From **minimal monitoring** to Airbus **cockpit**?

Prof. Jean-Louis TEBOUL
Prof Claude Martin


AirlineReporter.com

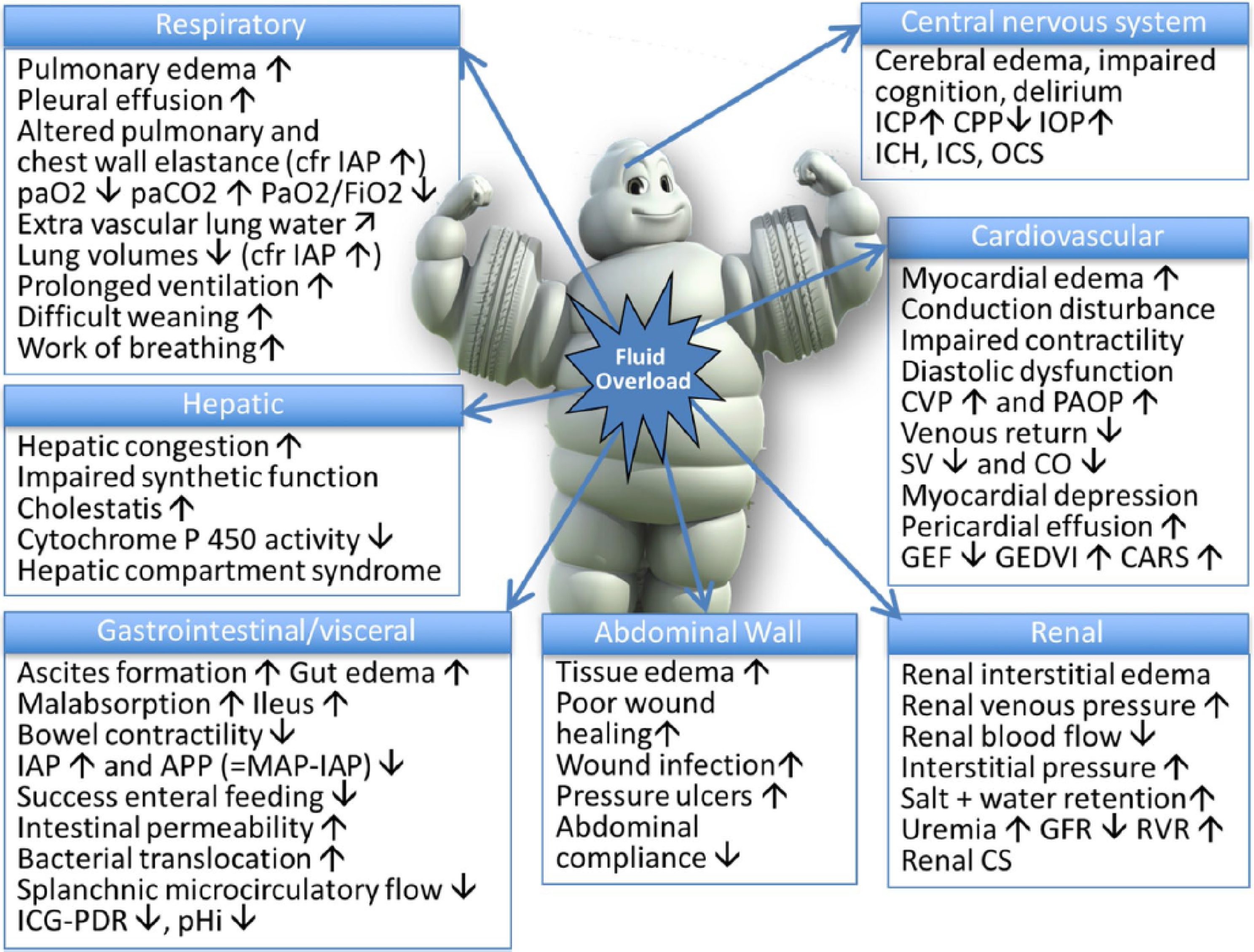


Fig. 2 Potential consequences of fluid overload on end-organ function. Adapted from Malbrain et al. with permission [1, 2]. APP: abdominal perfusion pressure, IAP: intra-abdominal pressure, IAH: intra-abdominal hypertension, ACS: abdominal compartment syndrome, CARS: cardio-abdominal-renal syndrome, CO: cardiac output, CPP: cerebral perfusion pressure, CS: compartment syndrome, CVP: central venous pressure, GEDVI: global enddiastolic volume index, GEF: global ejection fraction, GFR; glomerular filtration rate, ICG-PDR: indocyaninegreen plasma disappearance rate, ICH: intracranial hypertension, ICP: intracranial pressure, ICS: intracranial compartment syndrome, IOP: intra-ocular pressure, MAP: mean arterial pressure, OCS: ocular compartment syndrome, PAOP: pulmonary artery occlusion pressure, pHi: gastric tonometry, RVR: renal vascular resistance, SV: stroke volume

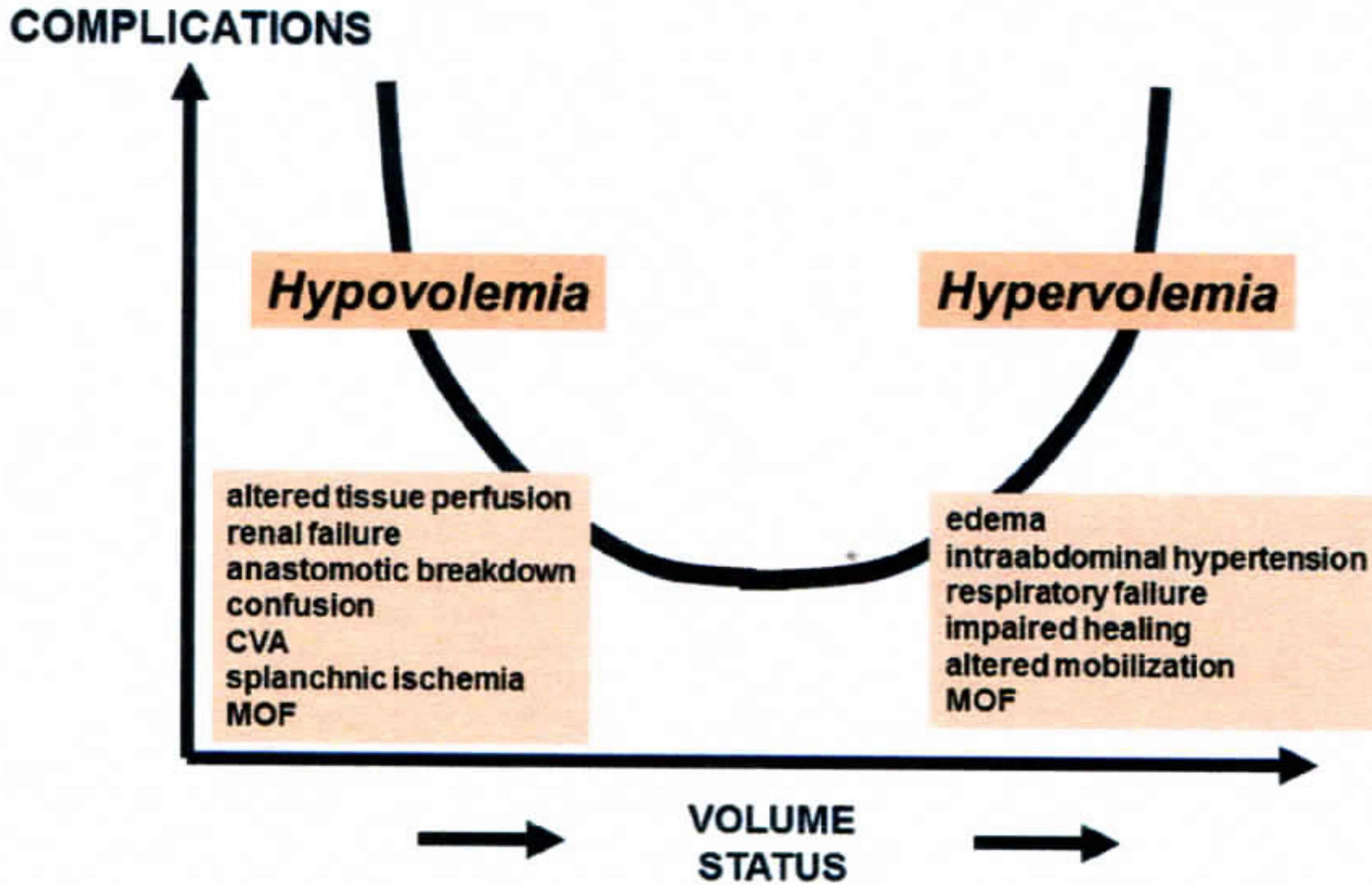


Figure 3 Both hypo- and hypervolemia are associated with more complications. CVA, cerebrovascular accident; MOF, multiple organ failure.

