Hemodynamic monitoring in Severe Cardiac failure

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Disclosure: Potential of conflict of interest

Edwards company: Lectures and Hemodynamic products formation
Hemodynamic monitoring in ICU

1. INTRODUCTION, Hemodynamic Market
2. Rules concerning hemodynamic monitoring
3. Swan Ganz
4. ScVO2
5. Trans-pulmonary indicator dilution and waveform analysis
Introduction

• Hemodynamic monitoring have an essential role in ICU’s.
• Conventional monitoring (BP, ECG, sAO2) is often not enough to understand the hemodynamic status of the patient.
• To treat patient in shock: should I give more fluids? Is the cardiac function is Ok? Should we give Vasopressors or and inotropes?
• But also to prevent worsening before catastrophic event.
## Hemodynamic monitoring US Market

<table>
<thead>
<tr>
<th>year</th>
<th>PAC sales M $</th>
<th>Annual change %</th>
<th>Other cardiac output monitoring</th>
<th>Annual change %</th>
<th>Total sales M $</th>
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<td>154.7</td>
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</table>

less invasive monitoring products world sales
Clinical review: Update on hemodynamic monitoring - a consensus of 16

Jean-Louis Vincent1*, Andrew Rhodes2, Azriel Perel3, Greg S Martin4, Giorgio Della Rocca5, Benoit Vallet6, Michael R Pinsky7, Christoph K Hofer8, Jean-Louis Teboul9, Willem-Pieter de Boode10, Sabino Scolletta11, Antoine Vieillard-Baron12, Daniel De Backer1, Keith R Walley13, Marco Maggiorini14 and Mervyn Singer15
Key principles of hemodynamic monitoring

• Principle 1: no hemodynamic monitoring technique can improve outcome by itself

• Principle 2: monitoring requirements may vary over time and can depend on local equipment availability and training

• Principle 3: there are no optimal hemodynamic values that are applicable to all patients.
• Principle 4: we need to combine and integrate variables

Any variable on its own provides relatively little information; it is just one piece of a large puzzle.

• Principle 5: measurements of SvO2 can be helpful. SvO2 reflects the balance between oxygen consumption.
• **Principle 6:** a high cardiac output and a high SvO$_2$ are not always best. Excessive fluid administration to increase cardiac output may result in fluid overload with massive edema, giving inotropic agents in the presence of coronary artery disease is like **trying to stimulate a tired horse.**

• **Principle 7:** cardiac output is estimated, not measured. A measurement obtained by a less invasive technique may be preferable if it can be obtained more rapidly and easily, even if it is slightly less accurate.
• Principle 8: monitoring hemodynamic changes over short periods of time is important.

• Monitoring of acute changes in cardiac output can be important, to separate fluid responders from non-responders.

• Evaluating the response to a dobutamine or to a nitrate infusion.

Is Cardiac echocardiography really an ICU monitoring? Availability, time consuming, operator dependency, acute changes.....
PA catheter

• Intermittent thermo-dilution technique (not continuous) is still recognize as a gold standard.

• The newest PA catheter with thermal filament with warming of blood in the SVC and thermistor at the PAC tip (Vigilance) are allowing a more continuous CO measurement each few minutes (stable thermal conditions).

Direct PA measurement and true continuous Svo2!
The current guidelines reserve the use of a pulmonary artery catheter for the management of refractory heart failure and select conditions.

The pulmonary artery catheter remains a useful instrument in clinical situations when clinical and laboratory assessment alone is insufficient in establishing the diagnosis and pathophysiologic condition, and in guiding effective, safe therapy.
The pulmonary artery catheter 2008

- **OBJECTIVE:** To clarify the role of the pulmonary artery catheter in the intensive care unit.
- Based largely on clinical experience and assessment of the relevant published literature and in response to recent articles attacking the pulmonary artery catheter, we propose that the pulmonary artery catheter is still a valuable tool for the hemodynamic monitoring of patients with complex disease processes in whom the information obtained from the pulmonary artery catheter may influence management.

