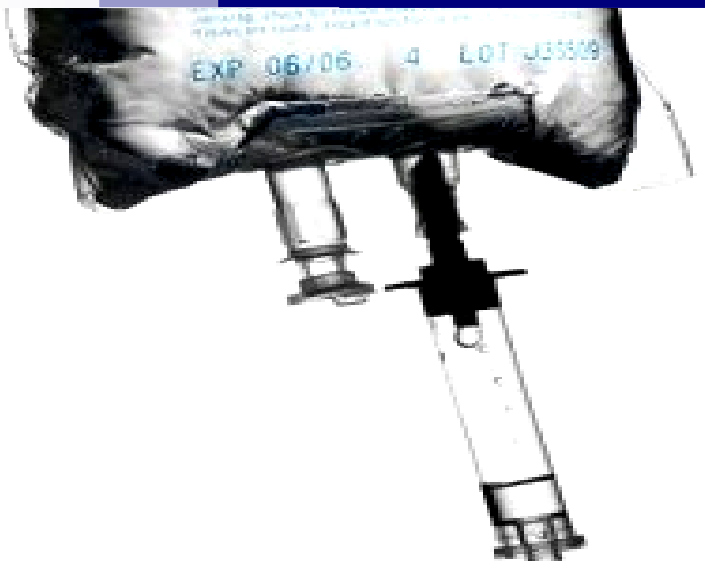
Fluid responsiveness Monitoring in Surgical and Critically Ill Patients



Impact clinique de la *Goal-directed-therapy*

Patrice FORGET, M.D

Cliniques universitaires Saint Luc
Université catholique de Louvain, Brussels, Belgium.

Introduction

- Expansion volémique
  - Intervention fréquente et importante
  - But: augmenter le *stroke volume* pour améliorer l'outcome
- Individualiser le remplissage reste un challenge
  - Prédire la réponse au remplissage
  - Eviter l'hypo- comme l'hypervolémie

Why do I need to fill my patient?

- To rise his CO
- To improve clinical parameters
- To improve oxygen delivery
- To correct lactic acidosis
- …

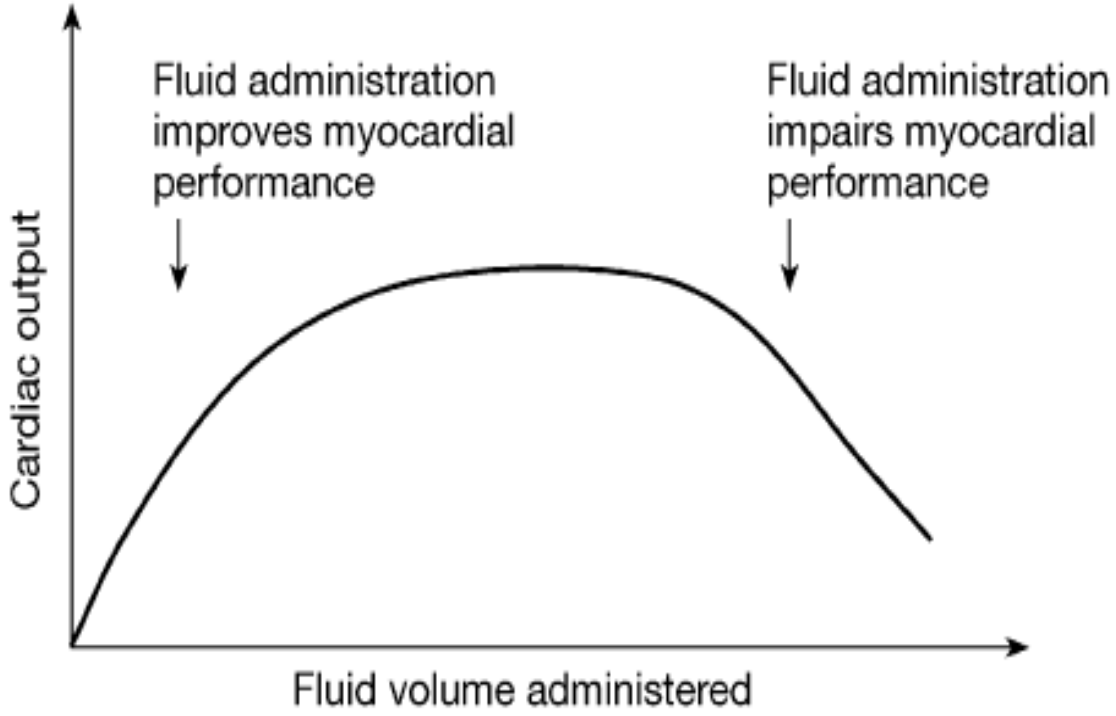
Rapidity is determinant!

But fluid loading may be insufficient

- Only 40 to 72% “responders”
- Cardiac failure, organic pathologies, renal tubulopathy

And potentially harmful…

Fluids may be harmful!



Kehlet *et al,* BJA 2002

Fluids may be harmful!

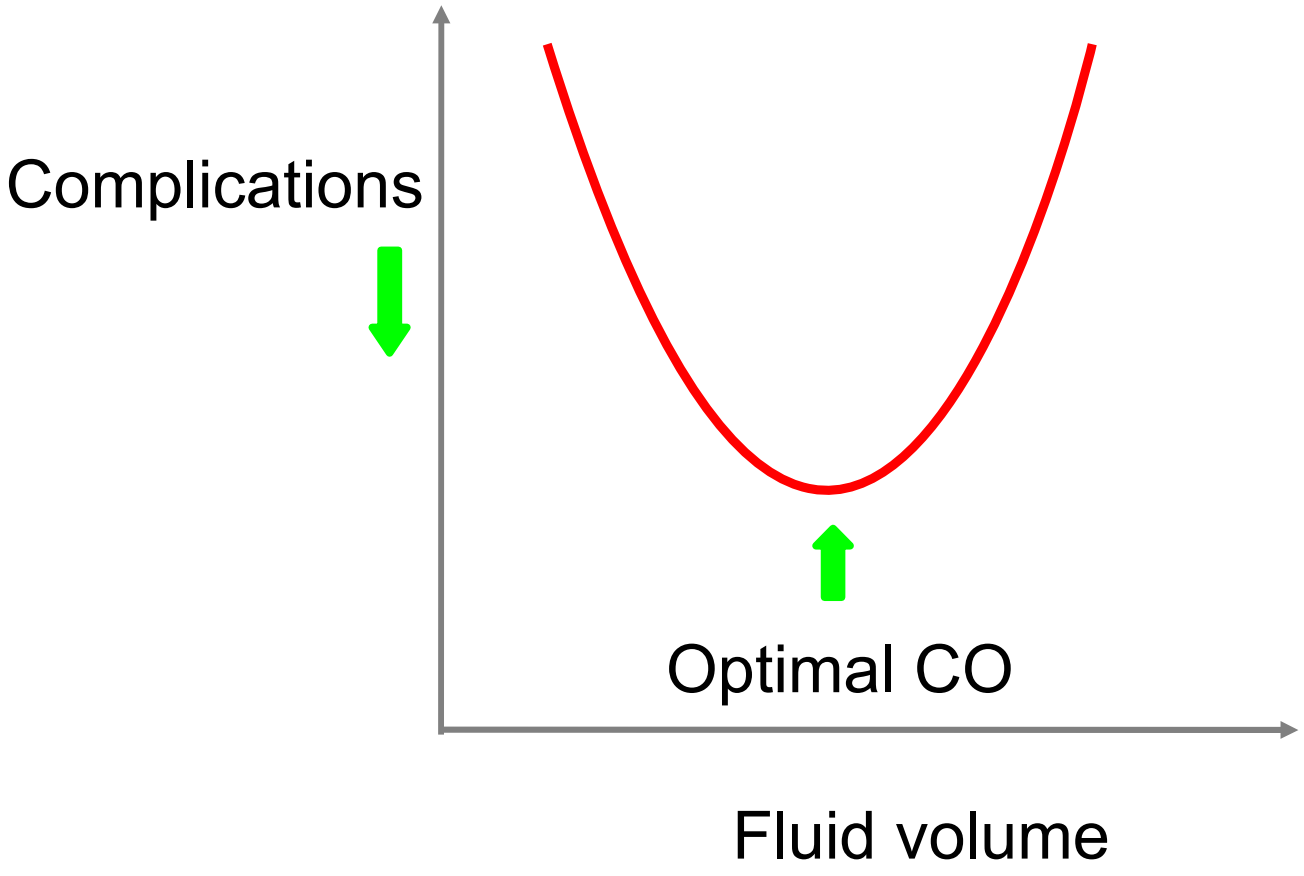
- To fear hypo- as hypervolemia
- Liberal vs Restrictive?
  - Interest of the fluid restriction in major abdominal surgery but…
  - Debate still open
    - Holte *et al,* B J Anaesth 2007
  - Tailoring the fluid management
    - Poeze *et al,* Crit Care 2005

