



# Hemodynamic Monitoring and Management in the ICU

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Vor allem Gesundheit

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

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# Roadmap

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

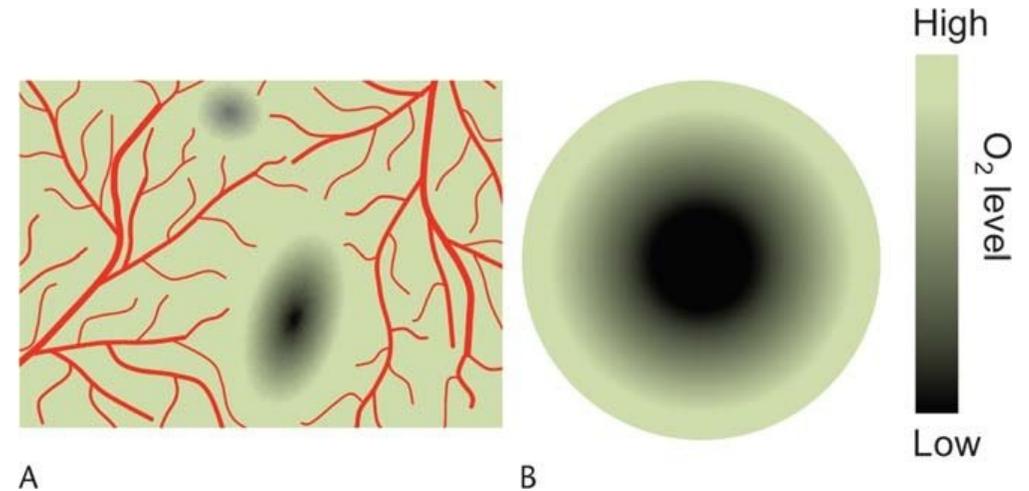
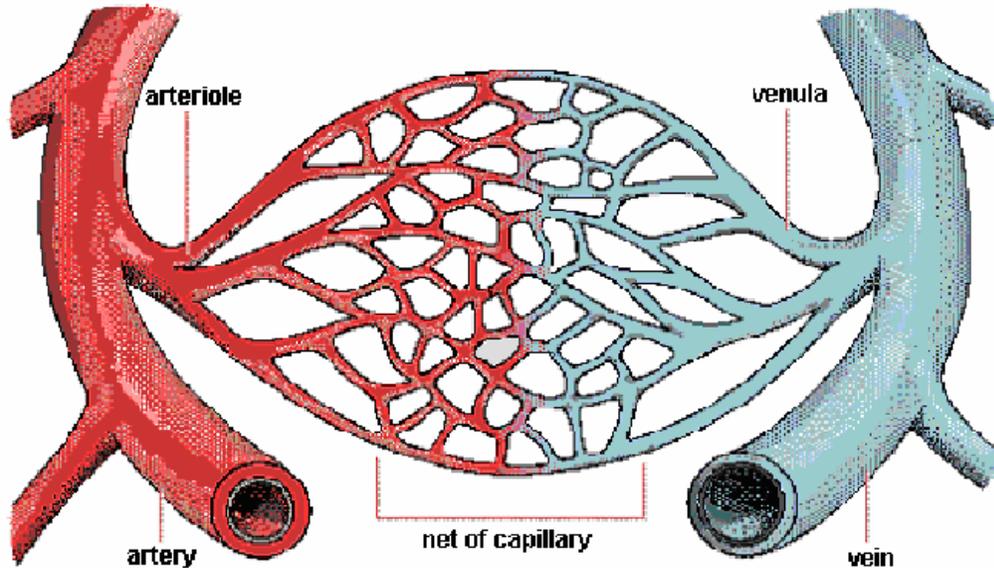
## What this lecture is not about:

**The various techniques and modalities of hemodynamic monitoring**

**The scientific evidence for specific treatment protocols; e.g. GDT**

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# What really matters and where it's happening



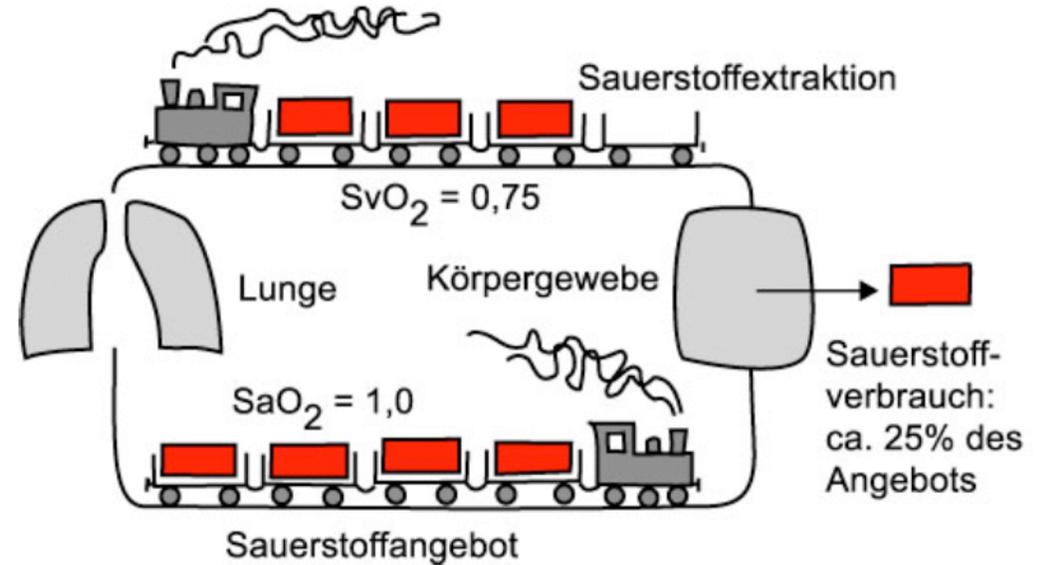
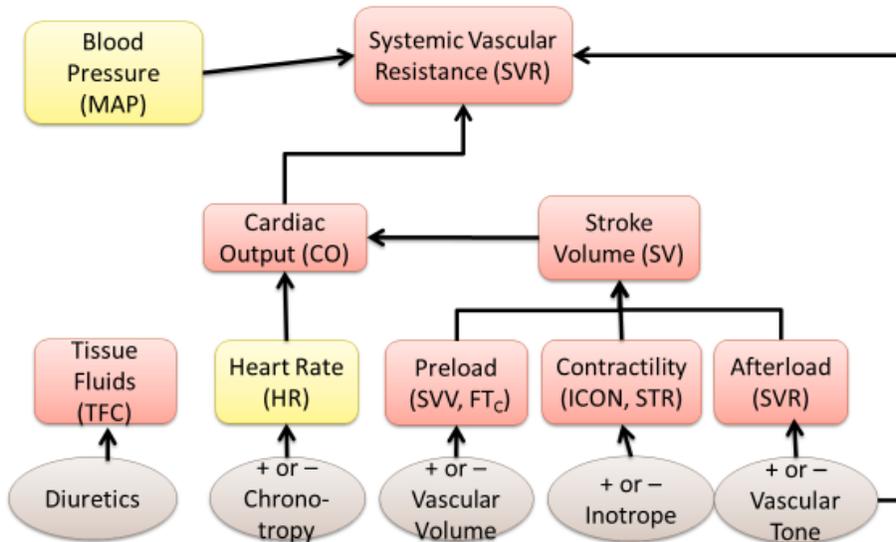
## Microcirculation and tissue oxygenation

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# Basics...