- **CONCLUSION:**
The pulmonary artery catheter is still a valuable tool for hemodynamic monitoring when used in selected patients and by physicians adequately trained to correctly interpret and apply the data provided.
RV end diastolic volume and Ejection Fraction

- Normal RVEDV: 100-160ml = RV Preload
- Normal RVEF: 40% - 60%

Thermal Filament
- 10 cm in length
- 14-25 cm from tip
- Rests between RA & RV

Swan-Ganz® Volumetric Thromodilution Catheter Edwards
The longer it takes the decay curve to reach baseline, the lower the ejection fraction (EF). The steeper the curve, the higher the EF.

\[ EF = 1 - \exp\left(-\frac{60}{(\tau \times HR)}\right) \]

\(\tau\) is the exponential decay time constant, and HR is the average heart rate during the R-wave interval.

\[ EDV = \frac{SV}{EF} \]
Indication of SWAN GANZ CATHETER?

1. Cardiogenic shock or severe heart failure, resistant to therapy.
2. RV Failure to monitor after-load of the RV (PA pressure)
3. Cardiac transplantation, Lung Transplantation, LVAD.
4. “Multi-factorial shock”: example patient with cardiac failure and sepsis.
5. High risk patients for cardiac or non cardiac surgery.
Cardiac output

Oxygen Delivery

Hemoglobin

Hemorrhage
Occult bleeding
Anemia
Hemodilution

Heart rate

Stroke volume

Preload:
CVP
PAD
PAOP
RVEDV

Afterload:
SVR
PVR

Contractility:
SWI
SVI
RVEF

Oxygen Consumption

FiO₂
Ventilation

FiO₂

Oxygenation

Fever
Pain
Agitation
Stress/anxiety
Suctioning
Shivering
Trauma
MSOF
Sepsis
Burns

VO₂

SvO₂
Continuous ScvO2 monitoring with oximetry catheter

- can reveal occult tissue hypoxia that traditional vital signs can miss. The prognostic value of ScvO2 has been demonstrated in post-op high-risk surgeries, trauma, sepsis, cardiac failure in CHF and recovery in cardiac arrest.

Guides therapy and enables early intervention

- Continuous ScvO2 is a more sensitive indicator of tissue perfusion compared to intermittent sampling and traditional vital signs alone.

- Continuous ScvO2 monitoring reveals the true adequacy of tissue oxygenation, enabling early detection and assessment of clinical response to intervention.
Review Article

Should We Monitor $\text{ScvO}_2$ in Critically Ill Patients?

Sophie Nebout$^1$ and Romain Pirracchio$^2$

$\text{ScvO}_2$ is considered as a suitable prognosis factor in many clinical situations in the critically ill patients. The Surviving Sepsis Campaign [33], gathering all European guidelines regarding severe sepsis and sepsis shock patients management, suggested including $\text{ScvO}_2$ as a goal parameter in the first 6 hours of management ($\text{ScvO}_2 >70\%$).
SCVO2 limitation

Theoretically, the distal extremity of the central venous catheter is supposed to be placed at the joining point of vena cava and the right auricle to enable a suitable assessment of tissue oxygenation of inferior and superior territories. However, checking the position of the catheter’s distal extremity with chest X-ray is not accurate.

ScvO2 depends on tissue oxygen extraction and hemoglobin affinity for oxygen. Experiments report that septic patients could suffer from a decrease in oxygen extraction capacity [34, 35], a rise in capillary shunt [34], as well as changes in hemoglobin affinity for oxygen [36]. All these changes may alter the theoretical relationship between SvcO2, and cardiac output, such as ScvO2 interpretation, to guide hemodynamic therapy becomes more complex.
IMPLEMENTATION OF A POST-CARDIAC ARREST CARE BUNDLE INCLUDING THERAPEUTIC HYPOTHERMIA AND HEMODYNAMIC OPTIMIZATION IN COMATOSE PATIENTS WITH RETURN OF SPONTANEOUS CIRCULATION AFTER OUT-OF-HOSPITAL CARDIAC ARREST: A FEASIBILITY STUDY