Fluids may be harmful!

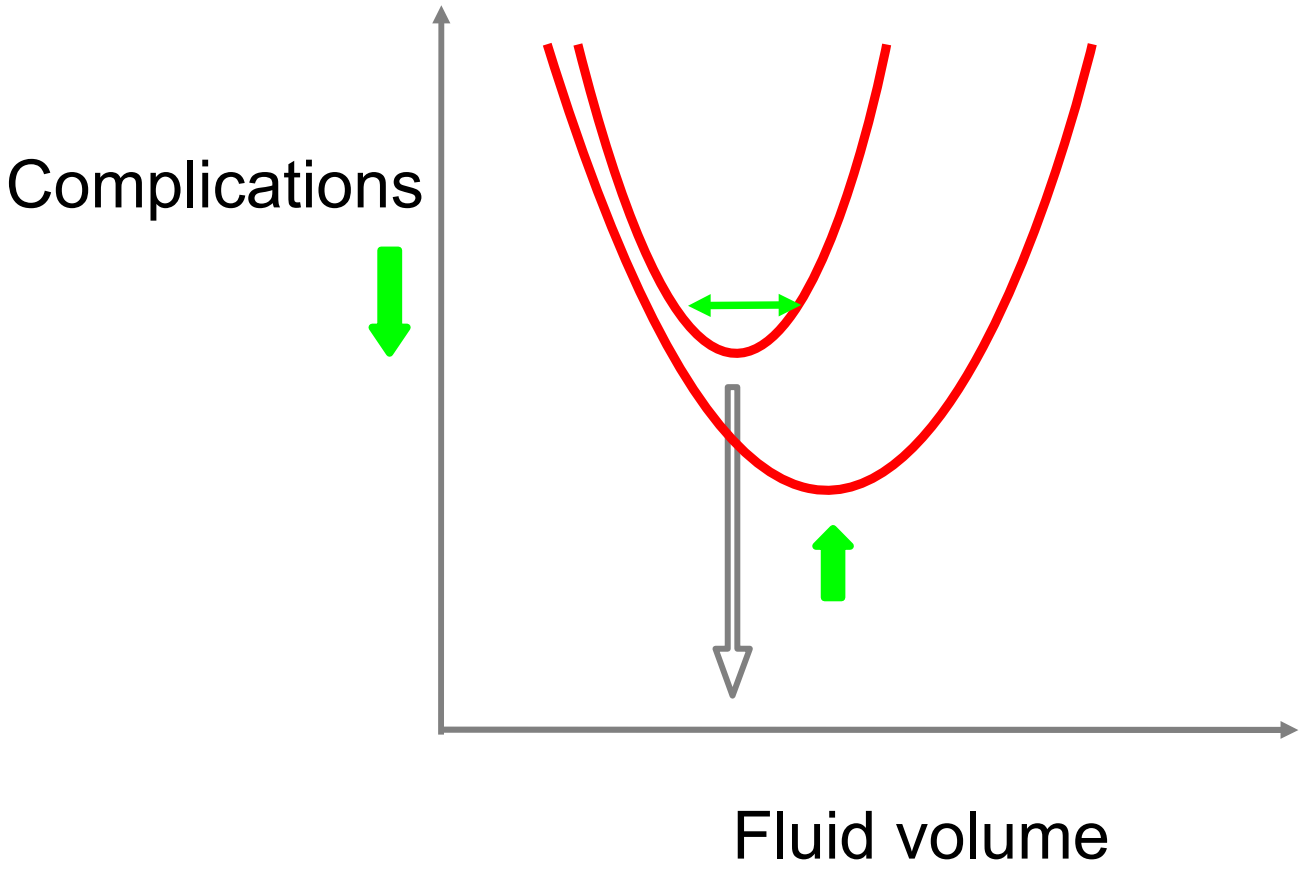
Optimization of perioperative fluid management may include a combination of limited crystalloid administration together with individualized goal-directed colloid administration to maintain a maximal stroke volume