## Getting The Full Hemodynamic Picture



$$MAP = CO \times SVR$$

$$DO_2 = CO \times Hb \times 1,34 \times SaO_2$$

$$VO_2 = CO \times (C_aO_2 - C_vO_2)$$

$$C_vO_2 = C_aO_2 - VO_2 / CO$$

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# Blood Pressure

## Period-dependent Associations between Hypotension during and for Four Days after Noncardiac Surgery and a Composite of Myocardial Infarction and Death

*A Substudy of the POISE-2 Trial*

Daniel I. Sessler, M.D., Christian S. Meyhoff, M.D., Ph.D., Nicole M. Zimmerman, M.S., Guangmei Mao, M.P.H., Kate Leslie, M.B.B.S., Skarlet M. Vásquez, M.Sc., Packianathaswamy Balaji, M.D., Jesús Alvarez-García, M.D., Ph.D., Alexandre B. Cavalcanti, M.D., Ph.D., Joel L. Parlow, M.D., Prashant V. Rahate, M.D., Manfred D. Seeberger, M.D., Bruno Gossetti, M.D., S. A. Walker, M.B.Ch.B., Rajendra K. Premchand, M.D., Rikke M. Dahl, M.D., Emmanuelle Duceppe, M.D., Reitze Rodseth, M.B.Ch.B., Fernando Botto, M.D., P. J. Devereaux, M.D., Ph.D.

**Caveat:**

$$\text{MAP} = \text{CO} \times \text{SVR}$$

→ **‘Normal’ MAP due to high SVR despite low CO and DO<sub>2</sub> !!!**

**Table 4.** The Association of Clinically Important Hypotension to Component of the 30-day Composite Outcome

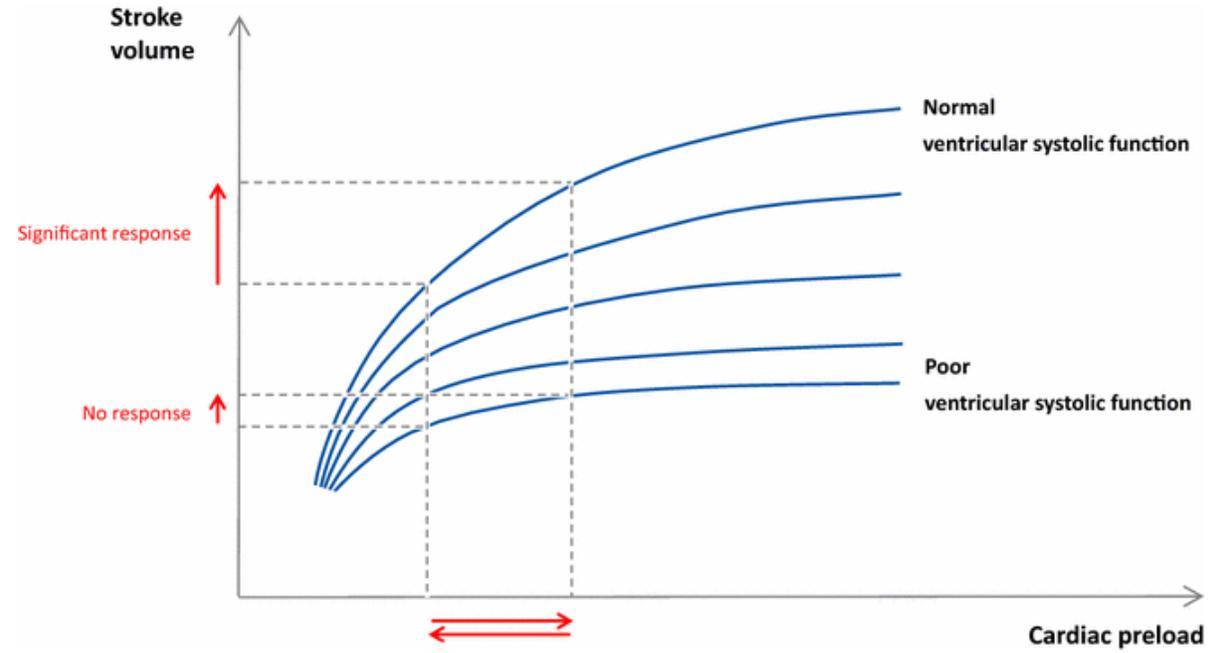
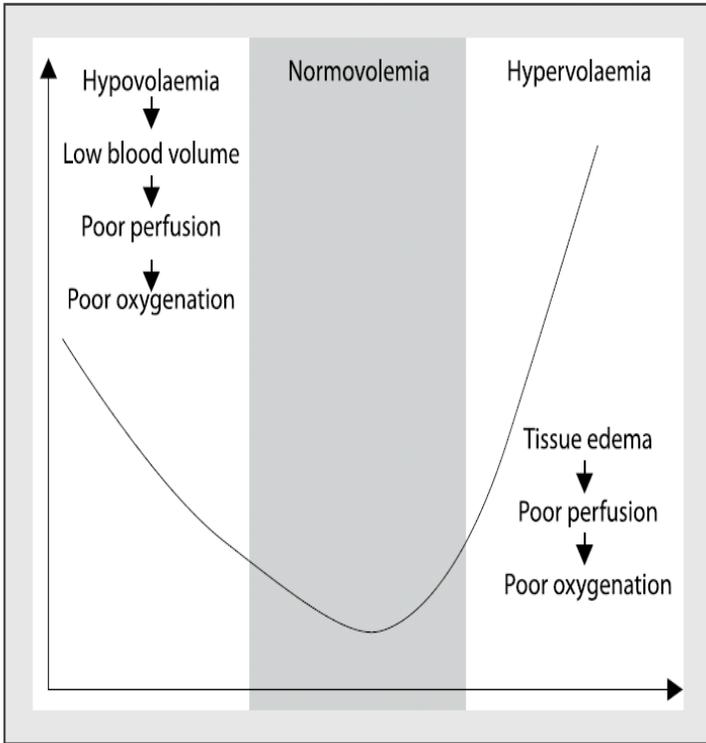
Period	Outcome	Incidence (%)*	OR (99.2% CI)†	P Value‡
10-min increase in hypotension Intraoperative	MI	590 (6.0%)	1.03 (0.97, 1.10)	0.162
	Mortality	116 (1.2%)	1.12 (1.05, 1.20)	< 0.001§
Remaining day of surgery	MI	418 (4.4%)	1.03 (1.00, 1.05)	0.002§
	Mortality	105 (1.1%)	1.03 (1.01, 1.06)	< 0.001§
Hypotension vs. nonhypotension: PODs 1 to 4	MI	29 (0.3%)	2.95 (0.84, 10.4)	0.023
	Mortality	63 (0.7%)	2.72 (1.07, 6.93)	0.004§