Elizabeth Lea Walters,† Kyle Morawski,‡ Ihab Dorotta,‡ Davinder Ramsingh,‡

A

ROSC after cardiac arrest

No

STEMI

Yes

PCI per AHA guidelines

Comatose

No

Yes

Exclusion Criterion?*

Yes

Optimize Supportive Care

No

Initiate therapeutic hypothermia with 4°C normal saline 2 liters

1. Insert rectal temperature probe, record temperature every hour
2. Target 32-34°C within 4 hours and continue for 24 hours
   a. Initiate blanket cooling (torso, extremities)
   b. Insert orogastric tube and lavage with 4°C normal saline
   c. Insert Foley catheter and irrigate bladder with 4°C normal saline

Optimize mechanical ventilation

Initiate CVP/ScvO₂ monitoring and optimize hemodynamic support

Sedate and paralyze to avoid shivering

Initiate continuous EEG monitoring

Obtain formal neurology consult examination

B

1. Therapeutic hypothermia initiated
2. CVP/ScvO₂ monitoring in 2 hours
3. Target temperature in 4 hours
4. CVP > 12 mmHg in 6 hours
5. MAP > 65 mmHg in 6 hours
6. ScvO₂ > 70% in 6 hours
7. Therapeutic hypothermia maintained for 24 hours
8. Decreasing lactate in 24 hours

observed a 14% lower mortality during the bundle implementation phase compared with the prebundle period. As this
Assessing optimal volume status

Heart failure cannot be ascertained unless volume loading is optimal. The evaluation of effective circulating blood volume is more important than the total blood volume. Signs of increased sympathetic tone and/or organ hypoperfusion (increased serum lactate and decreased mixed venous saturation (SvO2) or central venous O2 saturation (ScvO2)) indicate increased oxygen extraction secondary to altered cardiovascular physiology/hypovolaemia.
Using Central venous Oxygenation to facilitate the weaning of IABP in MI related Acute Heart Failure

Ho-Tsung Hsin, Cardiovascular Intensive care unit
Far Eastern Memorial Hospital
New Taipei city, Taiwan

“Scvo2 offered an Objective index to guide the weaning process of IABP and made rapid decision possible“
Transpulmonary Thermodilution Technology
Cardiac Output Calculation

\[
CO = \left( T_b - T_i \right) \times V_i \times K \int_{\infty}^{\Delta T_b dt} \int_0^\infty \Delta T_b dt
\]
Transpulmonary thermodilution-derived cardiac function index identifies cardiac dysfunction in acute heart failure and septic patients: an observational study

Simon Ritter, Alain Rudiger* and Marco Maggiorini

Conclusion: In critically ill medical patients, assessment of cardiac function using transpulmonary thermodilution technique is an alternative to the PAC. A low CFI identifies cardiac dysfunction in both AHF and septic patients.
Calculating GEDV
Global End Diastolic Volume

GEDV = slope function \times ITTV

PTV
Pulmonary Thermal Volume

PTV = CO \times DSt

Calculating (ITTV)
Intra Thoracic blood volume

ITTV = CO \times MTt
EVLW (extra vascular lung water) : Pulmonary edema

- EVLW: thermal volume within the lungs
- PTV: Pulmonary Thermal Volume
- PBV: Pulmonary Blood Volume
High Pressure pulmonary edema VS ARDS: PVPI

\[ \text{PVPI} = \frac{\text{EVLW}}{\text{PBV}} \]
CO from Arterial waveform

- There is 2 different methods, sometimes mixed in the same device:
  - **Calibrated CO**: the reference is the CO calculated by thermodilution (EV 1000, Picco) or Lidco.
    - A thermodilution study should be performed each few hours.
  - **Non-calibrated CO**: the device is analyzing the waveform, with the ability to analyze size of the vascular tone and vessel compliance.
    - Example: Vigileo (Edwards)

It is important to understand that the Arterial line waveform is not only proportional to the CO but that the vascular tone and the compliance are leading to modification of the waveform.
Khi is made up of a fraction of complex variables, each describing a different aspect of waveform conformation. Khi factor automatically calculates the effect of changes in vascular tone & compliance, and resistance on stroke volume.
Detailed analysis of the waveform shape **continuously** assesses patient specific effects of vascular tone on flow.