Bungaard-Nielsen, Secher and Kehlet *et al*, Acta Anaesthesiol Scand 2009

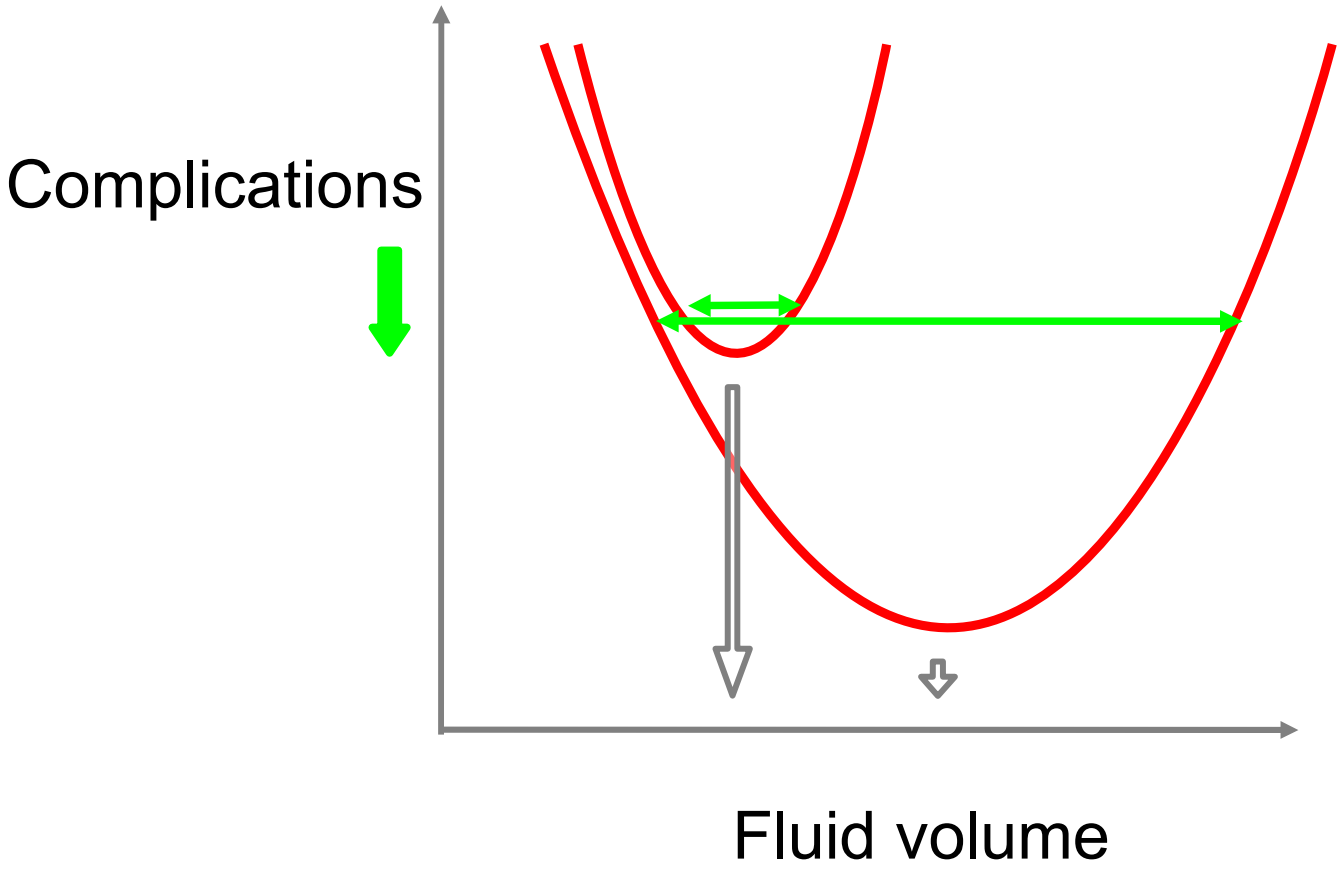
Goal directed fluid management



Goal directed fluid management



Goal directed fluid management



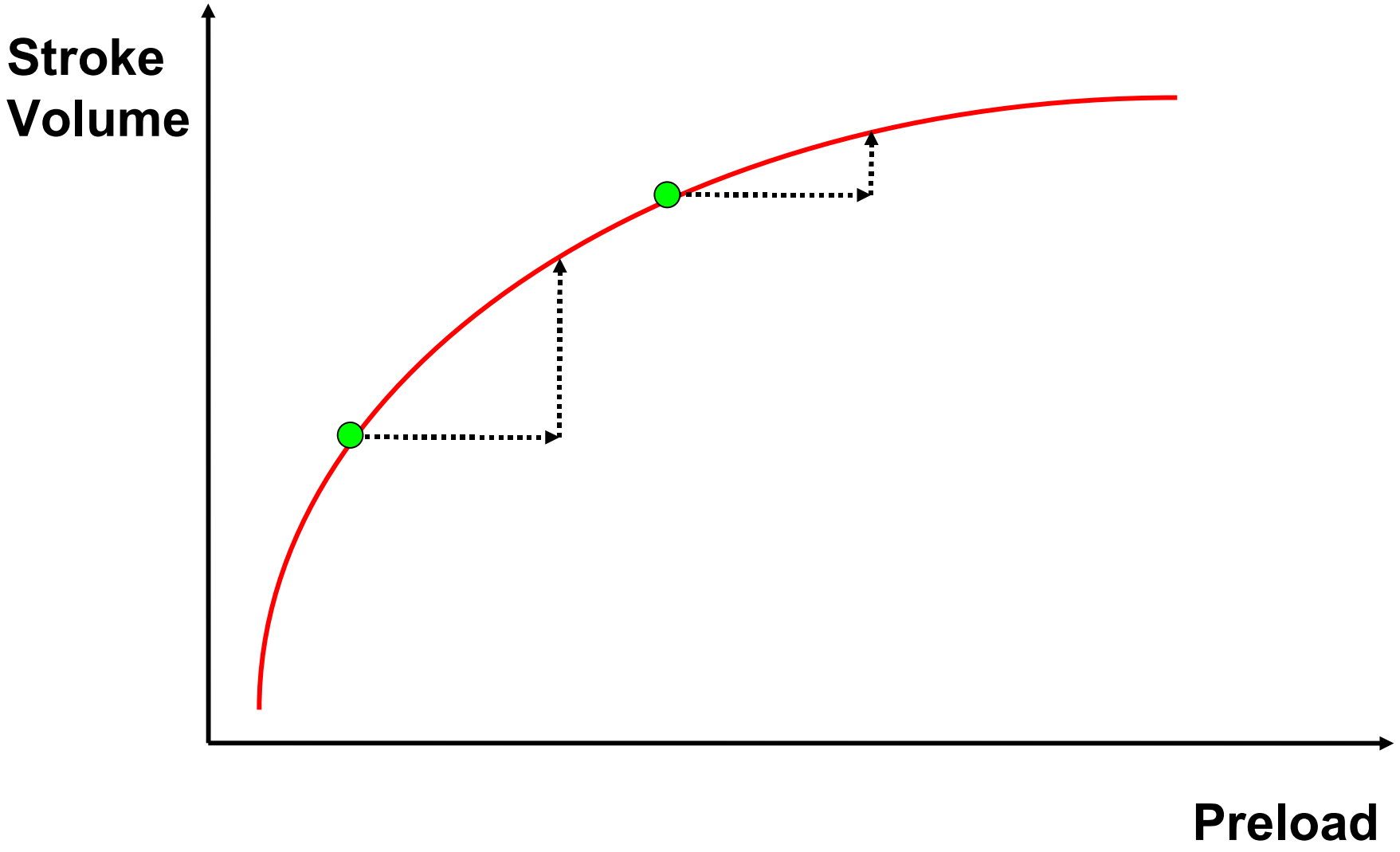
Goal directed fluid management

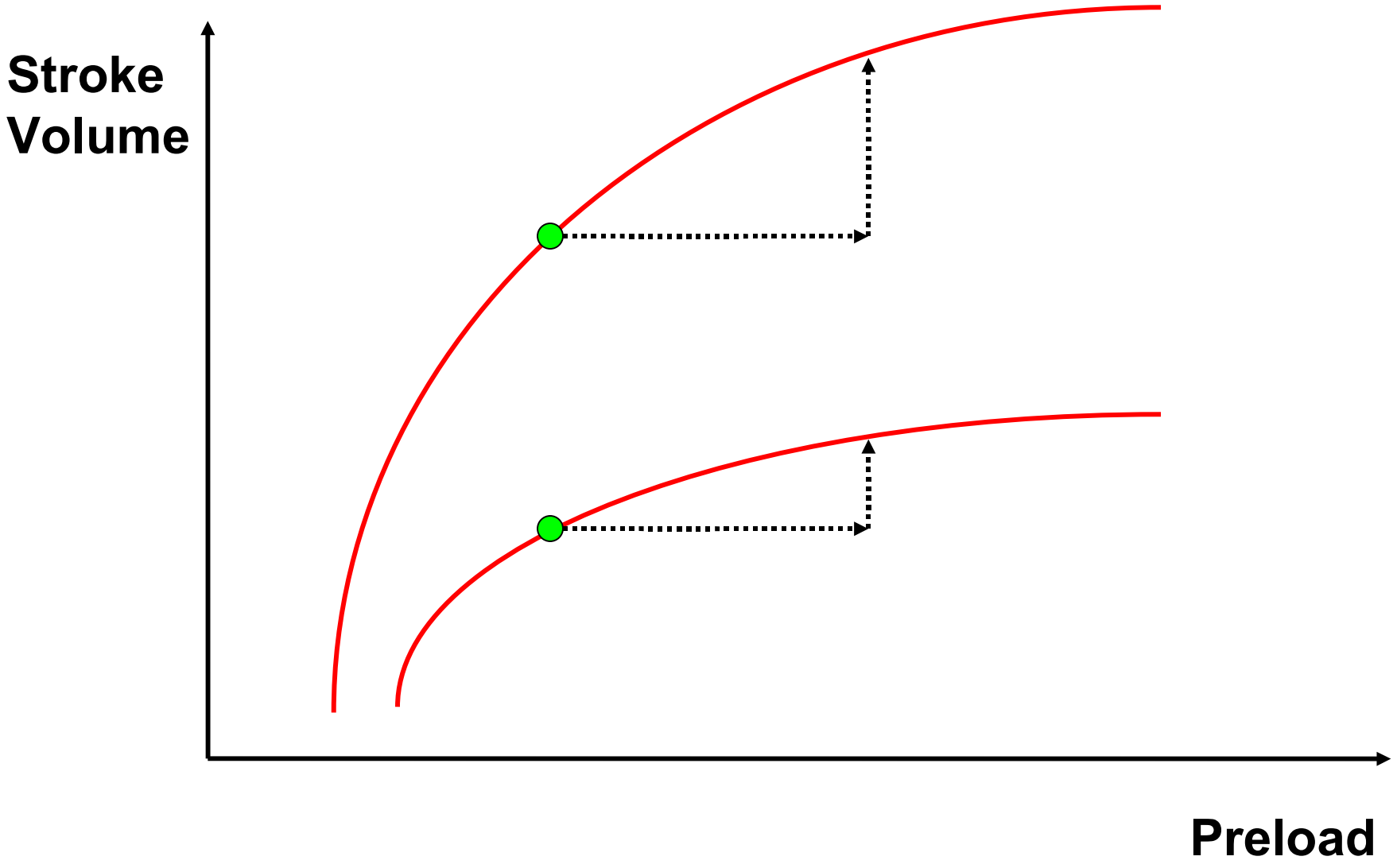
- *To fill before the clinical signs of hypovolemia*
  - To optimise the CO
  - To improve the morbi- mortality
  - To improve the quality of care and accelerate the rehabilitation
  - To shorten the hospital stay
  - To limit the costs

Goal directed therapy

