dimensions
- Ventricular function (RV / LV)
- Valvular pathologies
- Pericardial / pleural effusion

Original Article

Transthoracic echocardiography for cardiopulmonary monitoring in intensive care

M. B. Jensen, E. Sloth, K. M. Larsen, M. B. Schmidt

Aarhus University Hospital, Department of Anaesthesiology and Intensive Care, Skejby Sygehus, Denmark

European Journal of Anaesthesiology 21: 700–707
Which monitoring? There is no magic bullet!

Table 2. The key properties of an 'ideal' hemodynamic monitoring system

- Provides measurement of relevant variables
- Provides accurate and reproducible measurements
- Provides interpretable data
- Is easy to use
- Is readily available
- Is operator-independent
- Has a rapid response-time
- Causes no harm
- Is cost-effective
- Should provide information that is able to guide therapy

- The more invasive the more accurate!
- Continuous or intermittent?
- Calibrated or uncalibrated?
Look at your patient – choose a risk adjusted approach!

Vor allem Gesundheit
A practical approach to monitoring:

CONSENSUS STATEMENT

Hemodynamic monitoring in the critically patient. Recommendations of the Cardiological Intensive Care and CPR Working Group of the Spanish Society of Intensive Care and Coronary Units


Vor allem Gesundheit
A fool with a tool is still a fool!

Most importantly, one must never forget that it is not the monitoring itself that can improve outcomes, but the changes in therapy guided by the data obtained.
Define goals and follow an algorithm!
### PiCCO / PAC

#### Decision tree for hemodynamic / volumetric monitoring

<table>
<thead>
<tr>
<th>CI (l/min/m²)</th>
<th>&lt;3.0</th>
<th>&gt;3.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEDI (ml/m²)</td>
<td>&lt;700</td>
<td>&gt;700</td>
</tr>
<tr>
<td>ELWV** (ml/kg)</td>
<td>&lt;10</td>
<td>&gt;10</td>
</tr>
<tr>
<td></td>
<td>V+</td>
<td>V+</td>
</tr>
<tr>
<td></td>
<td>Cat</td>
<td>Cat</td>
</tr>
<tr>
<td></td>
<td>V-</td>
<td>V-</td>
</tr>
</tbody>
</table>

** V+ = volume loading (! = cautiously)  V- = volume contraction  Cat = catecholamine / cardiovascular agents

** SVV only applicable in ventilated patients without cardiac arrhythmia

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### Vor allem Gesundheit

Oliver Herden-Kirchhof. 11-й Британо-Український Симпозіум. Київ, 2019

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Nach: Pinsky M, Vincent J-L: Let us use the pulmonary artery catheter correctly and only when we need it. Crit Care Med 2005; 33 1119–1122 [6].
Take home messages

• Know your physiology
• Look at your patient – assess morbidity and risk
• Get the picture – combine and integrate variables from multiple sources
• Choose wisely - monitoring requirements depend on the individual patient
• Have a plan – monitoring is not an end in itself - it guides treatment
• There are no magic bullets …
Vielen Dank für Ihre Aufmerksamkeit

Ihr Ansprechpartner:

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v.name@ameos.de

https://youtu.be/ctS_bEfWAW8