Skewness

<table>
<thead>
<tr>
<th>Vasodilatation</th>
<th>Vasoconstriction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Decreased Skewness</strong></td>
<td><strong>Increased Skewness</strong></td>
</tr>
<tr>
<td>Low Resistance</td>
<td>Constant MAP High Resistance</td>
</tr>
</tbody>
</table>

“peaks and valleys" Kurtosis

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Compliance of Large Vessels</strong></td>
<td><strong>High Compliance of Large Vessels</strong></td>
</tr>
<tr>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>Elderly</td>
<td>Young</td>
</tr>
<tr>
<td>Low BSA</td>
<td>High BSA</td>
</tr>
</tbody>
</table>
Example of Effect of \( \chi \)

- CO = 6.5L/min
- CO = 6.5L/min
Bioreactance

• Inspired from the Bioimpedance, but measure changes in frequency of the electrical currents traversing the chest rather than change of impedance.
The size of the heart may have an important weight concerning hemodynamic management:

- We probably target the GEDI or the wedge pressure higher for a patient with severe LV hypertrophy.

Patient with LV dilatation will need more higher filling pressures as well.

- We will make a different interpretation of the SVR in a patient with a dilated LV.
SVR ?????

• SVR is used in clinical practice as the after-load parameter.

• The measurement of the after-load is not a target by himself. But a parameter measured in order to maintain BP and also to ease the LV work

• The LV after-load is best reflected by measurement of the LV wall tension which is not always in good correlation with the SVR.
LV wall tension

Can be measured with TTE or TEE

**TEE**: $ES : BP \, \text{systolic} \times (LV - ESA)$

End systolic cross sectional LV area

**TTE**: $0 = 1.35 \times BP \times \frac{LVID}{4h(1+h/LVID)}$

Where $LVID = LV$ internal diameter

$h = \text{end systolic wall sickness}$
normal ventricle

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal Ventricle</th>
<th>Dilated Ventricle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>3 cm</td>
<td>5 cm</td>
</tr>
<tr>
<td>Wall surface tension</td>
<td>76 dyne/cm²</td>
<td>196 dyne/cm²</td>
</tr>
<tr>
<td>P syst</td>
<td>100 mmHg</td>
<td></td>
</tr>
<tr>
<td>Pmean</td>
<td>75 mmHg</td>
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</tr>
<tr>
<td>CO</td>
<td>5 l/min</td>
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</tr>
<tr>
<td>SVR</td>
<td>1200 mmHg/s/cm^5</td>
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</tbody>
</table>
• For a distended LV: a "normal" SVR value can lead to high wall tension and then to cardiac failure.

• It means that we have to implement geometrical factors in the analysis of afterload conditions! (as well for fluid Therapy).
Continuous TEE Monitoring
Single use TEE probe

Superior vena cava: to evaluate fluid responsiveness

Mid-esophageal 4 chambers:
To evaluate Biventricular size and function

Trans-gastric short axis: to assess preload and contractility
Automatic wall detection

Transgastric short axis view of the left ventricle

Software tool for comparing LV size over time

Software tool for calculating fractional area change

Software tool for synchronizing cineloops
Trans-pulmonary indicator monitoring

Cardiac function

Cardiac failure

Normal or good enough: Follow on same treatment and monitoring

RV Failure

LV Failure

Consider Swan Ganz SCVO2 and RVEF

Pulmonary hypertension: NO, Ventavis, Milrinone, ECMO ...
Conclusion

• Use hemodynamic monitoring for difficult patients!
• Continuous SVO2 monitoring is an excellent warning system
• Use of PAC in selected patients
• Use of less invasive monitoring seems to be very helpful in the management of severe Heart failure.
Trans-pulmonary indicator monitoring

Volemia according target from GEDV and cardiac geometry (Cardiac echo)

Overload:
- Fluid restriction
- Diuretics, CVVHDF

Hypovolemic:
- EVLW?