Anesthesiology 2018; 128:317-27



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# Fluids

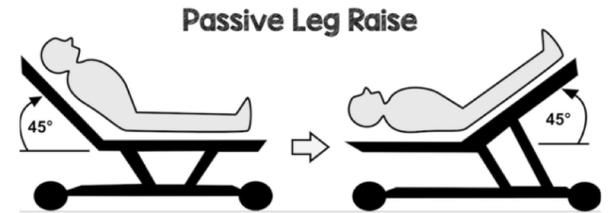


Intensive Care Med (2010) 36:1475–1483  
DOI 10.1007/s00134-010-1929-y

REVIEW

Fabio Cavallaro  
Claudio Sandroni  
Cristina Marano  
Giuseppe La Torre  
Alice Mannocci  
Chiara De Waure  
Giuseppe Bello  
Riccardo Maviglia  
Massimo Antonelli

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



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# The Evidence-Practice-Gap

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Cannesson *et al. Critical Care* 2011, **15**:R197  
<http://ccforum.com/content/15/4/R197>



RESEARCH

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## Hemodynamic monitoring and management in patients undergoing high risk surgery: a survey among North American and European anesthesiologists

Maxime Cannesson<sup>1\*</sup>, Gunther Pestel<sup>2</sup>, Cameron Ricks<sup>1</sup>, Andreas Hoeft<sup>3</sup> and Azriel Perel<sup>4</sup>



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**Table 1 Hemodynamic monitoring used for the management of high-risk surgery patients?.**

Answer options	ASA respondents (n = 237)	ESA respondents (n = 195)
	Response percent	Response percent
Invasive arterial pressure	95.4%	89.7%
Central venous pressure	72.6%	83.6%
Non-invasive arterial pressure	51.9%	53.8%
Cardiac output	35.4%	34.9%
Pulmonary capillary wedge pressure	30.8%	14.4%
Transesophageal echocardiography	28.3%	19.0%
Systolic pressure variation	20.3%	23.6%
Plethysmographic waveform variation	17.3%	17.9%
Pulse pressure variation	15.2%	25.6%
Mixed venous saturation (ScvO2)	14.3%	15.9%
Central venous saturation (SvO2)	12.7%	33.3%
Oxygen delivery (DO2)	6.3%	14.4%
Stroke volume variation	6.3%	21.5%
Near infrared spectroscopy	4.6%	5.1%
Global end diastolic volume	2.1%	8.2%

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)?**

Answer Options	ASA Respondents (n = 209)	ESA Respondents (n = 165)
	Response Percent	Response Percent
Blood pressure	88.5%	77.6%
Urine output	83.3%	77.0%
Clinical experience	77.5%	64.8%
Central venous pressure	70.8%	64.2%
Cardiac output	49.3%	53.3%
Pulse Pressure Variation or Systolic Pressure Variation	45.0%	55.8%
Transesophageal echocardiography	43.5%	28.5%
Pulmonary capillary wedge pressure	38.8%	24.2%
Plethysmographic Waveform Variation	25.4%	25.5%
Stroke Volume Variation	19.1%	36.4%
Mixed venous saturation (ScvO2)	18.7%	21.8%
Global end diastolic volume	10.5%	17.0%
Central venous saturation (SvO2)	10.0%	34.5%

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?**

	ASA respondents (n = 203)	ESA respondents (n = 162)
Answer options	Response percent	Response percent
Increase in blood pressure	92.1%	75.3%
Increase in urine output	84.7%	73.5%
Decrease in heart rate	74.4%	75.3%
Increase in cardiac output	59.1%	54.3%
Decrease in pulse pressure variation or systolic pressure variation	56.7%	54.9%
Decrease in plethysmographic waveform variation	28.6%	25.9%
Increase in mixed venous saturation (SvO2)	22.2%	18.5%
Decrease in stroke volume variation	21.7%	35.2%
Increase in central venous saturation (SvO2)	19.2%	27.8%

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

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

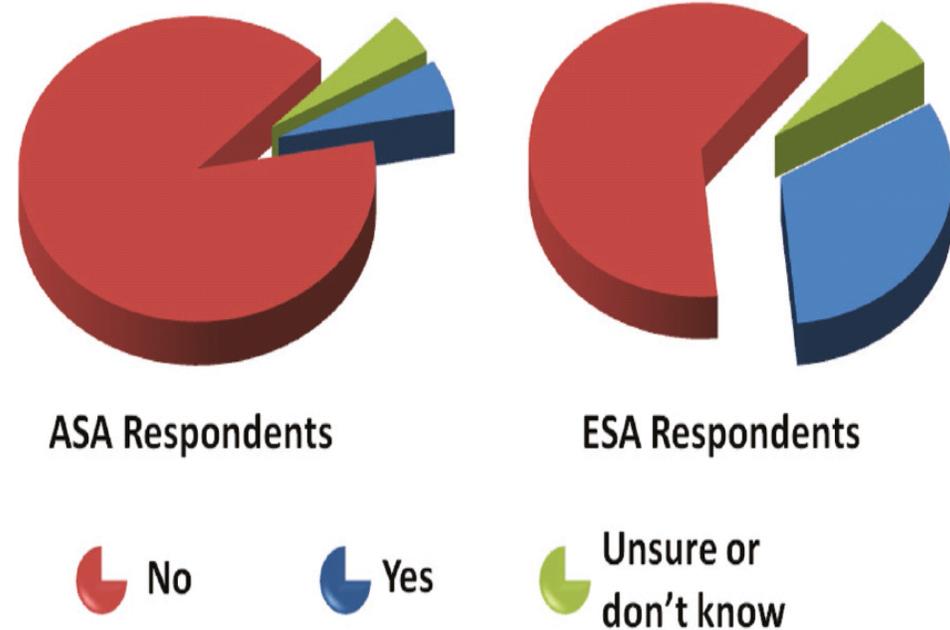


Figure 2 Incidence of institutional guidelines concerning hemodynamic management in this setting?