Well defined parameters

Which parameters?


Stroke Volume
Preload


Stroke Volume
Preload

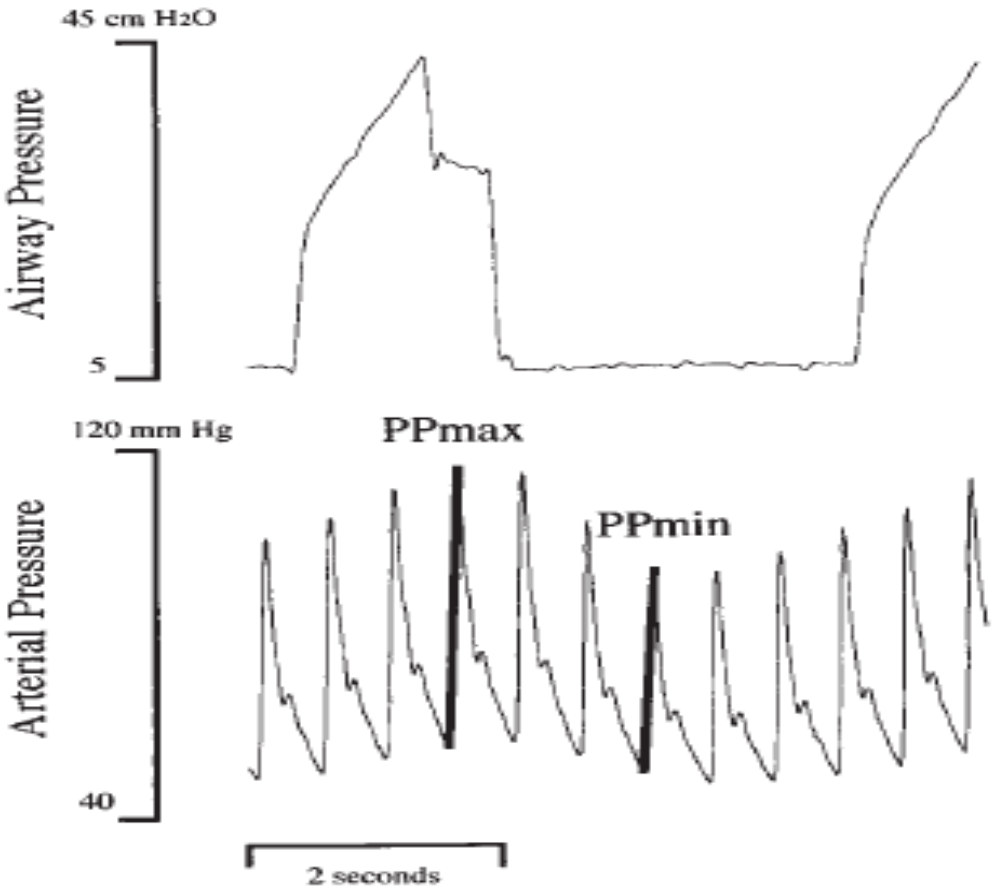
Goal directed fluid management

- Clinical signs and context
- Evolution of static “classical” parameters (CVP, PAOP, CF)
- Dynamic tests (Passive leg raising, fluid challenge)
- Biological parameters
  - *Helpful but insufficient!*

Goal directed fluid management

- Dynamic parameters
  - Cyclic variations of cardiac preload
  - Preload-dependency analysis
    - PPV (deltaPP), SVV, SPV, dDown, PVI

Pulse Pressure Variation



Michard *et al*, Am J Resp Crit C Med 2000.