Hemodynamic failure in critically ill patients: 3 components

hypovolemia

vascular tone depression

myocardial **depression**

Importance of assessing

the degree of each component

to select and apply the best therapeutic option

fluids

vasopressors

inotropes

presence of associated **lung injury**

Basic monitoring

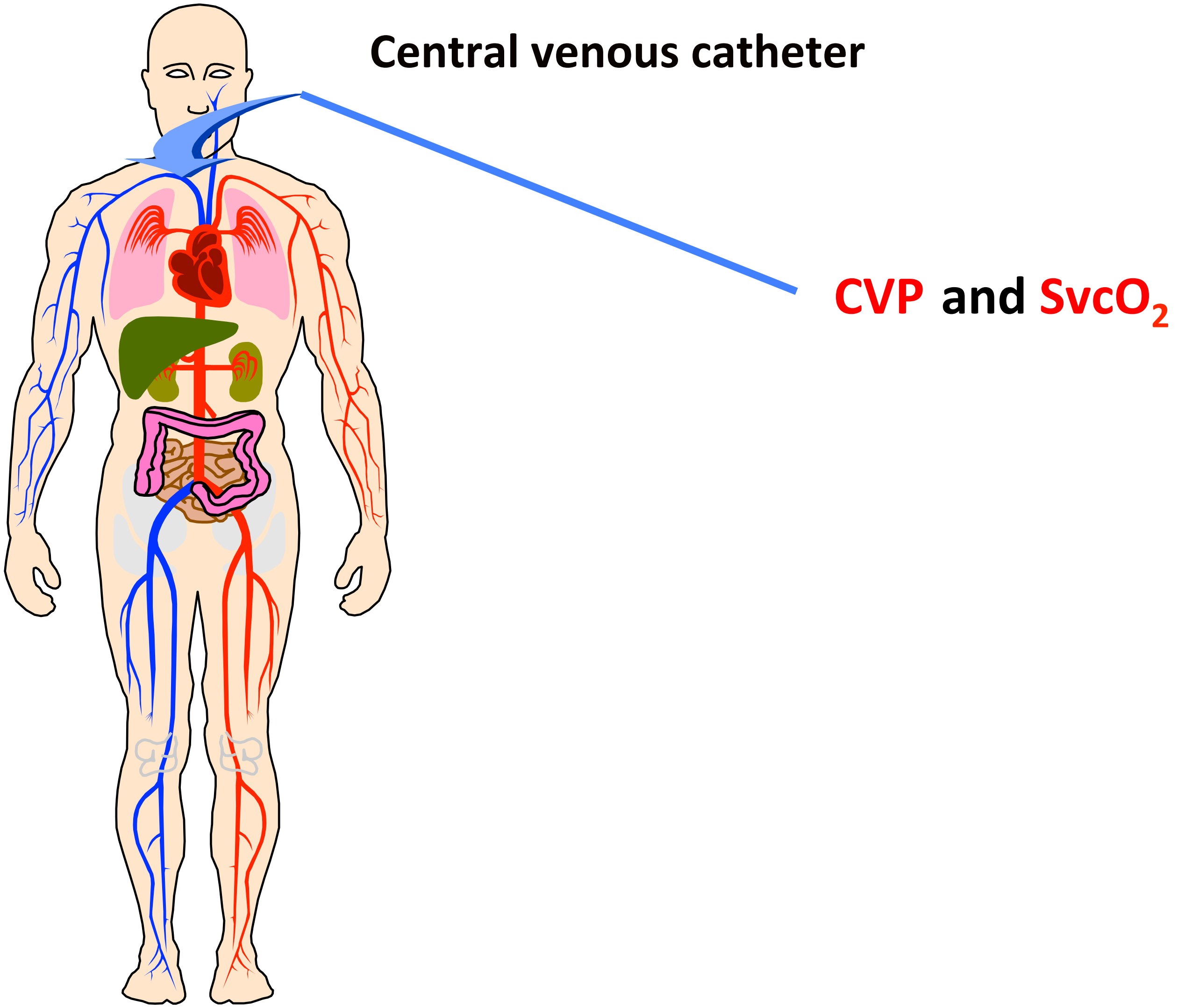
Central venous catheter

- **CVP**
- **$ScvO_2$**

Arterial catheter

- **SAP**
- **DAP**
- **MAP**
- **PP**
- **PPV**

+ Echocardiography


Central venous catheter
CVP and SvcO2

CVP cannot predict **preload / fluid responsiveness**

CVP provides **two** other important pieces of **information**

CVP cannot predict **preload** / **fluid responsiveness**

CVP can provide **two** important pieces of **information**

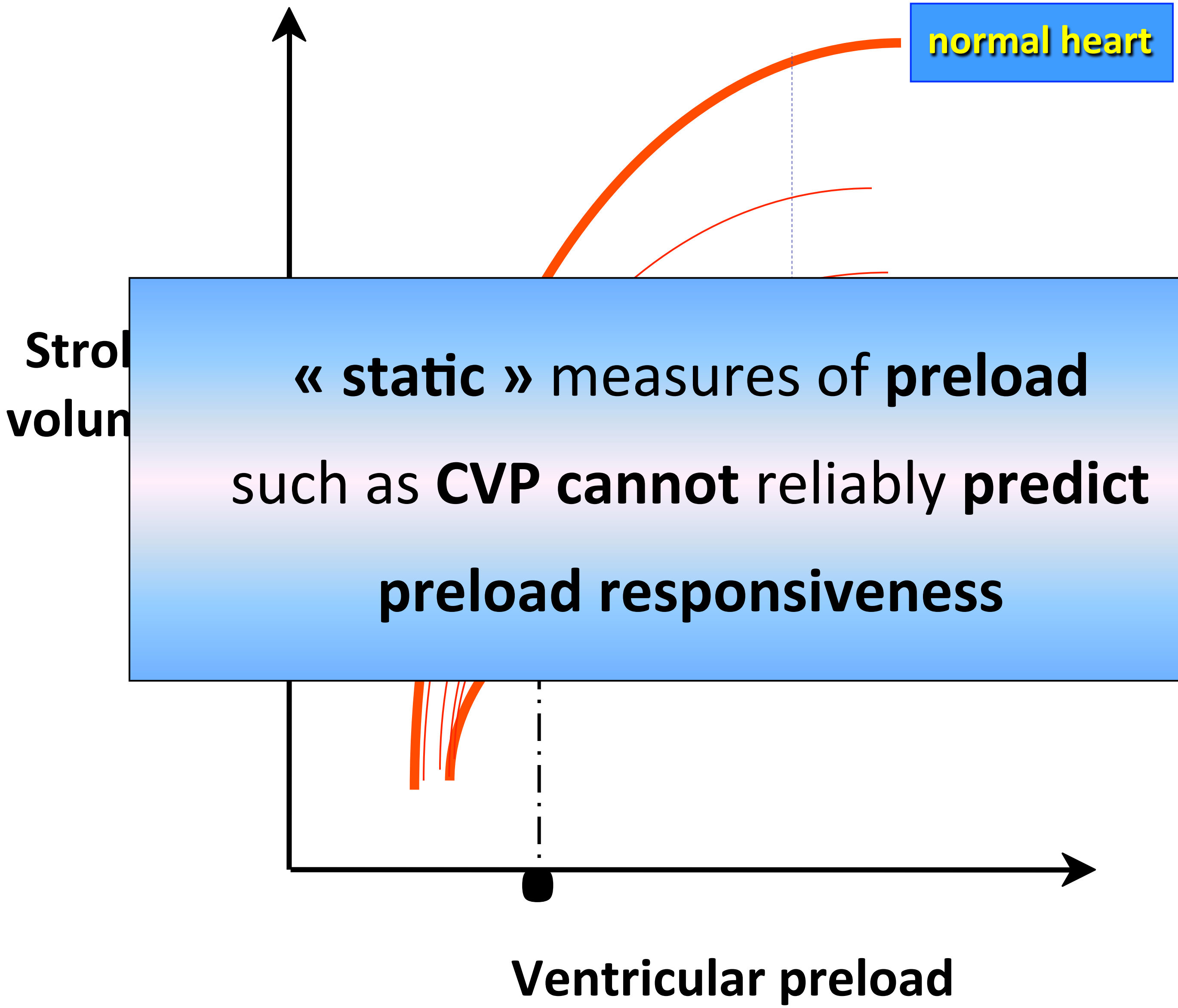
- As a **measure** of **RV** filling **pressure**,

  → **CVP** helps to **diagnose RV dysfunction** and its **response** to **treatment**

- As a **measure** of the **back pressure** to the venous circulation

  → **CVP** helps to **choose** the **MAP target** in shock

  → a high **CVP** associated with organ dysfunction



« **static** » measures of **preload** such as **CVP cannot** reliably **predict** **preload responsiveness**

Does the Central Venous Pressure Predict Fluid Responsiveness? An Updated Meta-Analysis and a Plea for Some Common Sense*

Paul E. Marik, MD, FCCM[1]; Rodrigo Cavallazzi, MD[2]