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)**

	ASA Respondents (n = 157)	ESA Respondents (n = 142)
Answer Options	Response Percent	Response Percent
I use dynamic parameters of fluid responsiveness (Pulse Pressure Variations, Systolic Pressure Variations, Plethysmographic Waveform Variations) as surrogates for cardiac output monitoring	54.1%	60.6%
Available cardiac output monitoring solutions are too invasive	48.4%	26.8%
Cardiac output monitoring does not provide any additional clinically relevant information in this setting	24.2%	14.1%
I use SvO2 and/or ScVO2 as surrogates for cardiac output monitoring	13.4%	26.1%



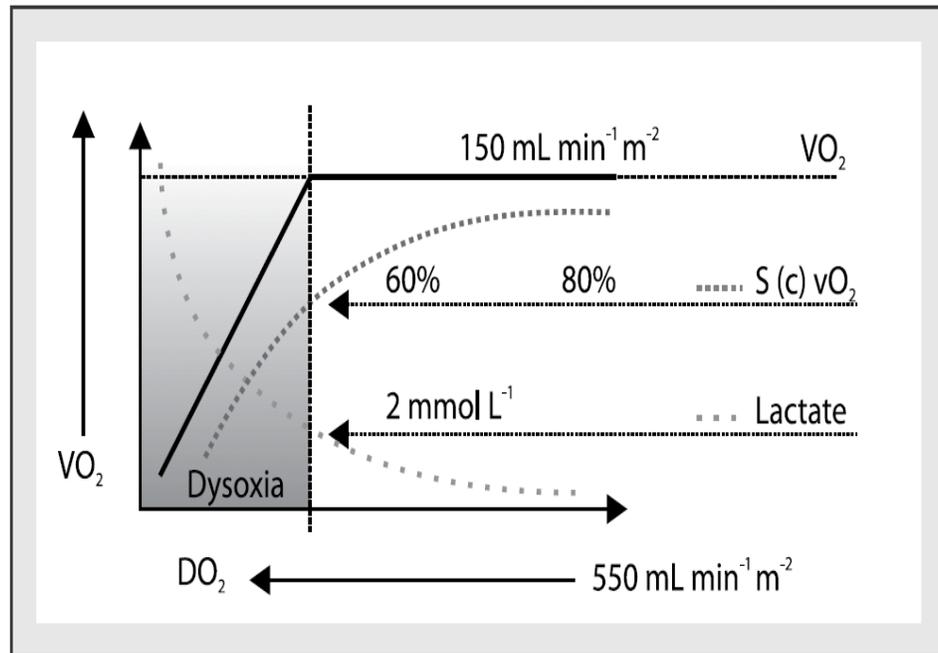
# Monitoring options – Mix and Match

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- **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: SvO<sub>2</sub>, Lactate,  $\Delta$ PCO<sub>2</sub>**
- **Echocardiography – evaluation of contractility**



# Oxygen supply and demand balance



**Figure 5.** The relationship between oxygen delivery and lactate level and  $SvO_2$

Vincent et al. *Critical Care* (2016) 20:257  
DOI 10.1186/s13054-016-1403-5

Critical Care

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## The value of blood lactate kinetics in critically ill patients: a systematic review

Jean-Louis Vincent<sup>\*</sup>, Amanda Quinteiros e Silva<sup>†</sup>, Lúcio Couto Jr<sup>†</sup> and Fabio S. Taccone

Research

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

Collaborative Study Group on Perioperative ScvO<sub>2</sub> Monitoring

Received: 5 Jul 2006 Revisions requested: 27 Jul 2006 Revisions received: 30 Aug 2006 Accepted: 13 Nov 2006 Published: 13 Nov 2006

*Critical Care* 2006, 10:R158 (doi:10.1186/cc5094)



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# The new kid on the Block

Robin et al. *Critical Care* (2015) 19:227  
DOI 10.1186/s13054-015-0917-6



RESEARCH

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



Emmanuel Robin<sup>1\*</sup>, Emmanuel Futier<sup>2</sup>, Oscar Pires<sup>1</sup>, Maher Fleyfel<sup>1</sup>, Benoit Tavernier<sup>1</sup>, Gilles Lebuffe<sup>1</sup> and Benoit Vallet<sup>1</sup>

Futier et al. *Critical Care* 2010, **14**:R193  
<http://ccforum.com/content/14/5/R193>



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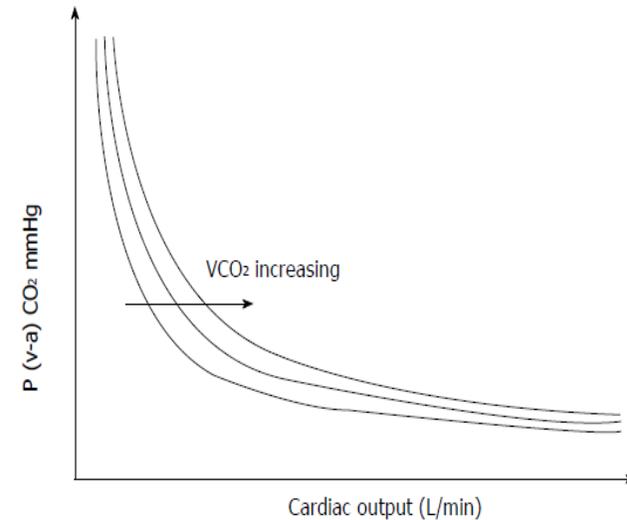
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## Central venous O<sub>2</sub> saturation and venous-to-arterial CO<sub>2</sub> difference as complementary tools for goal-directed therapy during high-risk surgery

Emmanuel Futier<sup>1\*</sup>, Emmanuel Robin<sup>2</sup>, Matthieu Jabaudon<sup>1</sup>, Renaud Guerin<sup>1</sup>, Antoine Petit<sup>1</sup>, Jean-Etienne Bazin<sup>1</sup>, Jean-Michel Constantin<sup>1</sup>, Benoit Vallet<sup>2</sup>