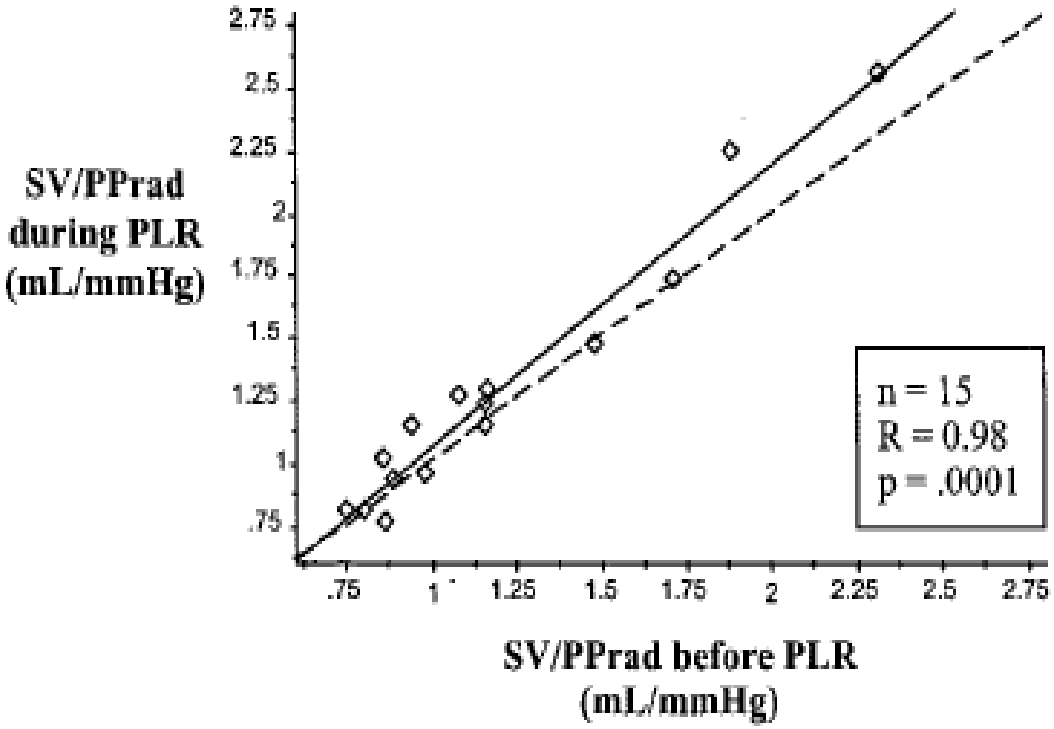
Pulse Pressure Variation

Inspiratory positive pressure

- ↓ venous return
- ↓ right ventricular output
- ↓ left ventricular preload

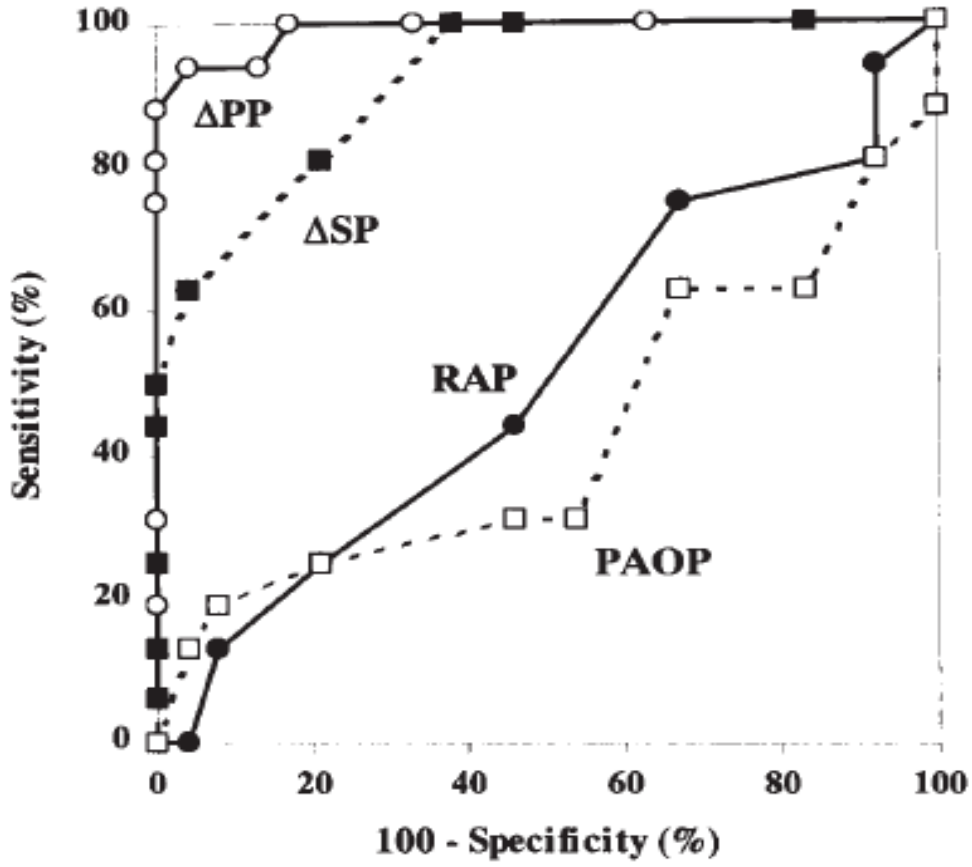
- ↑ transmural pressures
- ↑ ANS

Physiology Background



Boulain *et al,* Chest 2002

Goal directed fluid management



Michard *et al*, Am J Resp Crit C Med 2000.

Pulse Pressure Variation

- Colorectal (Haifang *et al*, Chin Med J 2002)
- Pheo (Mallat *et al*, C J Anesth 2003)
- CABG (Cannesson *et al*, A&A 2008)
- PO CABG (Rex *et al*, B J Anaesth 2004)
- Hepatectomy (Solus *et al*, B J Anaesth 2006)
- High-risk (Lopes *et al*, Crit Care 2007)

Dynamic parameters

Method	Advantages	Limitations
Minimally Invasive		
ΔPP	Considered gold standard for accuracy Clinical validation	Subject to con-founding effects

Dynamic parameters

Method	Advantages	Limitations
Invasive		
SVV, ΔPP (PiCCO Plus; Pulsion Medical Systems AG)	Clinical validation SVV Pulse pressure variations Multimodal monitoring (eg, CO, vascular resistances)	Requires specific material Calibration No artifact detection Proprietary algorithm

Dynamic parameters

Method	Advantages	Limitations
Minimally Invasive		
SVV (FloTrac/ Vigileo; Edwards Lifesciences LLC)	Multimodal monitoring (eg, CO, vascular resistances) No calibration Clinical validation	Requires specific material No artifact detection Divergent data regarding cardiac output determination Proprietary algorithm

Dynamic parameters

Method	Advantages	Limitations
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SVV (FloTrac/ Vigileo; Edwards Lifesciences LLC)	Multimodal monitoring (eg, CO, vascular resistances) No calibration Clinical validation	Requires specific material No artifact detection Divergent data regarding cardiac output determination Proprietary algorithm