Crit Care Med 2013; 41:1774-81

Summary

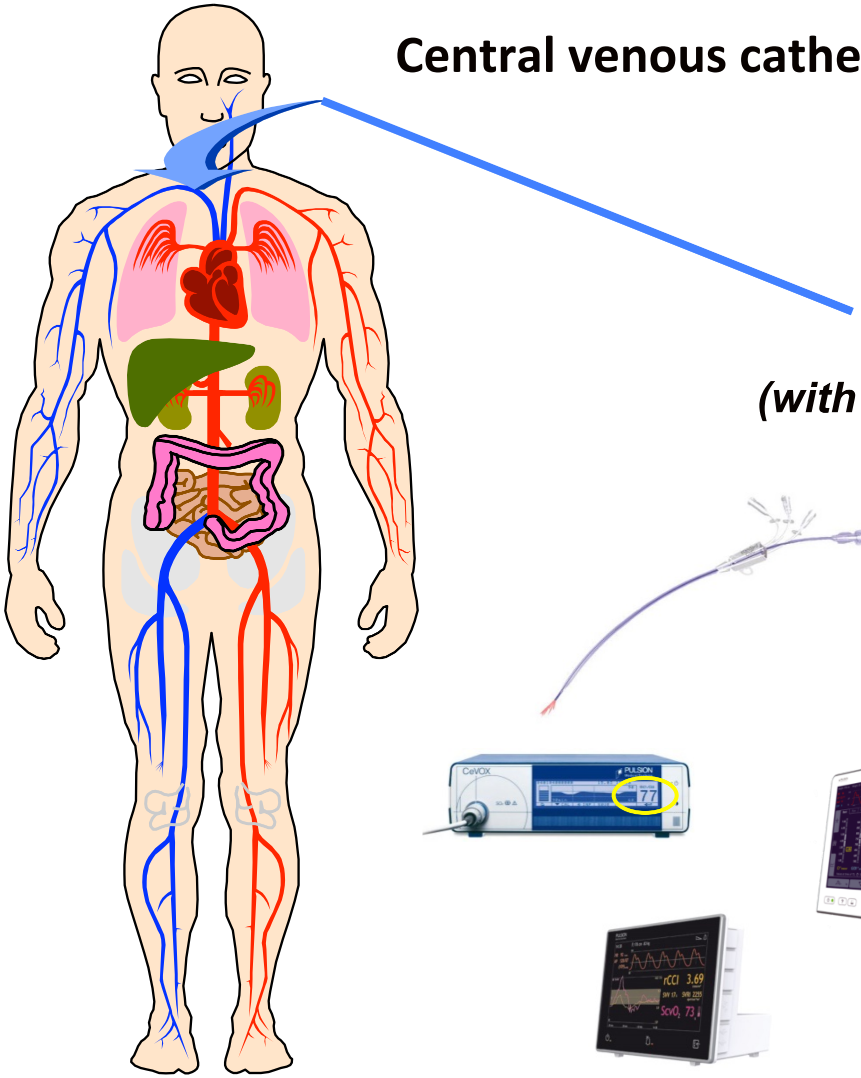
AUC **0.56**

Author	Year	Patients	No. of Patients	Method
ICU				
Calvin et al (23)	1981	Various	28	PAC
Reuse et al (24)	1990	Various	41	PAC
Wagner and Leatherman (25)	1998	Various	25	PAC
Michard et al (26)	2000	Sepsis	40	PAC
Reuter et al (27)	2002	CABG	20	PiCCO
Barbier et al (28)	2004	Sepsis	20	TEE
Kramer et al (29)	2004	CABG	21	PAC
Marx et al (30)	2004	Sepsis	10	PAC, PiCCO
Perel et al (31)	2005	Vascular surgery	14	TEE
De Backer et al (32)	2005	Various	60	PAC
Osman et al (33)	2007	Septic	96	PAC
Magder and Bafaqeeh (34)	2007	CABG	66	PAC
Wyffels et al (35)	2007	CABG	32	PAC
Auler et al (36)	2008	CABG	59	PAC
Muller et al (37)	2008	Various	35	PiCCO
Huang et al (38)	2008		22	PAC, PiCCO
Garcia et al (39)	2009		38	Flotrac (Edwards Life-Sciences, Irvine, CA)
Thiel et al (40)	2009		89	Doppler
Garcia et al (41)	2009	Various	30	Flotrac
Moretti and Pizzi (42)	2010	SAH	29	PiCCO
Muller et al (43)	2011	Various	39	TTE
Lakhal et al (44)	2011	ARDS	65	PAC/PiCCO
Operating room				
Berkenstadt et al (45)	2001	Neurosurg	15	PiCCO
Rex et al (46)	2004	CABG	14	PiCCO/TEE
Preisman et al (47)	2005	CABG	18	TEE, PiCCO
Hofer et al (48)	2005	CABG	40	PAC, PiCCO
Wiesenack et al (49)	2005	CABG	20	PiCCO
Solus-Biguenet et al (50)	2006	Hepatic	8	PAC, TEE
Cannesson et al (51)	2006	CABG	18	TEE

1802 pts

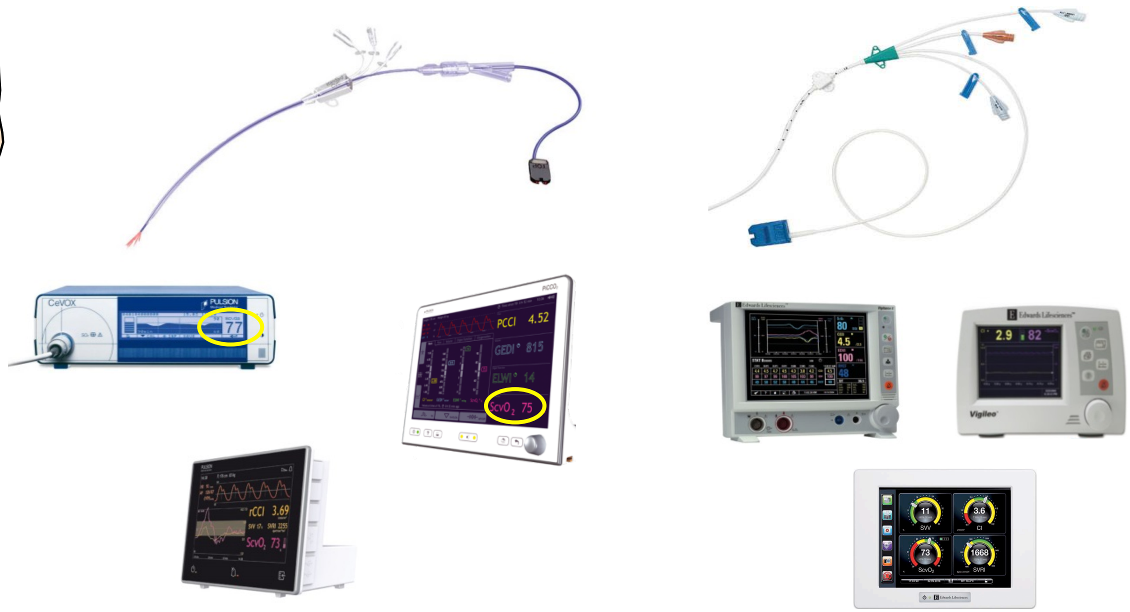
In conclusion, there are no data to support the widespread practice of using CVP to guide fluid therapy. This approach to fluid resuscitation is without a scientific basis and should be abandoned.

Central venous catheter



CVP and $SvcO_2$

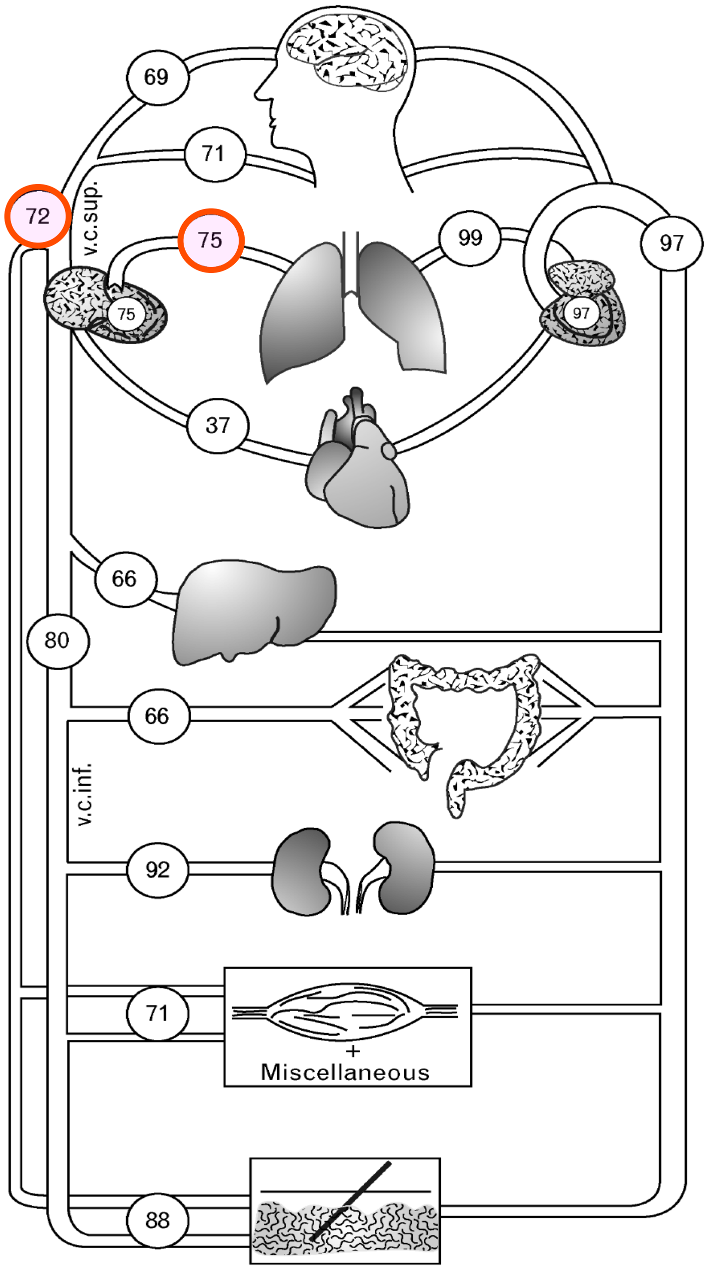
(with or without fiberoptic probe)



Fick equation: $VO_2 = CO \cdot (CaO_2 - CvO_2) \cdot 10$

$$SvO_2 = SaO_2 - \frac{VO_2}{CO \times Hb \times 13.4}$$

SvO_2 indicator of the VO_2 / DO_2 balance



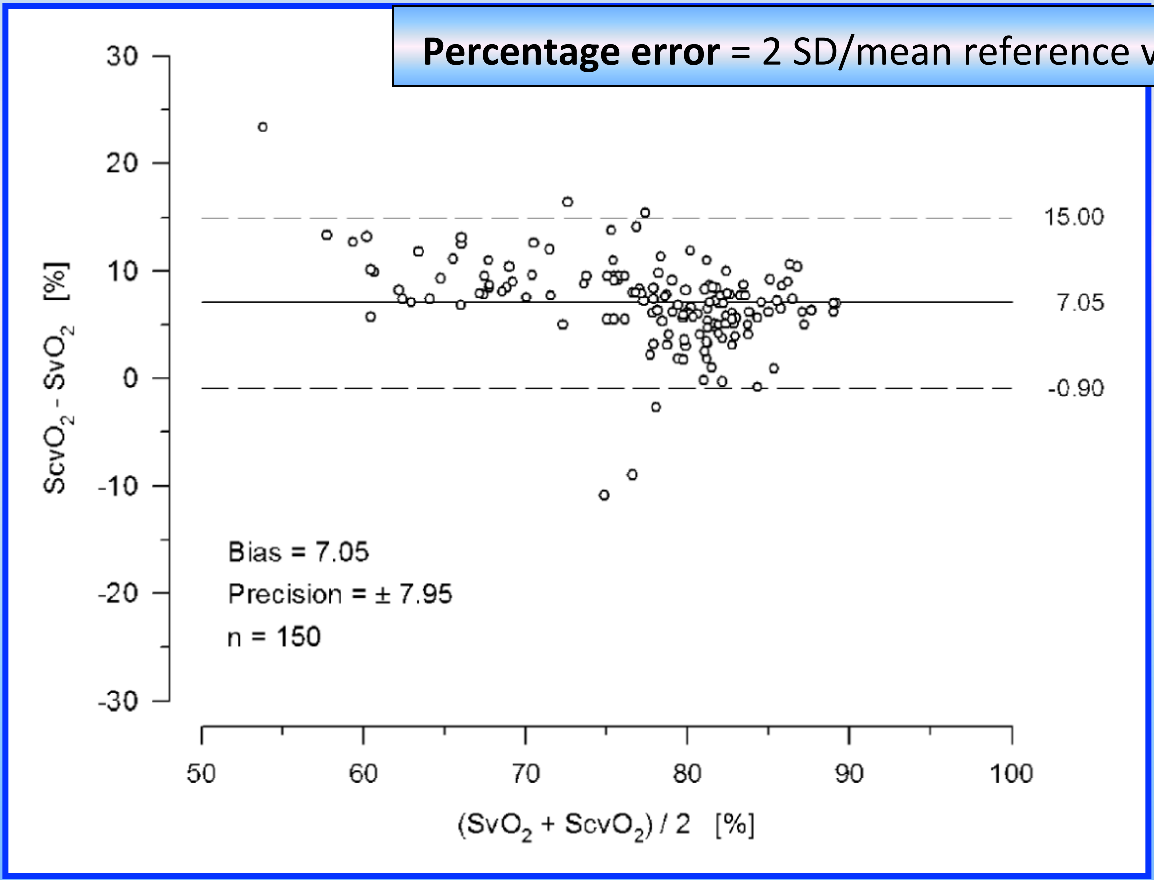
69
71
72
v.c.sup.
75
75
99
97
97
37
66
80
66
v.c.inf.
92
71
+
Miscellaneous
88