High EVLW
- PVPI?
  - High PVPI
    - Fluids can be dangerous!
  - Low PVPI

Low EVLW

Normal or good enough: Follow on same monitor and treatment

High PVPI
- Fluids can be dangerous!

Low PVPI
- More fluids, Albumin...
Trans-pulmonary indicator monitoring

After load: Target according cardiac geometry (cardiac echography)

- Normal (goal directed)
  - No change

- High: Decrease vasoconstrictors
  - Hypovolemia ??

- Low: Increase NorEpinephrine, vasopressin, Steroids ?
## Comparison

**Advantages and disadvantages**

<table>
<thead>
<tr>
<th>Positive</th>
<th>Negative</th>
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<tbody>
<tr>
<td>positive argument 1</td>
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<td>positive argument 2</td>
<td>negative argument 2</td>
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<tr>
<td>positive argument 5</td>
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1. This is a placeholder which can be replaced your own texts.
2. This is a placeholder which can be replaced your own texts.
3. This is a placeholder which can be replaced your own texts.
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Your Text Here

Add text title

1

Add text title

2

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3

Add text title

4

Click to add text

• Add text 1
• Add text 2
• Add text 3
Your Text Here
Target Diagram
High aims to a successful presentation

1. Conduct a test run of your presentation
2. Prepare technology and media
3. Create a handout and speaker’s notes
4. Design slides in PowerPoint
5. Collect and structure contents
6. Define goals & analyse target audience
Your Text Here

Add title text

1. Add text title
2. Add text title
3. Add text title
4. Add text title
Ying and Yang for your presentation

Common symbols for clear illustrations

Your text

- If you don’t want to use the size of the fonts as used in this placeholder it is possible to replace it by selecting different options.

- This text can be replaced with your own text. This is a placeholder text.

- The text you type keeps the same style and formatting as the placeholder text. This text can be replaced with your own text.
Hereon, you should pay attention:

**Fast and effective creation of your presentation**
- Apply a collection of regularly used slides.
- Pay attention to a clear and comprehensible file deposition, so that contents can be found at any time.

**Appealing visualization of your contents**
- Use colors and the layout of your corporate design.
- Create of text slides and numbers descriptive graphics and "pictures".

**Improved performing**
- Practice a convincing appearance.
- Personal speech and interaction with the audience.
Your Text Here

Concept

Concept

Concept

Concept

Click to add text

• Add text 1
• Add text 2
• Add text 3
Comparison
Impress your audience with clear 3D shapes.

Description 1

Description 2

Placeholder
If you don’t want to use the size of the fonts as used in this placeholder it is possible to replace it by selecting different options. This is a placeholder text.

Placeholder
The text you type keeps the same style and formatting as the placeholder text. This text can be replaced with your own text. This is a placeholder text.
Demonstrate with charts business areas to your customers

**Your profile illustrated as puzzle**

- **Division 1**
  Describe e. g. your business

- **Core Competences**

- **Division 3**
  Demonstrate your core competence

- **Division 2**
  Departments and service areas can be visualized with an image
Diagrams indicated with flags

Layout sample for banners and flags
Your Text Here
Arrow Process

Make strong and visual PowerPoint presentations in less time

Customize the graphics to fit your need

Leave an impact on your audience

Support your message with professional graphics

Capture your audience

SAVE TIME

PROFESSIONAL

EASE TO USE

ENGAGE

IMPRESS

ENGAGE
Your Text Here

Click to add text

Add text 1
Add text 2
Add text 3
Your Text Here

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• Add text C
• Add text D
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Your Text Here