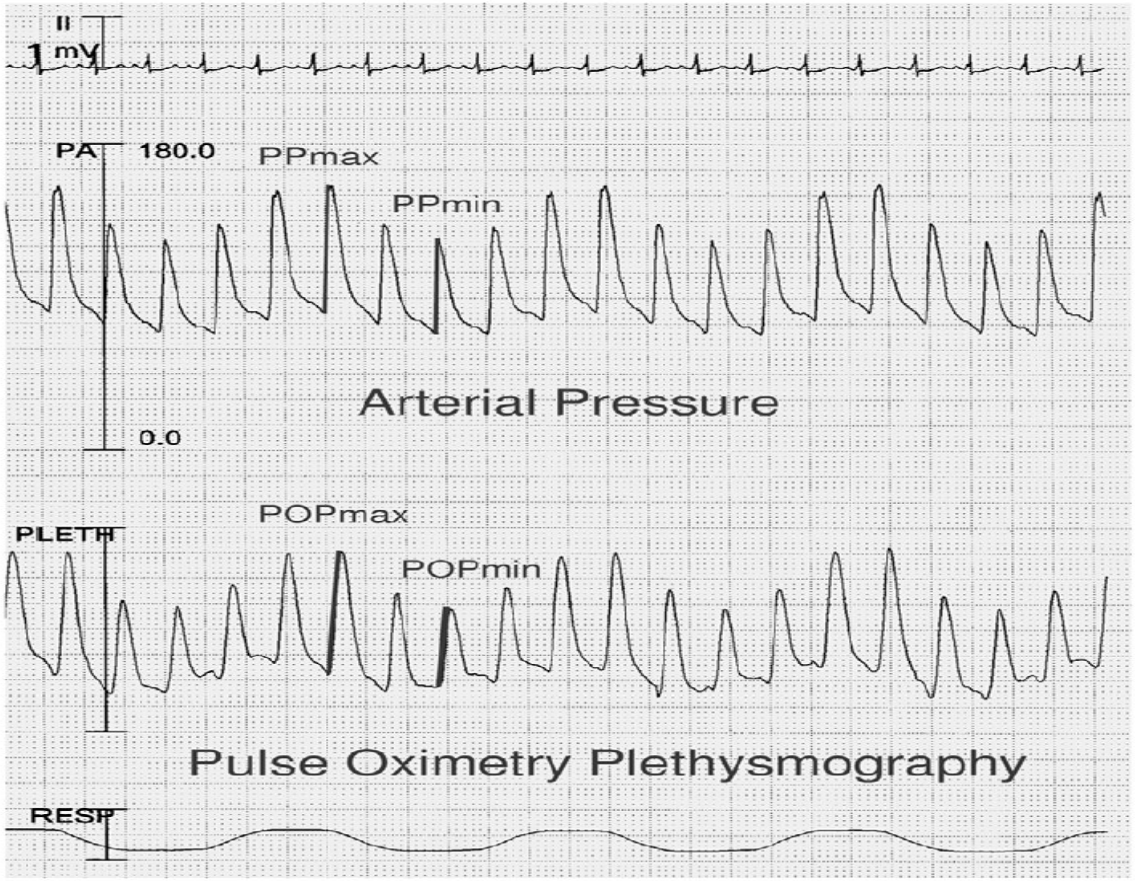
Pulse Pressure Variation

- *But…*
  - Actually limited to controlled ventilation
  - In the absence of arrhythmia
  - *Importance of the clinical context!*
    - Orthopic liver transplantation (Gouvêa *et al,* B J Anaesth 2009)
  - *In the case of automated calculation, importance of the validation of the software!*
    - Vigileo? (Lahner *et al,* B J Anaesth 2009)
  - Dynamic invasive methods are often impractical, complex and costly.

Dynamic parameters

Method	Advantages	Limitations
Noninvasive		
PVI (part of Masimo Rainbow SET platform; Masimo Corp.)	Multimodal monitoring (eg, hemoglobin, oxygen content) No calibration Real-time and continuous information Ease of use Clinical validation	Vasomotor tone No artifact detection Proprietary algorithm

PPV and deltaPOP



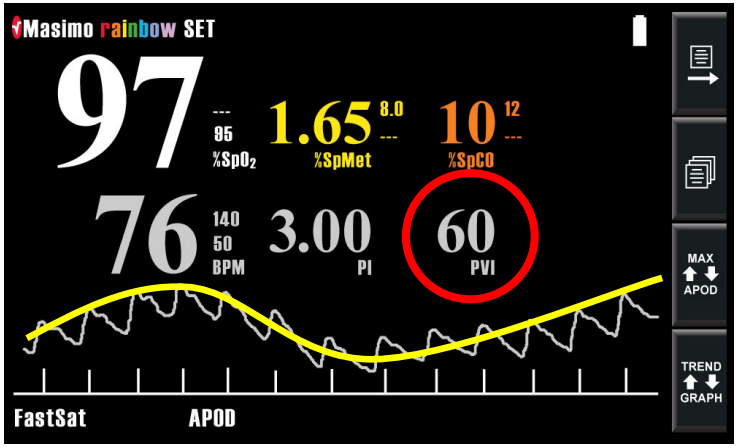
Cannesson *et al*, Crit Care 2005.

deltaPOP and PVI

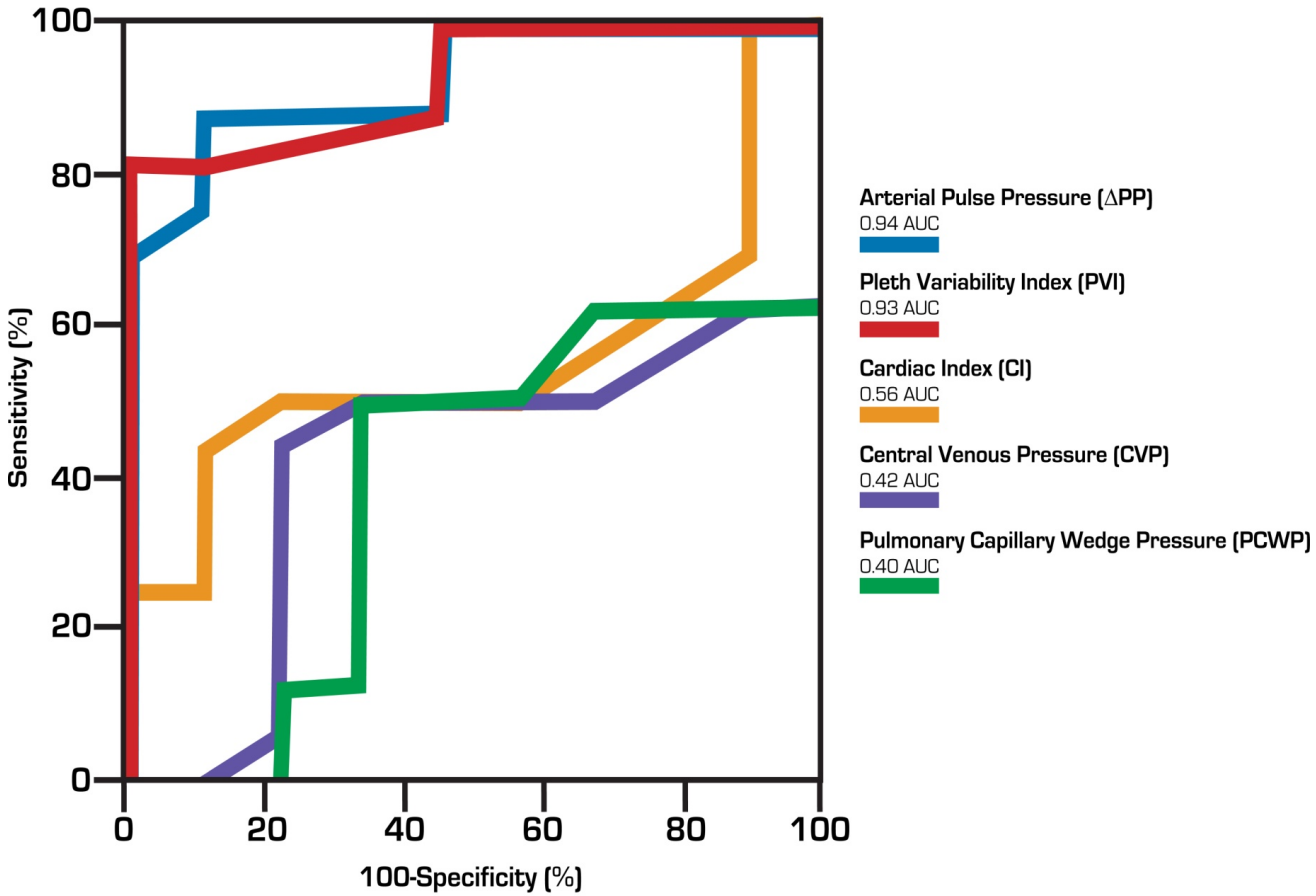
- Haifang *et al*, Chin Med J 2002
- Cannesson *et al*, Crit Care 2005
- Natalini *et al*, Anesthesiology 2006
- Solus *et al*, B J Anaesth 2006
- Cannesson *et al*, B J Anaesth 2008
  - *PVI >14% predicts fluid responsiveness.*

Pleth Variability Index

$$PVI = \frac{PI_{Max} - PI_{Min}}{PI_{Max}} \times 100\ \%$$



Pleth Variability Index



Adapted from Cannesson M et al. Br J Anaesth. 2008 Jun 2. [Epub ahead of print]

Pleth Variability Index

- 43 mechanically-ventilated septic shock patients
- 500 ml saline fluid challenge, passive leg raising
- Results
  - Correlation of 0.90 for PVI vs. ΔPP
  - PVI >20 vs. ΔPP >15%
    - Sensitivity 84%, specificity 90%
  - PVI >20 was 100% accurate in discriminating fluid responders from non-responders

Feissel *et al*. ISICEM 2009.