Intensive Care Med (2004) 30:1572–1578

ORIGINAL

Konrad Reinhart
Hans-Jörg Kuhn
Christiane Hartog
Donald L. Bredle

Continuous central venous and pulmonary artery oxygen saturation monitoring in the critically ill



Percentage error = 2 SD/mean reference value = **11%**

$SvcO_2$

is an acceptable reflection

of **SvO_2**

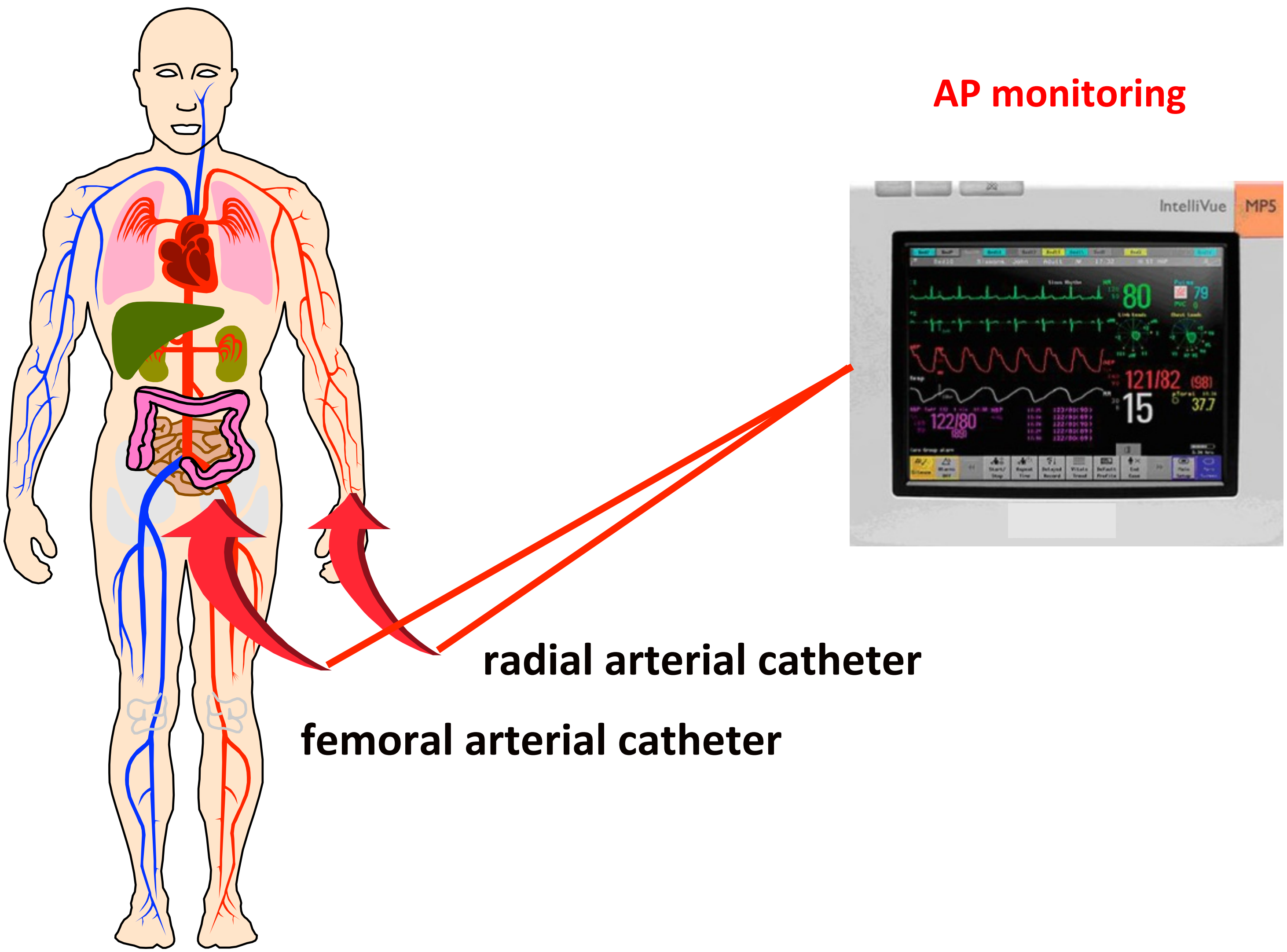
Basic monitoring

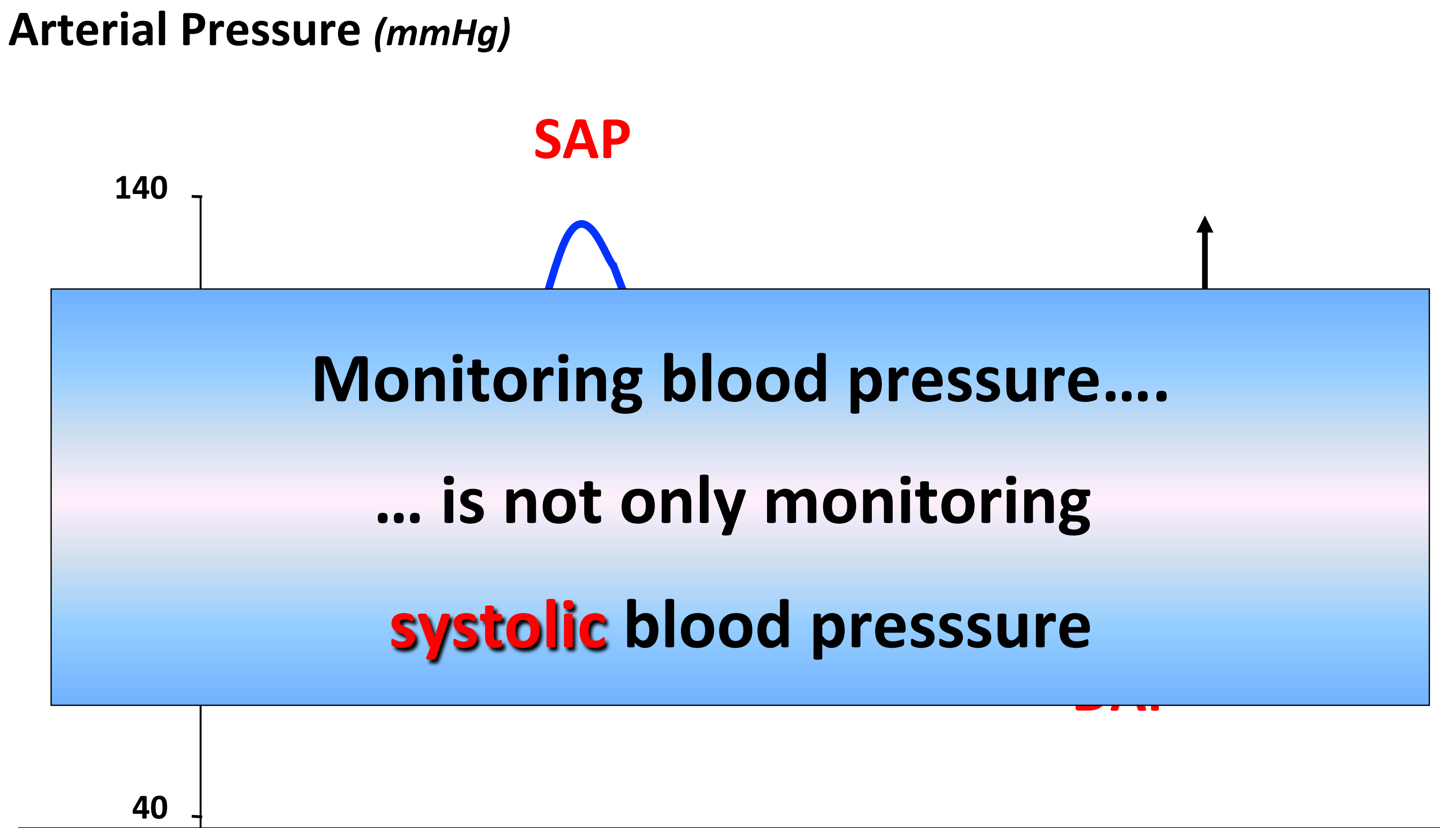
Central venous catheter

- CVP
- $ScvO_2$

Arterial catheter

- SAP
- DAP
- MAP
- PP
- PPV


AP monitoring
IntelliVue
MP5
radial arterial catheter
femoral arterial catheter



Monitoring blood pressure….