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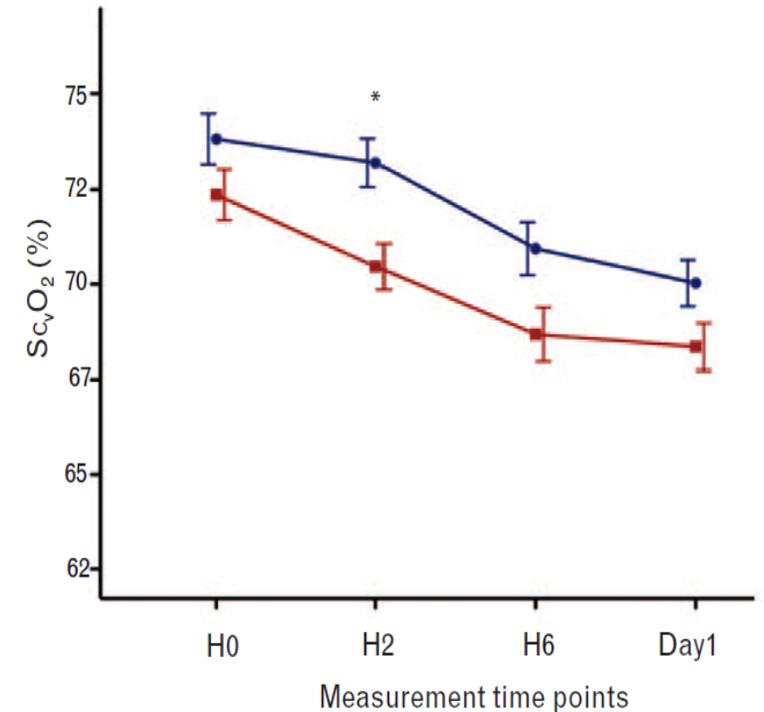
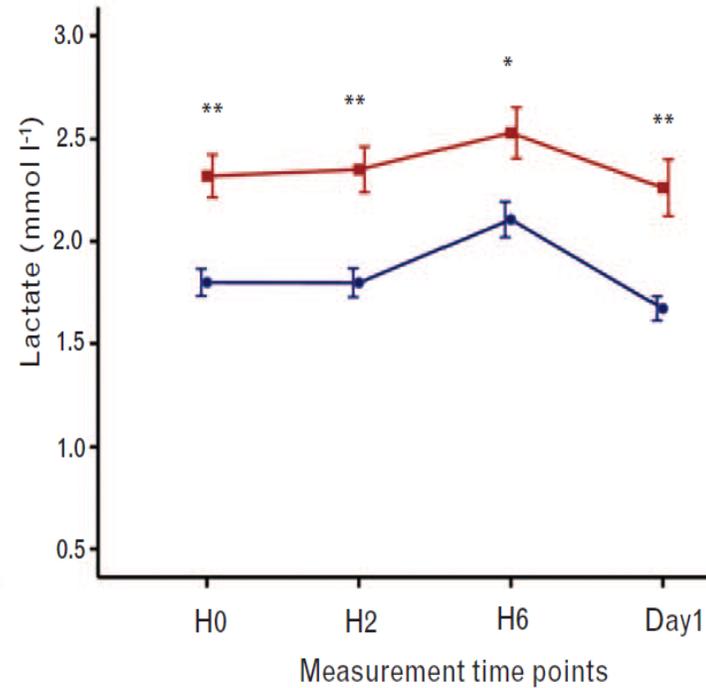
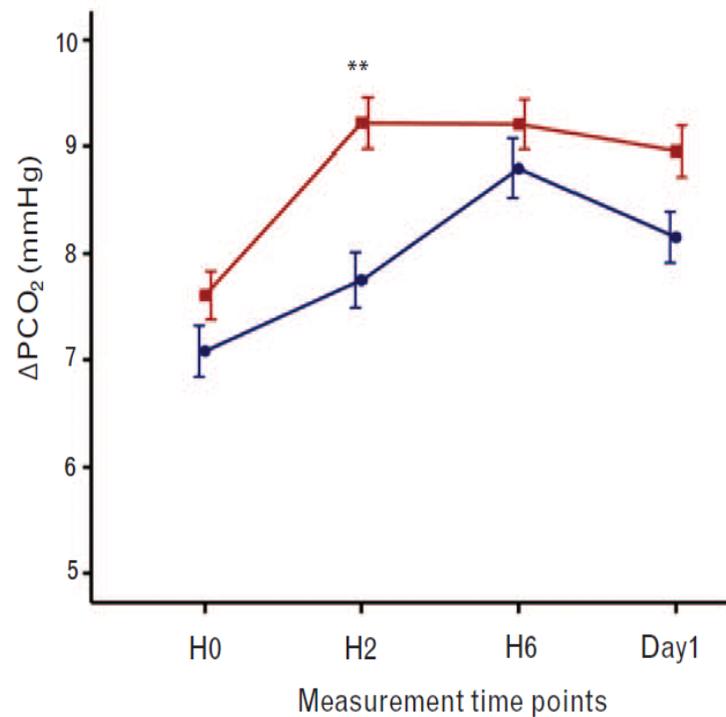
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**Figure 3 Relationship between the mixed venous-to-arterial PCO<sub>2</sub> difference P (v-a) CO<sub>2</sub> and cardiac output.** For a constant total CO<sub>2</sub> production (VCO<sub>2</sub>), changes in cardiac output result in large changes in P (v-a) CO<sub>2</sub> in the low values of cardiac output, whereas changes in cardiac output will not result in significant changes in P (v-a) CO<sub>2</sub> in the high values of cardiac output.

- **$\Delta$ PCO<sub>2</sub> is inversely correlated with both:**
  - **systemic perfusion and**
  - **microcirculation**
- **Elevated  $\Delta$ PCO<sub>2</sub> = defect in CO<sub>2</sub> 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



# Bedside Echocardiography

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

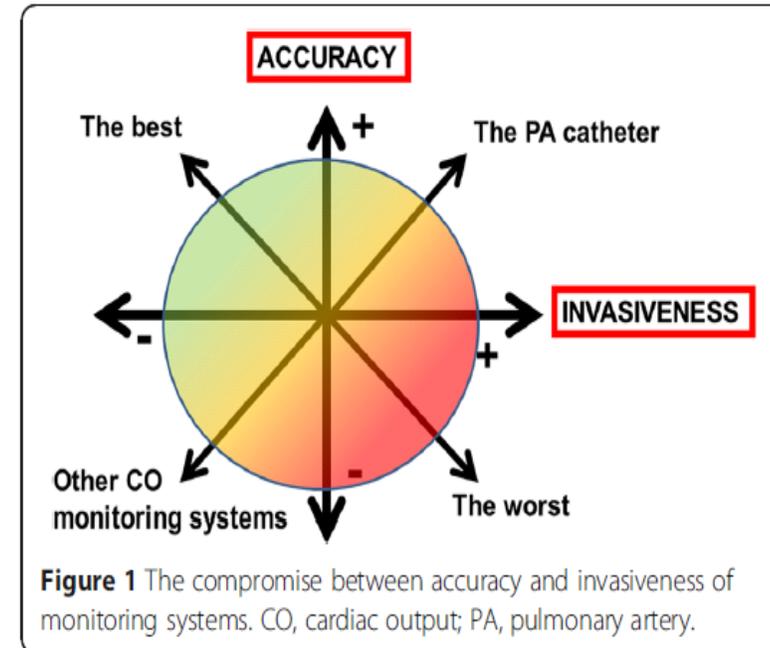
*European Journal of Anaesthesiology* 21: 700–707

	Normal basic FATE views	Normal basic FATE views	Examples of important pathology
	Normal basic FATE view	Normal basic FATE view	Pericardial effusion
Pos 1: Subcostal 4-chamber			
	Normal basic FATE view	Normal basic FATE view	Dilated LV
Pos 2: Apical 4-chamber			
	Normal basic FATE view	Normal basic FATE view	Hypertrophy LV + Dilated LA
Pos 3: Parasternal long axis			
	Normal basic FATE view	Normal basic FATE view	Dilated right ventricle
Pos 3: Parasternal short axis			
	Normal basic FATE view	Normal basic FATE view	Pleural effusion
Pos 4: Pleural scanning			