Optimisation of the PVI?

- To guide fluid management and to optimise circulatory status during the surgery?
- Randomised Clinical Trial
  - to compare the intraoperative PVI-directed fluid management vs standard care
  - Clinicaltrials.gov Number NCT00816153

Forget P, Lois F and De Kock M, Anesth Analg 2010.

Optimisation by the PVI

- **Group PVI (P)**
  - 500 mL of cristalloids followed by 2 mL.kg-1.h-1
  - Colloids 250 mL added for a PVI value of 10 to 13%
  - If required, vasoactive support to maintain the mean arterial pressure above 65 mmHg
- **Group Control (C)**
  - 500 mL of cristalloids followed by fluid management based on fluid challenges and CVP

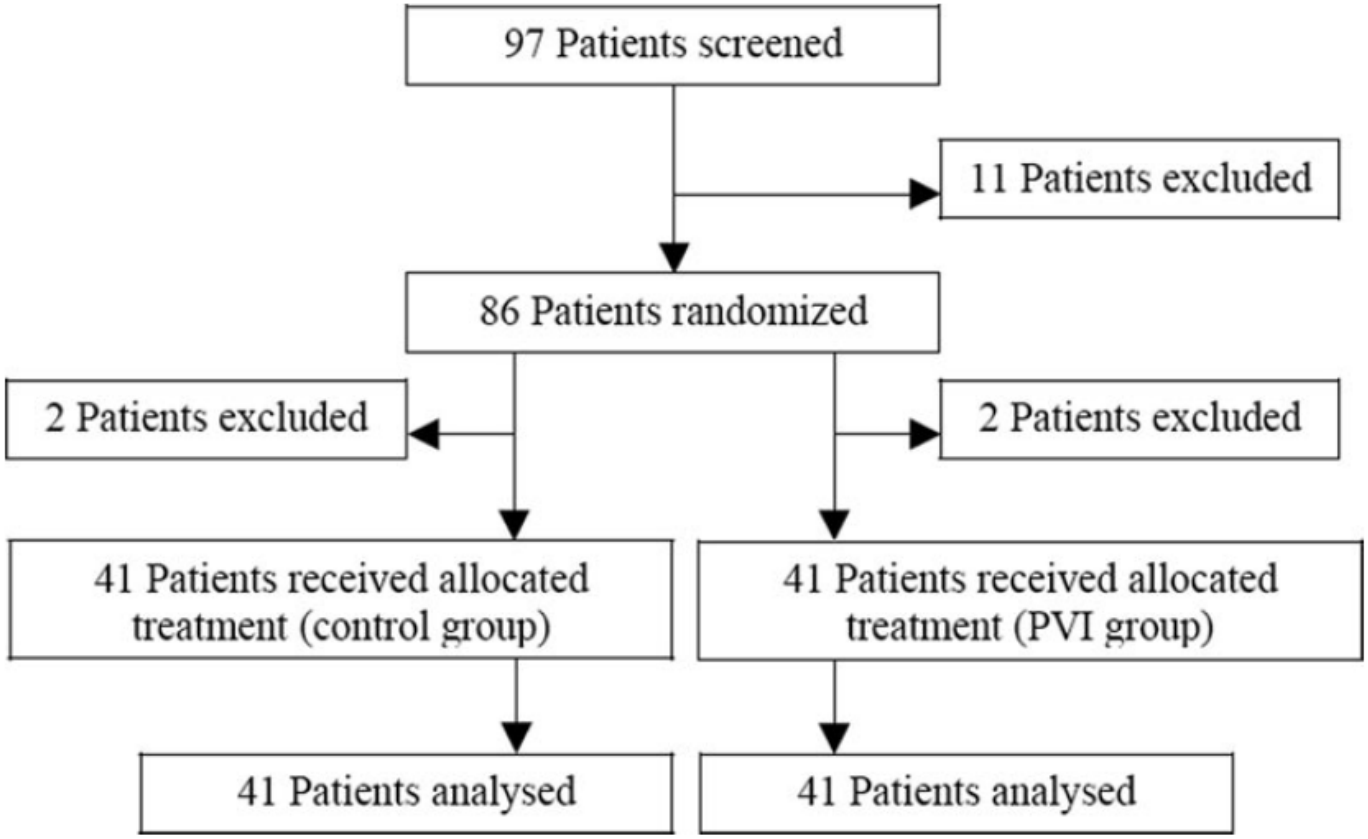
Forget P, Lois F and De Kock M, Anesth Analg 2010.

Optimisation by the PVI

- Primary outcome
  - Perioperative lactate levels
- Secondary outcomes
  - Hemodynamic data
  - Postoperative complications

Forget P, Lois F and De Kock M, Anesth Analg 2010.

Optimisation by the PVI



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Optimisation by the PVI

Table 1. Preoperative Characteristics, Incidence of Chronic Diseases, Type and Duration of Surgery and Anesthesia, Use of Epidural Analgesia in the Pleth Variability Index (PVI) Group (PVI-Guided Fluid Management) and Control Group

	PVI group (*N* = 41)	Control group (*N* = 41)
Age (years)	59 ± 14	61 ± 12
Weight (kg)	71 ± 15	68 ± 16
Height (cm)	169 ± 9	170 ± 9
Sex (female/male)	16/25 (39/61)	16/25 (39/61)
ASA score		
2	22 (54)	22 (54)
3	19 (46)	19 (46)
Chronic diseases		
Cirrhosis	3 (7)	0 (0)
Chronic obstructive pulmonary disease	2 (5)	2 (5)
Hypertension	18 (44)	13 (32)
Peripheral vascular disease	7 (17)	7 (17)
Coronary artery disease	5 (12)	2 (5)
Other cardiomyopathy	2 (5)	4 (10)
Diabetes mellitus	4 (10)	2 (5)

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Preoperative biological values		
Hemoglobin ($g \cdot dL^{-1}$)	12.5 ± 2	12.7 ± 2
Serum creatinine ($mg \cdot dL^{-1}$)	0.96 ± 0.2	0.97 ± 0.3
Type of surgery		
Upper gastrointestinal	7 (17)	5 (12)
Hepato-biliary	11 (27)	15 (37)
Lower gastrointestinal	24 (59)	22 (54)
Laparoscopic approach	5 (12)	5 (12)
Duration of surgery (minutes)	295 ± 125	301 ± 154
Duration of anesthesia (minutes)	346 ± 125	356 ± 158
Epidural analgesia	33 (81)	29 (71)