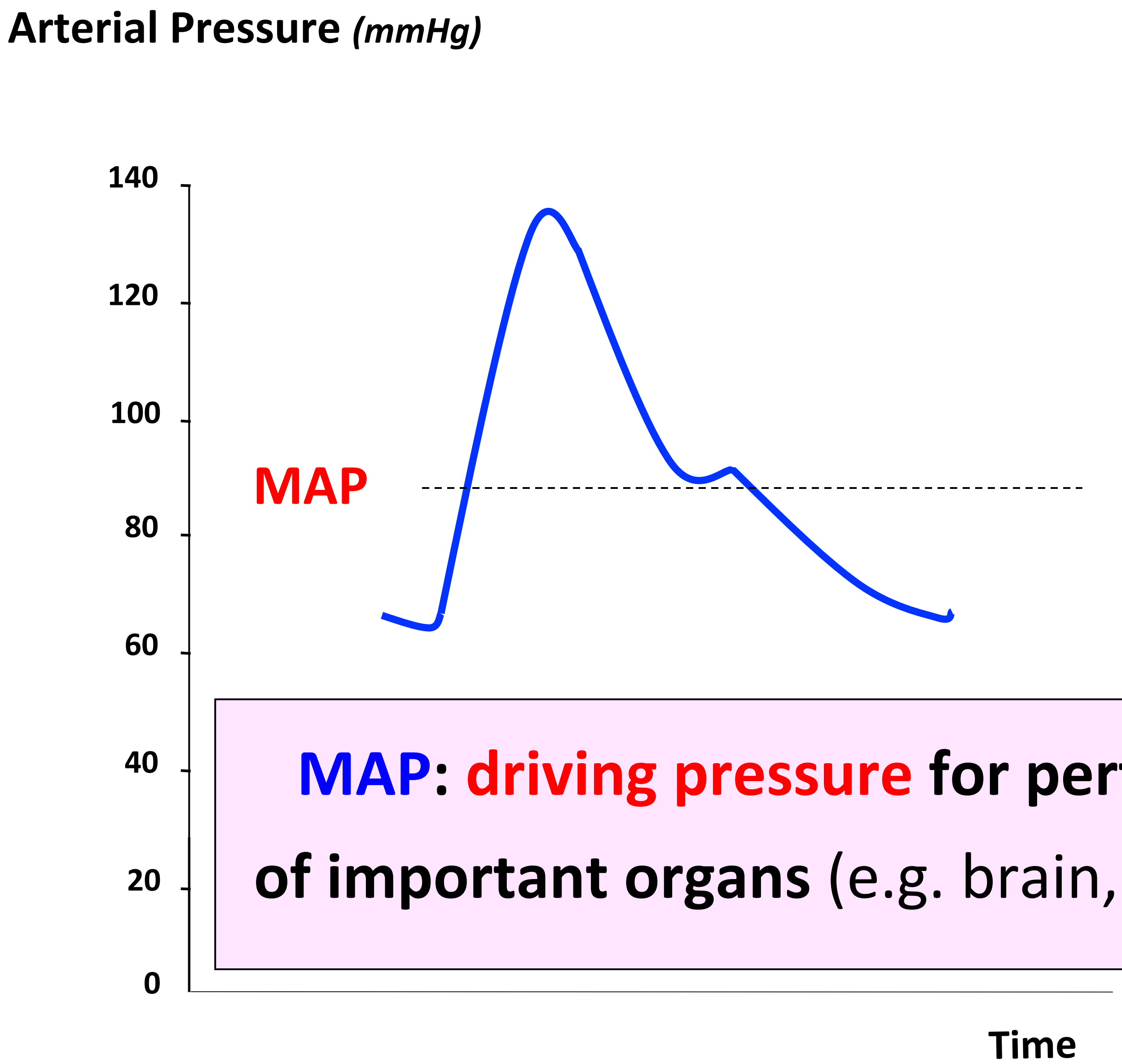
… is not only monitoring

systolic blood presssure

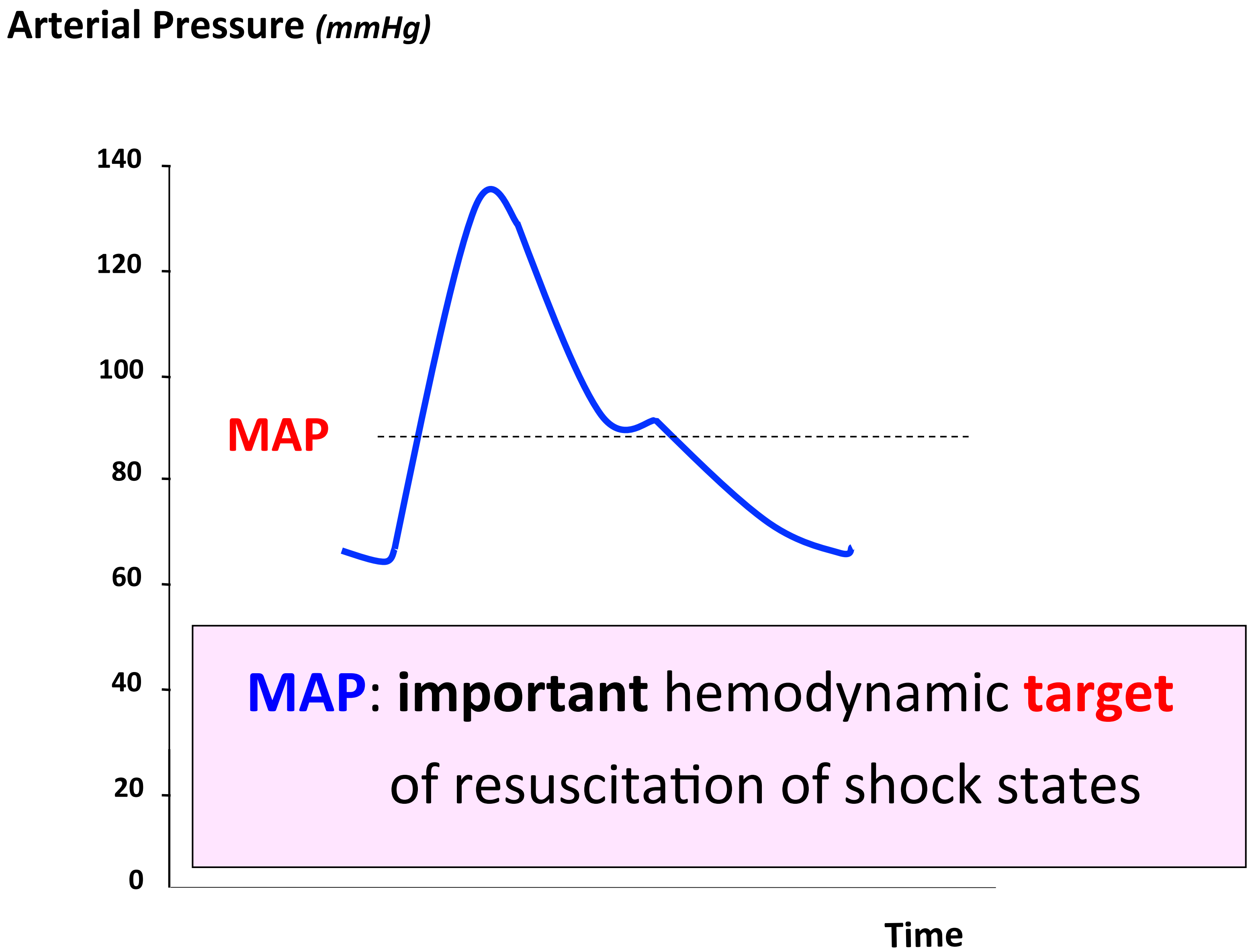
A lot of useful pieces of information can be drawn

from **MAP**, **DAP**, **PP**

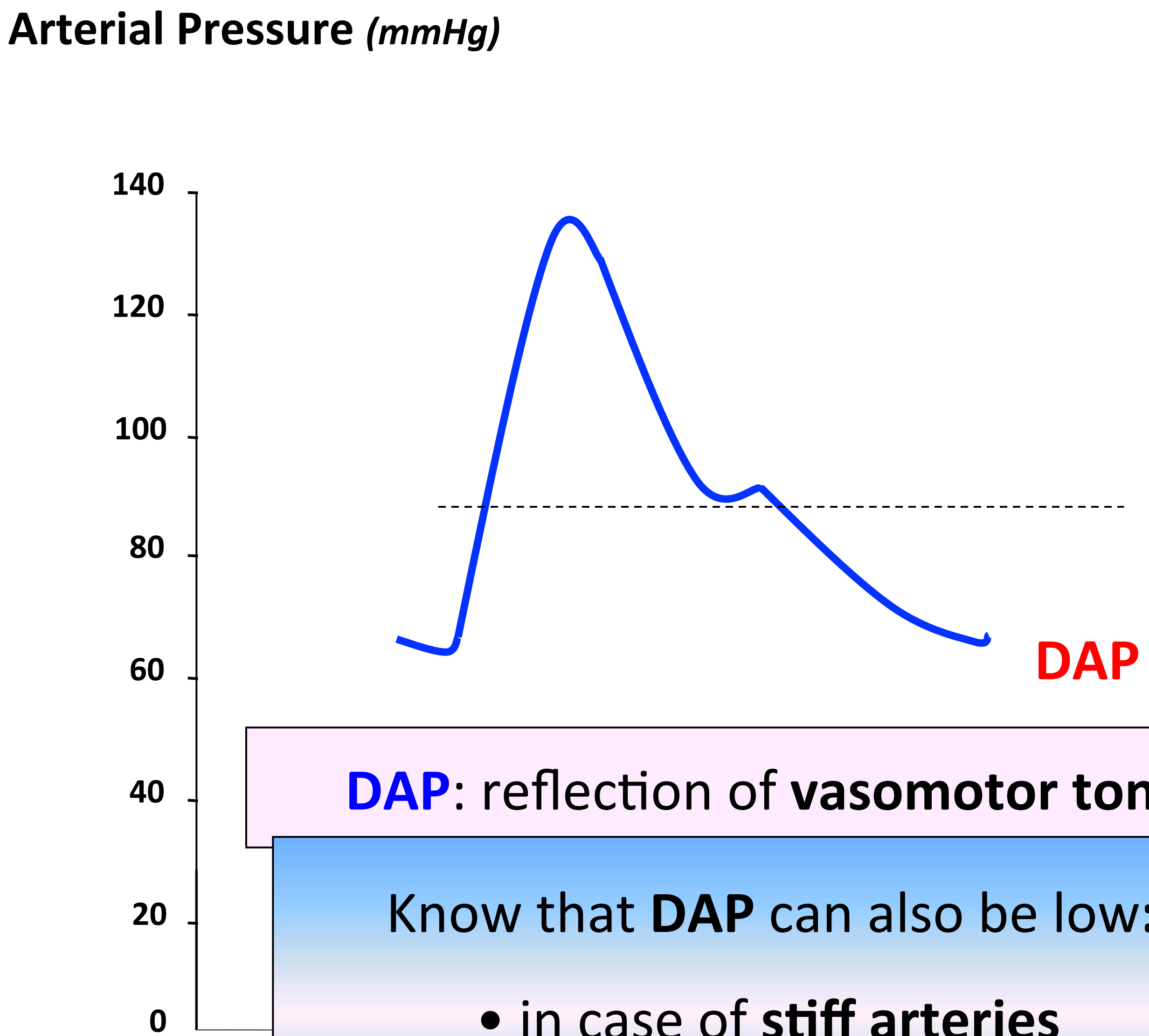
and from **analysis** of the **AP waveform**



MAP: **driving pressure** **for perfusion of important organs** (e.g. brain, kidney)