# Which monitoring? There is no magic bullet!

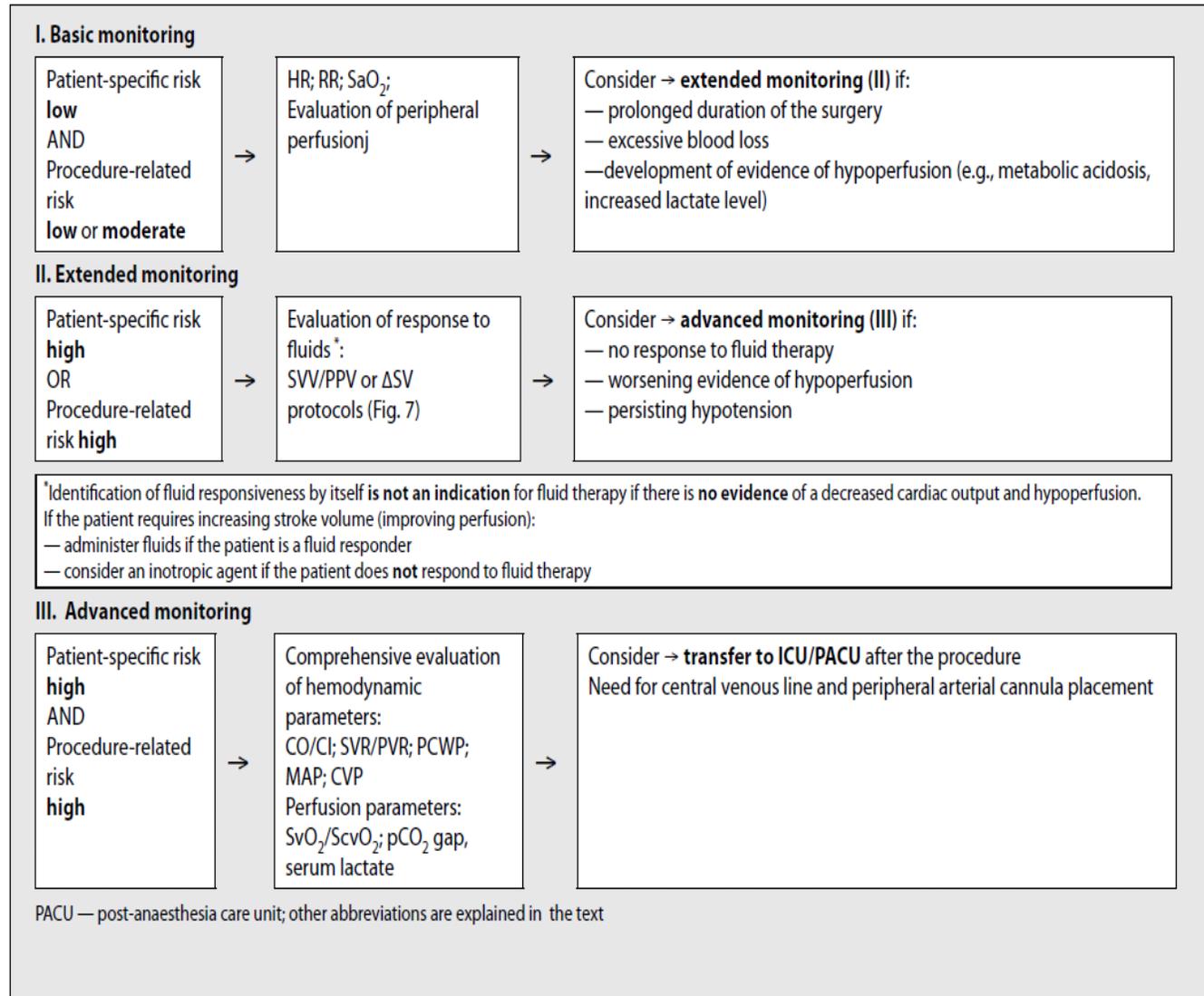
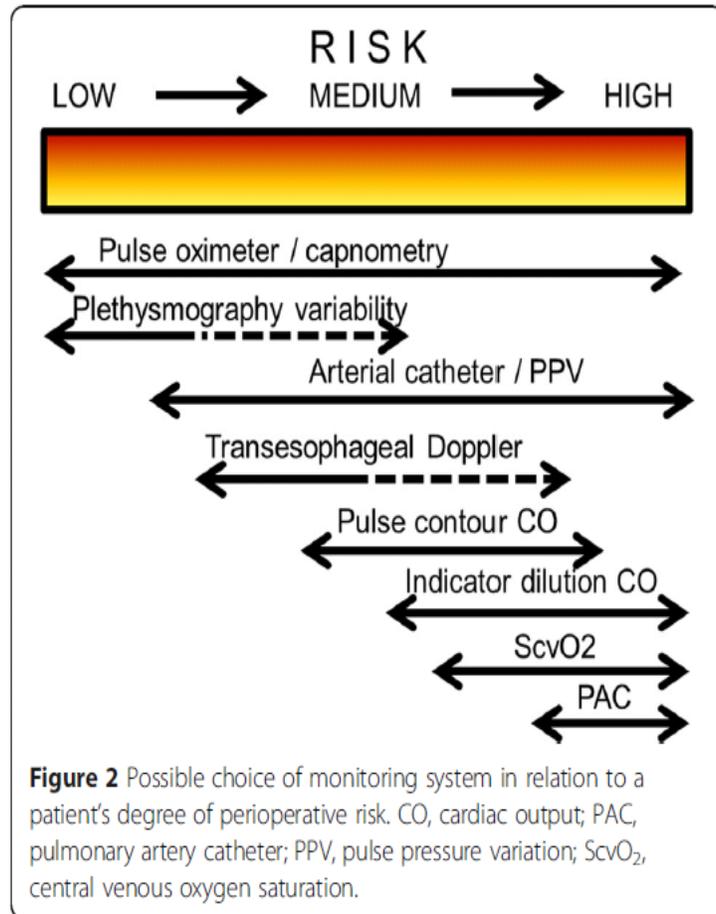
**Table 2. The key properties of an 'ideal' hemodynamic monitoring system**