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Optimisation by the PVI

Table 2. Fluids Administered, Blood Loss, Hemodynamic Status, Physiologic Status, and Renal Function During and After Surgery in the Pleth Variability Index (PVI) Group (PVI-Guided Fluid Management) and in the Control Group

	PVI group (*N* = 41)	Control group (*N* = 41)	*P* value
Intraoperative fluids (mL)			
Crystalloids	1363 [1185–1540]	1815 [1568–2064]	**0.004**
Colloids	890 [709–1072]	1003 [779–1227]	0.43
Blood products	141 [53–230]	99 [20–179]	0.48
Total of intraoperative fluids	2394 [2097–2692]	2918 [2478–3358]	**0.049**
Blood losses	349 [230–468]	440 [242–637]	0.43
Postoperative fluids (24 hours)			
Crystalloids	3107 [2760–3454]	3516 [3009–4024]	0.17
Colloids	268 [126–409]	358 [175–540]	0.43
Blood products	8 [−8–25]	44 [−45–133]	0.41

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Optimisation by the PVI

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	PVI group (*N* = 41)	Control group (*N* = 41)	*P* value
Lactate levels (mMol · L^{-1})			
Maximum intraoperative	1.2 [1–1.4]	1.6 [1.2–2]	**0.04**
At 24 hours	1.4 [1.3–1.5]	1.8 [1.5–2.1]	**0.02**
At 48 hours	1.2 [1–1.3]	1.4 [1.2–1.5]	**0.03**
Lactate levels >1.7 mMol · L^{-1}			
Intraoperatively	7 (17)	4 (10)	0.33
At 24 hours	2 (5)	28 (68)	**<0.0001**
At 48 hours	0	8 (20)	**0.003**
Lactate levels >5 mMol · L^{-1}			
Intraoperatively	0	1 (2)	0.31
At 24 hours	0	1 (2)	0.31
At 48 hours	0	1 (2)	0.31
Intraoperative hypotension	22 (54)	28 (68)	0.17

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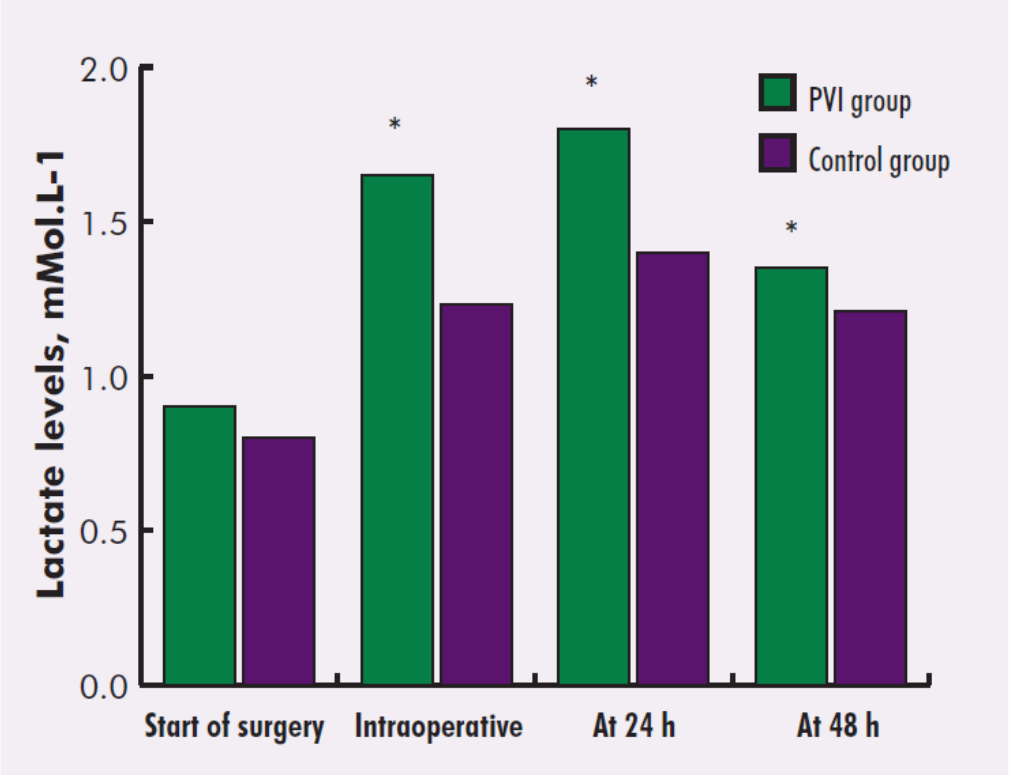
	PVI group (*N* = 41)	Control group (*N* = 41)	*P* value
Intraoperative hypotension	22 (54)	28 (68)	0.17
Continuous infusion of norepinephrine			
Intraoperative	9 (22)	9 (22)	1.0
At 24 hours	3 (7)	1 (2)	0.31
Renal function diuresis			
Intraoperative oliguria	13 (32)	17 (42)	0.34
Postoperative oliguria (24 hours)	3 (8)	3 (8)	0.97
Serum creatinine ($mg \cdot dL^{-1}$)			
At 24 hours	1.01 [0.9–1.1]	1.12 [0.9–1.3]	0.32
At 48 hours	0.91 [0.8–1]	1.09 [0.9–1.3]	0.11
Initiation of dialysis	1 (2)	0 (0)	0.32

Forget P, Lois F and De Kock M, Anesth Analg 2010.

Optimisation by the PVI



Forget P, Lois F and De Kock M, Anesth Analg 2010.

Optimisation by the PVI

Table 3. Postoperative Complications and Intensive Care Unit/Hospital Stay in the Pleth Variability Index (PVI) Group (PVI-Guided Fluid Management) and in the Control Group

	PVI group (N = 41)	Control group (N = 41)	P Value
Postoperative complications			
Infection of surgery site	8 (20)	8 (20)	1.0
Other infections (pulmonary, line-related, other abdominal)	6 (15)	7 (17)	0.77
Cardiovascular complications (acute myocardial infarction, acute lung injury/acute respiratory distress syndrome, pulmonary edema, arrhythmia)	4 (10)	8 (20)	0.26
Coagulopathy	5 (12)	6 (15)	0.75
Nausea and/or vomiting	0 (0)	4 (16)	0.08
Upper digestive hemorrhage	4 (10)	3 (7)	0.78
Leakage of anastomosis	5 (12)	5 (12)	1.0
Morbidity (event per patient)	1.2 ± 1.8	1.5 ± 2.2	0.46
Mortality	2 (5)	0 (0)	0.16
Length of stay			
Postoperative mechanical ventilation	1 (2)	3 (7)	0.31
Intensive care unit (days)	2.2 ± 5.7	1.8 ± 7.2	0.71
Hospital (days)	15.1 ± 14.3	16.0 ± 17.8	0.78

Forget P, Lois F and De Kock M, Anesth Analg 2010.

Conclusion

- Tailored fluid administration is associated with improved morbidity and hospital length of stay
- Focusing on optimization of CO help in the choice of monitoring methods
- More studies are needed to confirm the clinical value and the limits of available fluid responsiveness monitoring methods

Conclusion (2)

- The PVI allows for noninvasive, automated, continuous of fluid responsiveness monitoring
- Our study add evidence to the concept of *Goal-Directed fluid management*