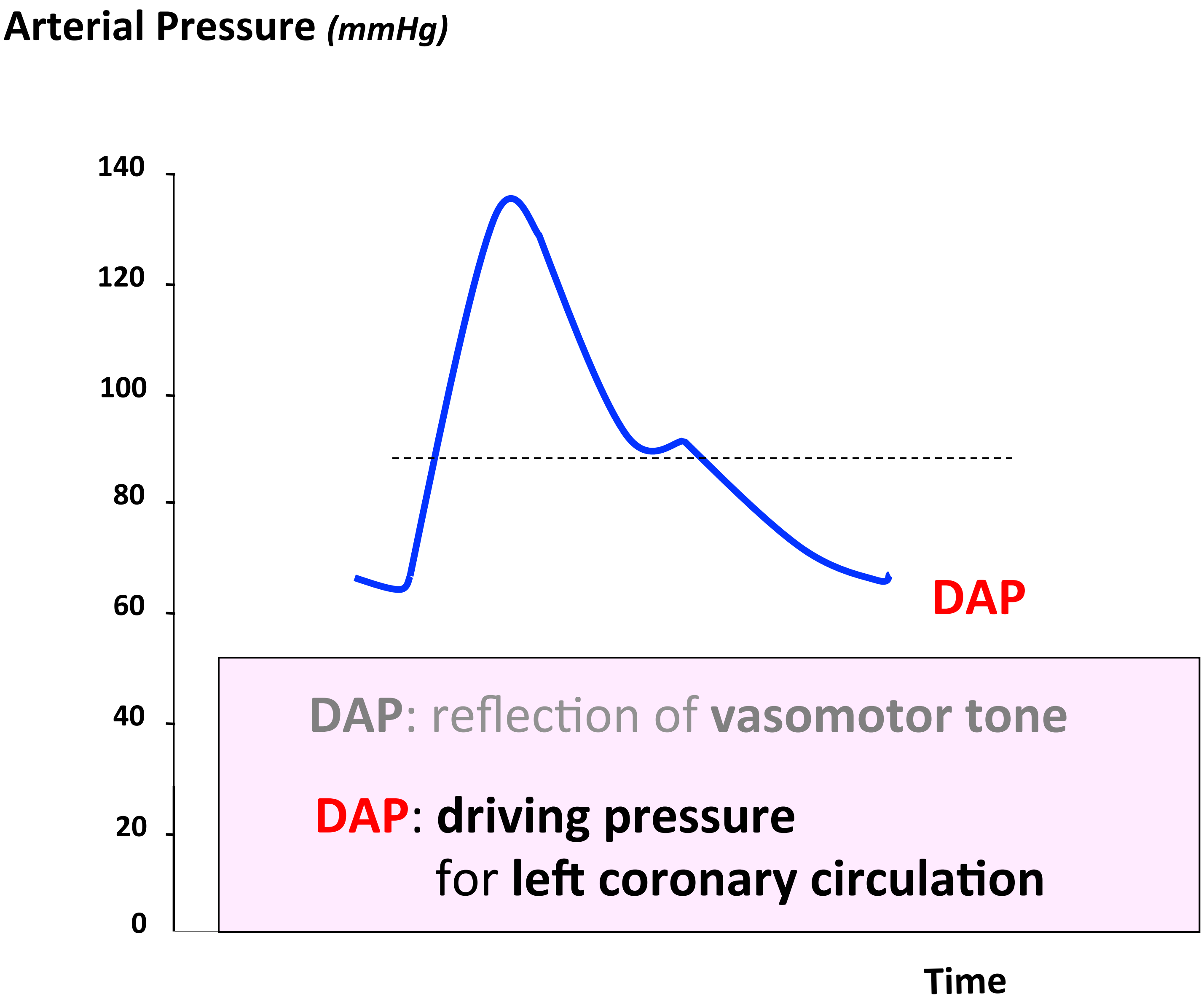
MAP: **important** hemodynamic **target** of resuscitation of shock states

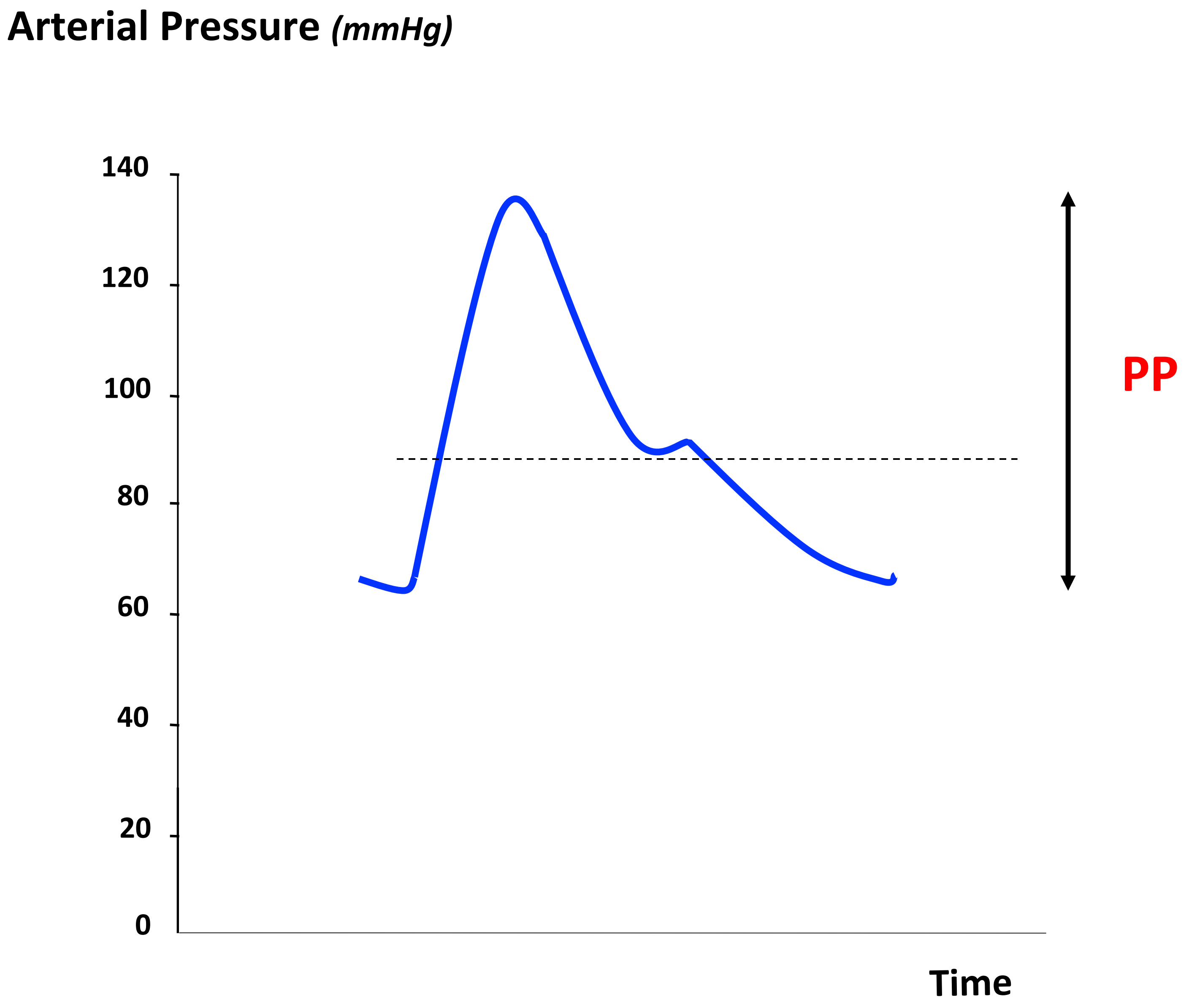


DAP: reflection of **vasomotor tone**

Know that **DAP** can also be low**:**

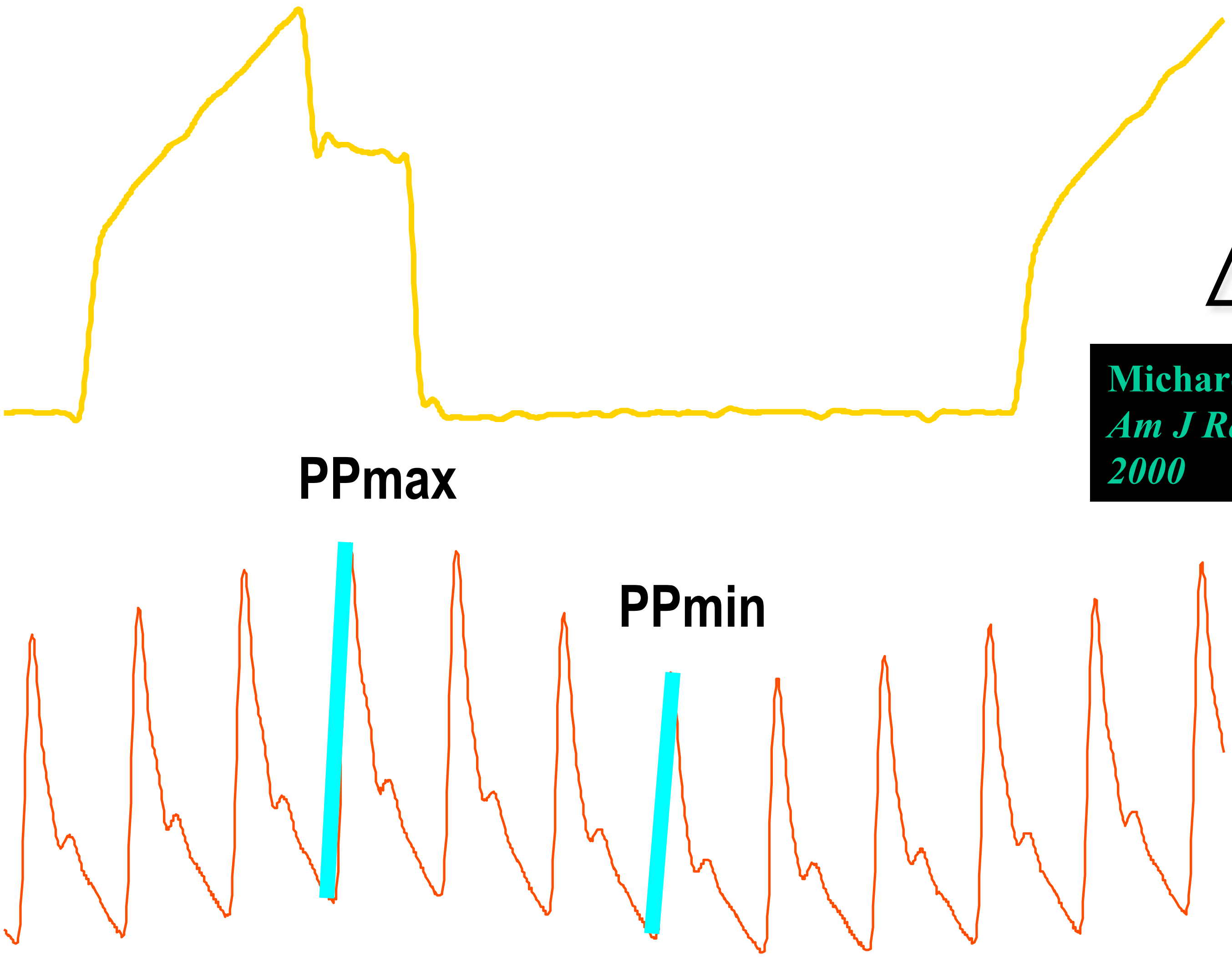
- in case of **stiff arteries**
- in case of **low heart rate**