- 
- 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
- 

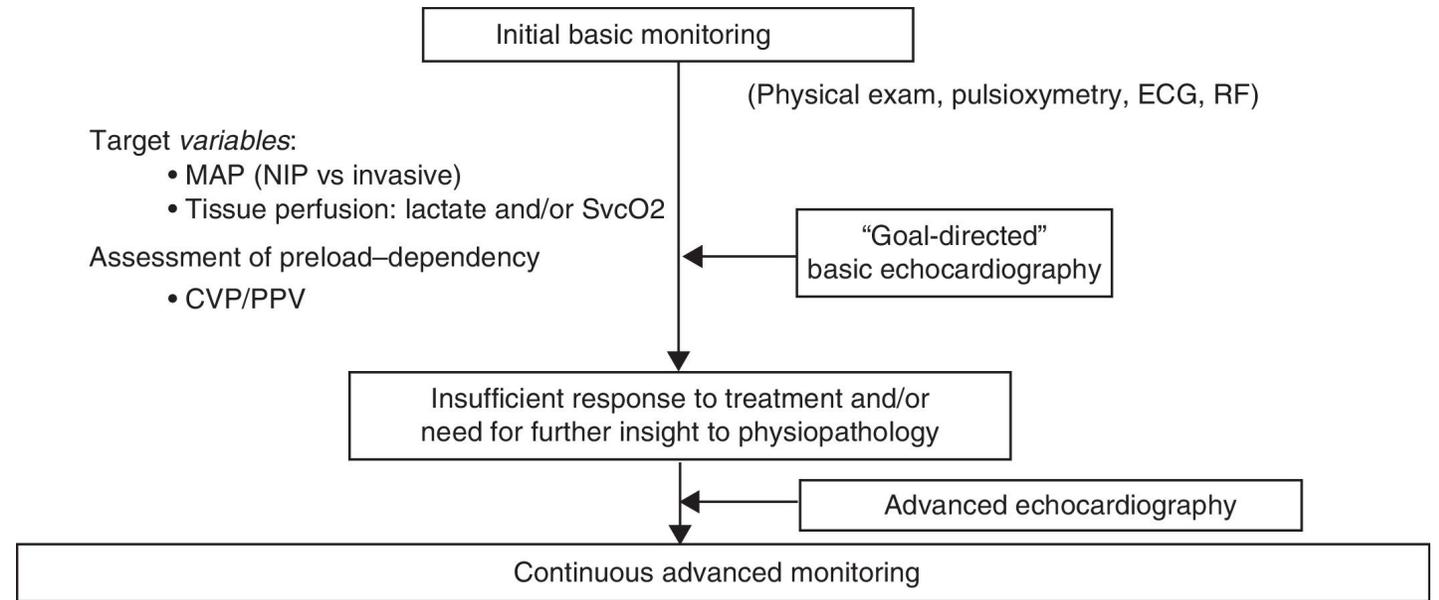


- **The more invasive the more accurate !**
- **Continuous or intermittent ?**
- **Calibrated or uncalibrated ?**

# Look at your patient – choose a risk adjusted approach!



# A practical approach to monitoring:



Target variables:

- MAP (NIP vs invasive)
- Tissue perfusion: lactate and/or SvcO2

Assessment of preload-dependency

- CVP/PPV

Target variables:

- MAP (invasive BP)
- Tissue perfusion: lactate and/or SvcO2

Advanced hemodynamic monitoring systems

- Noninvasive
  - (very limited utility in critical patients)
- Semi-invasive
  - Pulse wave analysis without calibration (not recommended in case of altered vascular tone)
  - Esophageal Doppler
  - Pulse wave analysis with calibration (transpulmonary thermodilution, lithium dilution)
- Invasive
  - PAC

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<sup>☆</sup>**

Med Intensiva. 2014;38(3):154-169



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# A fool with a tool is still a fool!

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**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 !

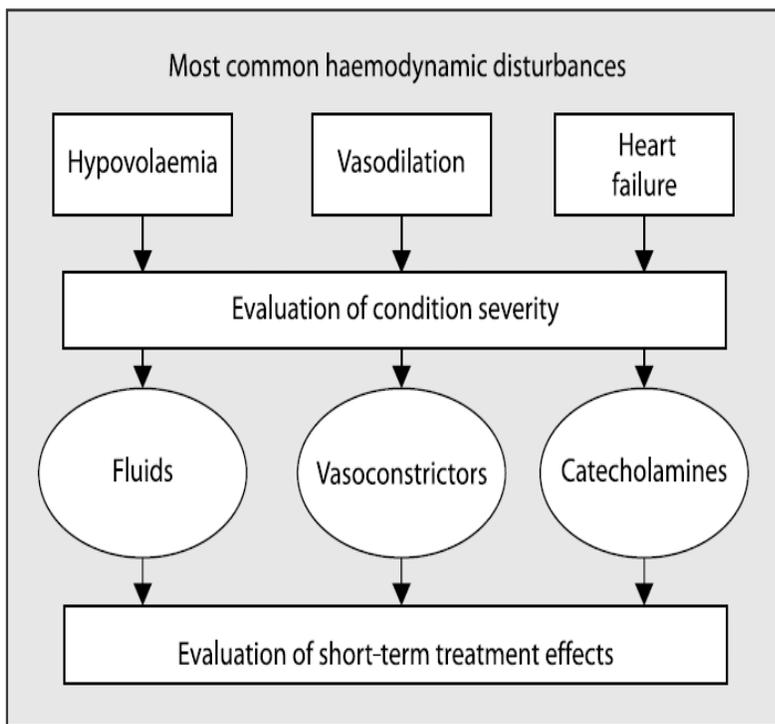


Figure 3. Basic principles of goal-oriented therapy

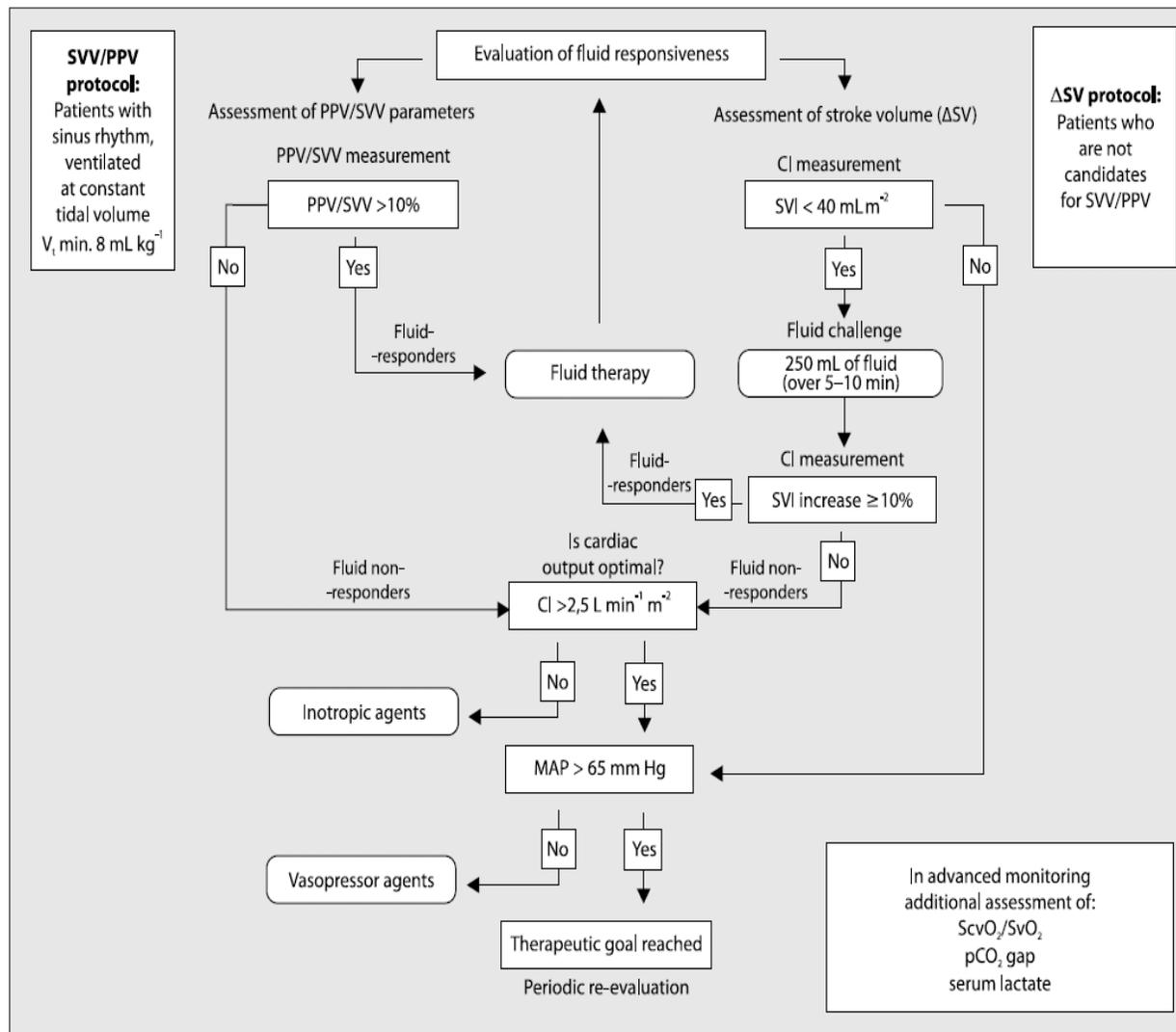
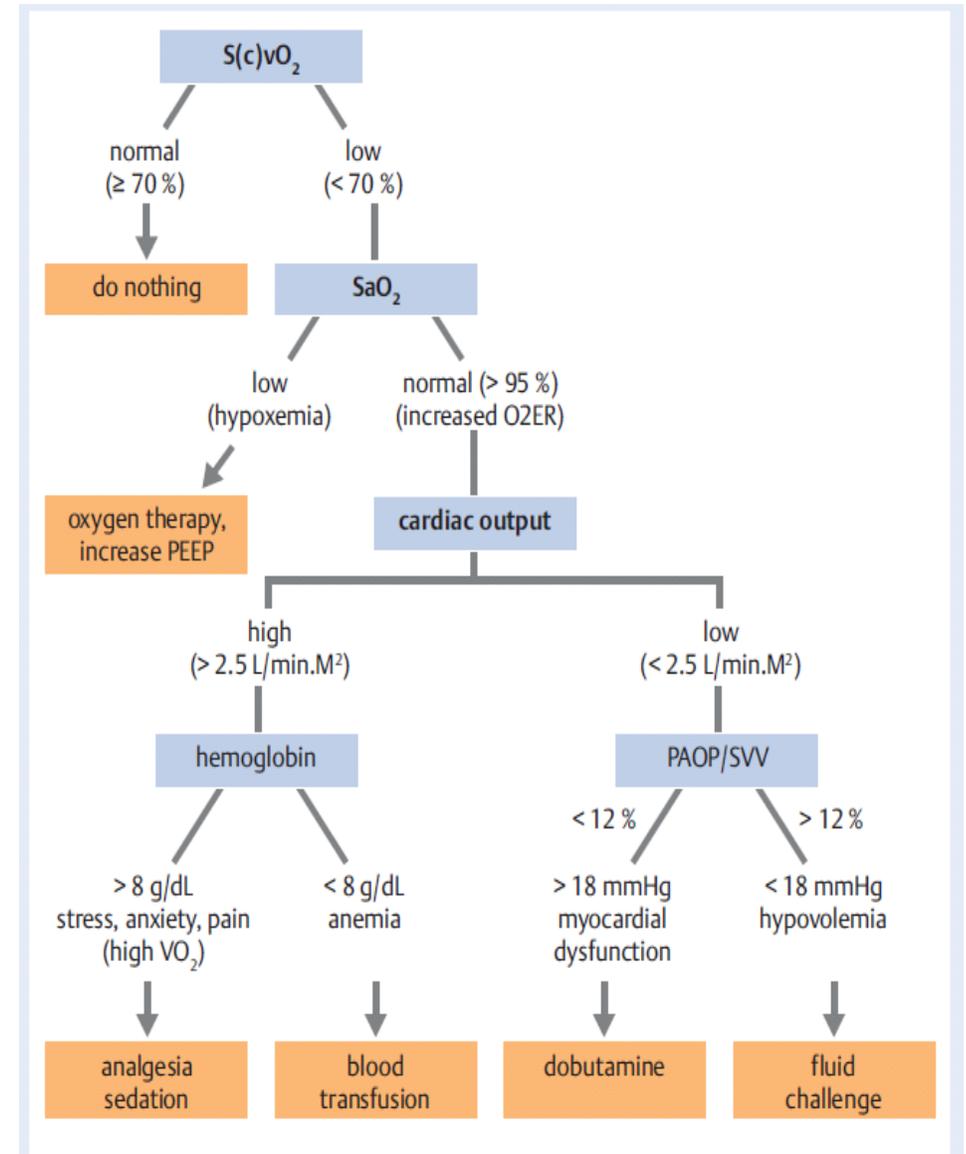
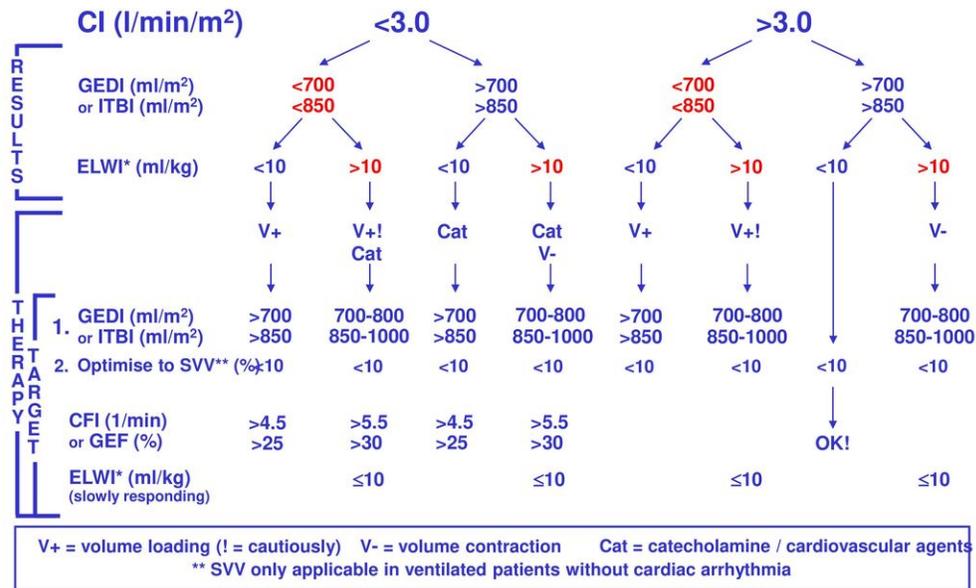


Figure 7. Algorithm describing perioperative haemodynamic optimisation in patients undergoing non-cardiac surgery



# PiCCO / PAC

Decision tree for hemodynamic / volumetric monitoring



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].



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# Take home messages

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- **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 ...**





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# Vielen Dank für Ihre Aufmerksamkeit

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[https://youtu.be/ctS\\_bEfWAW8](https://youtu.be/ctS_bEfWAW8)



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