Arterial Pressure (mmHg)
140
120
100
80
60
40
20
0
DAP
DAP: reflection of vasomotor tone
DAP: driving pressure
for left coronary circulation
Time



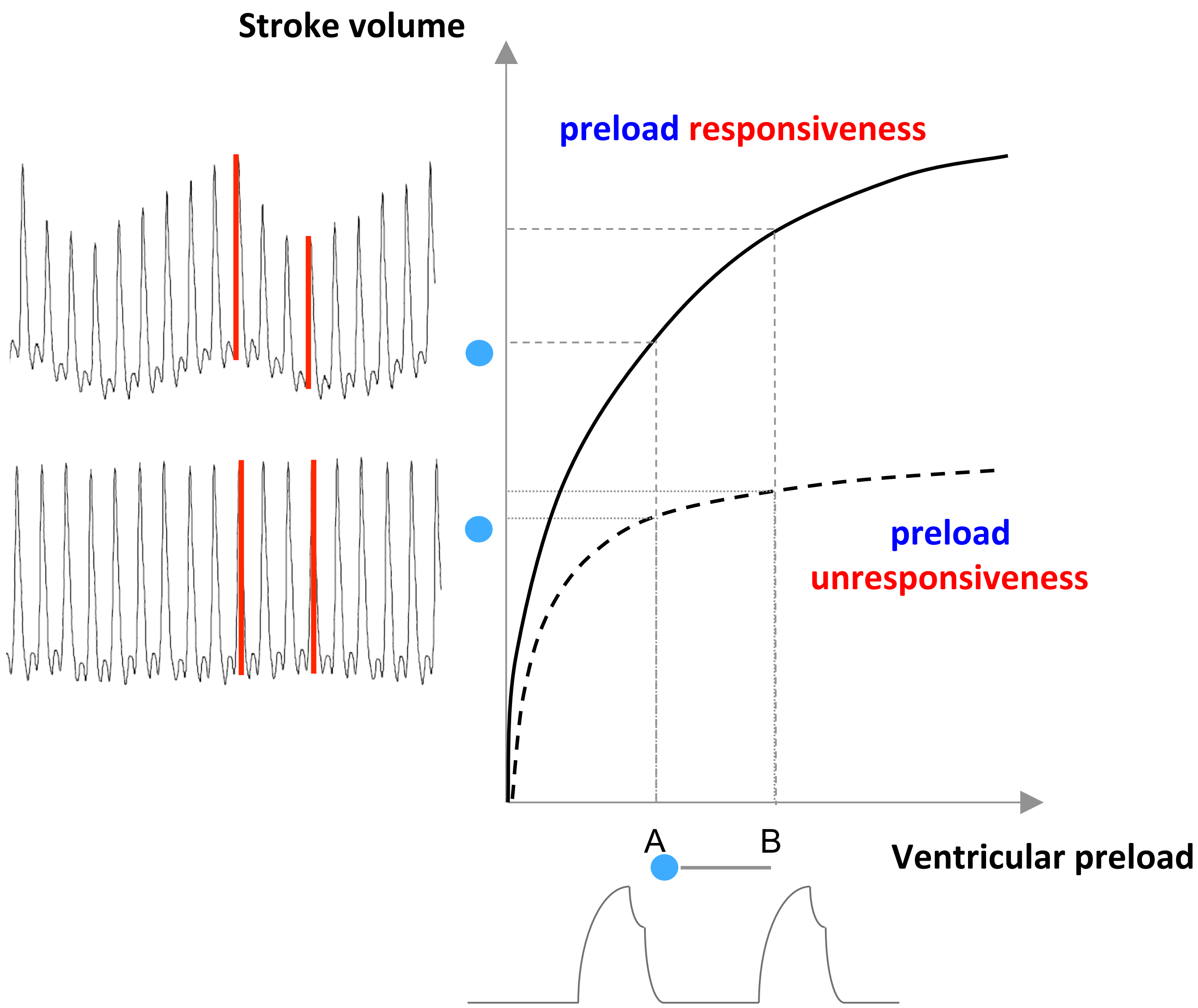
Arterial Pressure (mmHg)
140
120
100
80
60
40
20
0
PP
Time

Pulse Pressure Variations



ΔPP

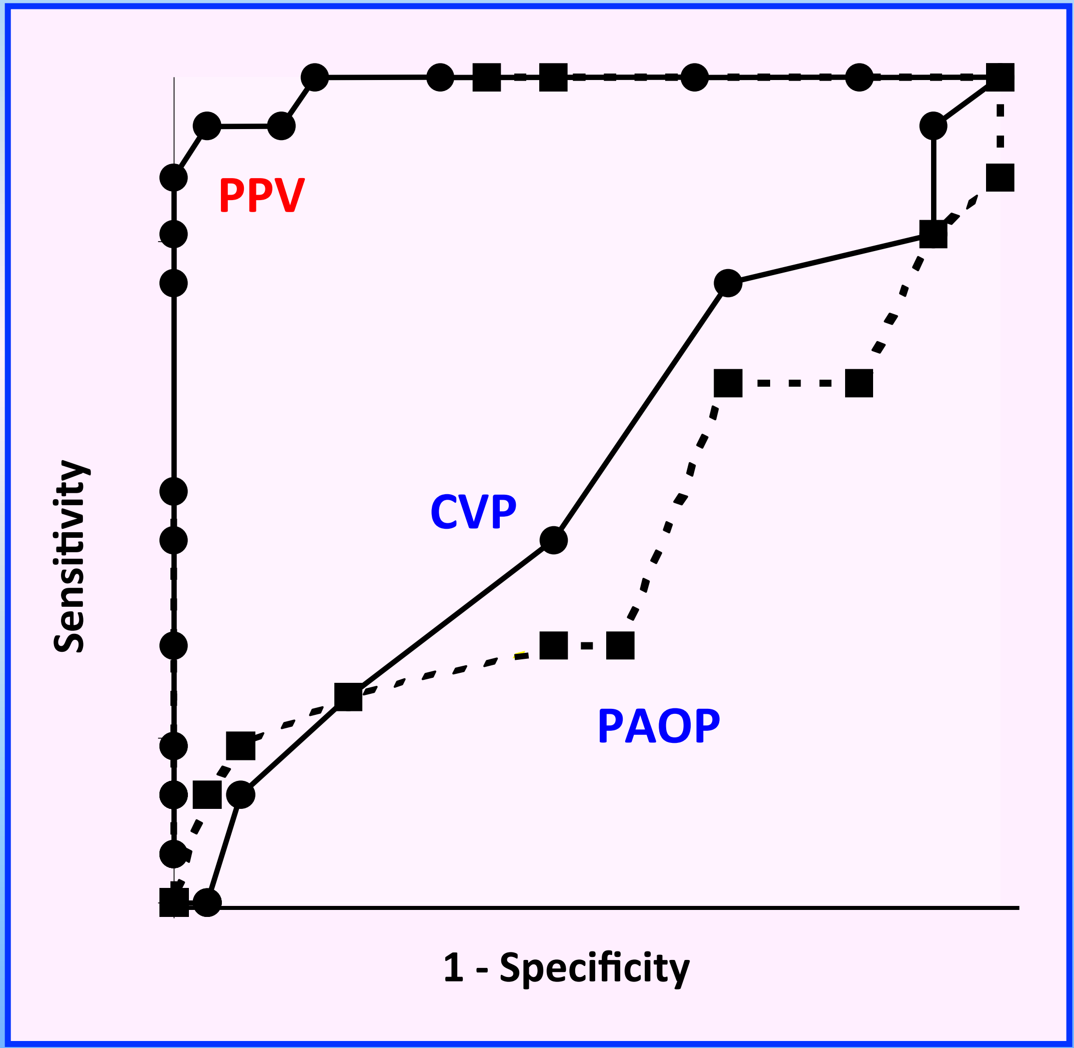
Michard et al.
Am J Respir Crit Care Med
2000


Stroke volume
preload responsiveness
preload
unresponsiveness
A
B
Ventricular preload

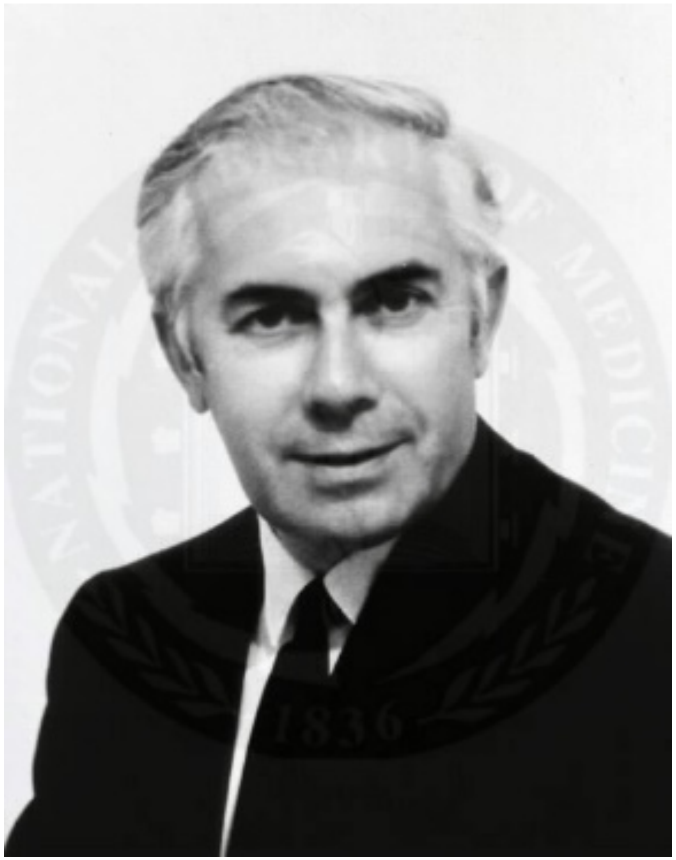
Relation between Respiratory Changes in Arterial Pulse Pressure and Fluid Responsiveness in Septic Patients with Acute Circulatory Failure

FRÉDÉRIC MICHARD, SANDRINE BOUSSAT, DENIS CHEMLA, NADIA ANGUEL, ALAIN MERCAT, YVES LECARPENTIER, CHRISTIAN RICHARD, MICHAEL R. PINSKY, and JEAN-LOUIS TEBOUL

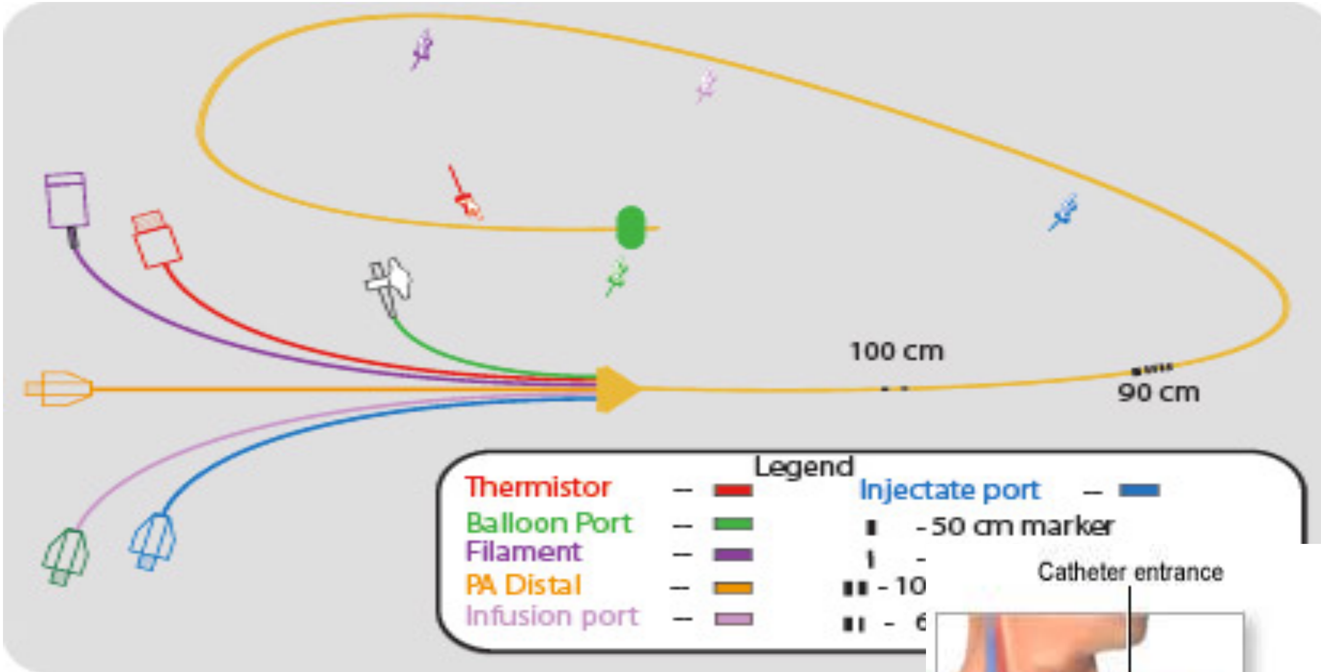
Am J Respir Crit Care Med 2000,162:134–138

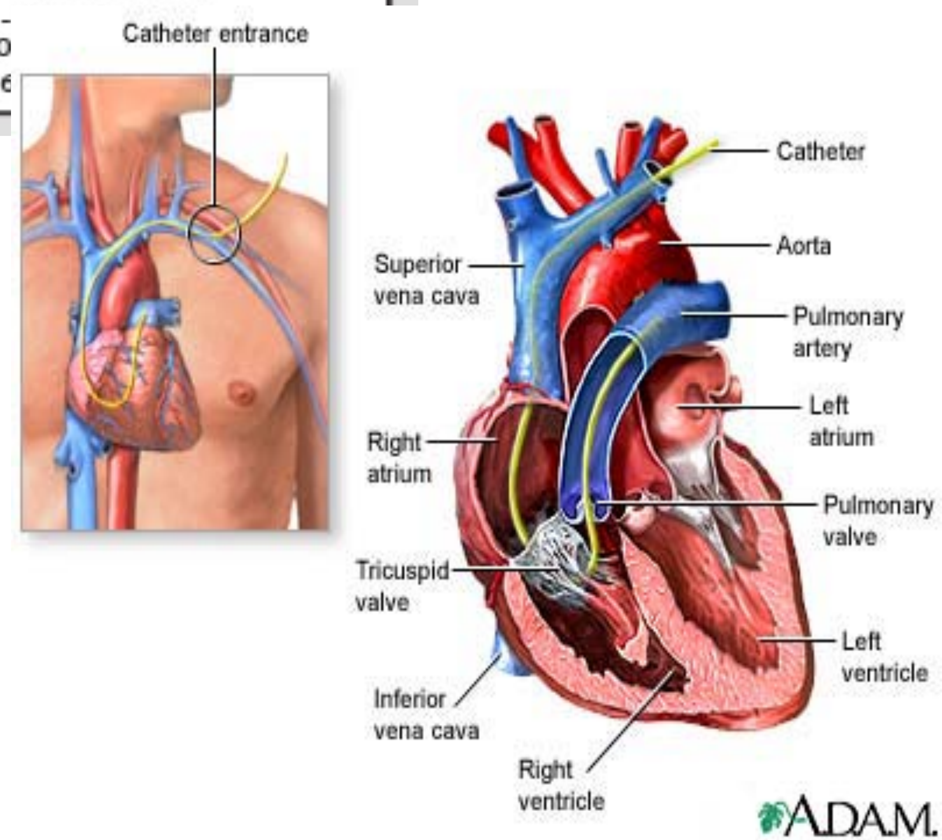


HJC Swan

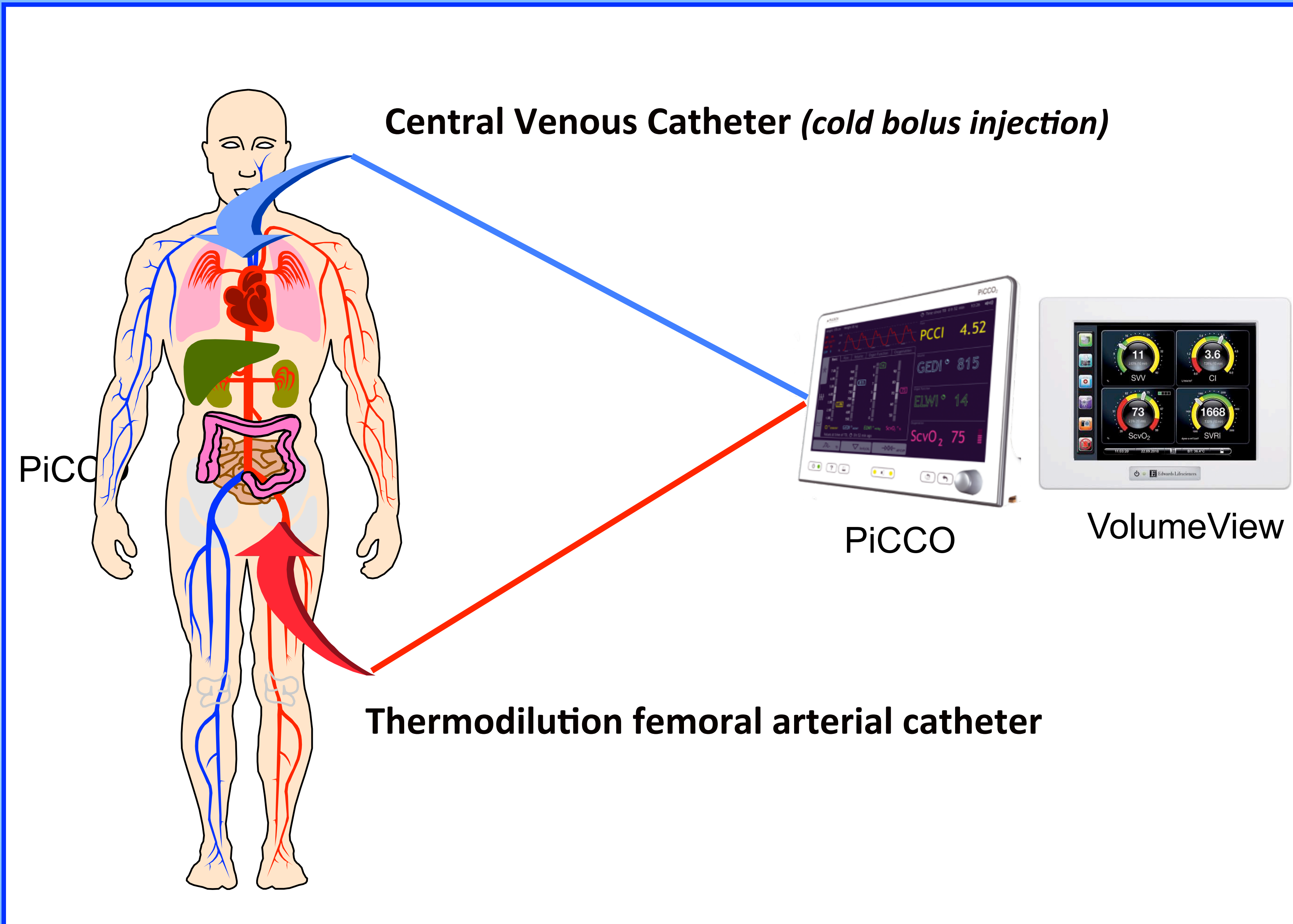


W Ganz


100 cm
90 cm
Legend
Thermistor
Balloon Port
Filament
PA Distal
Infusion port
Injectate port
- 50 cm marker


Catheter entrance
Catheter
Superior vena cava
Aorta
Pulmonary artery
Left atrium
Right atrium
Pulmonary valve
Tricuspid valve
Left ventricle
Inferior vena cava
Right ventricle

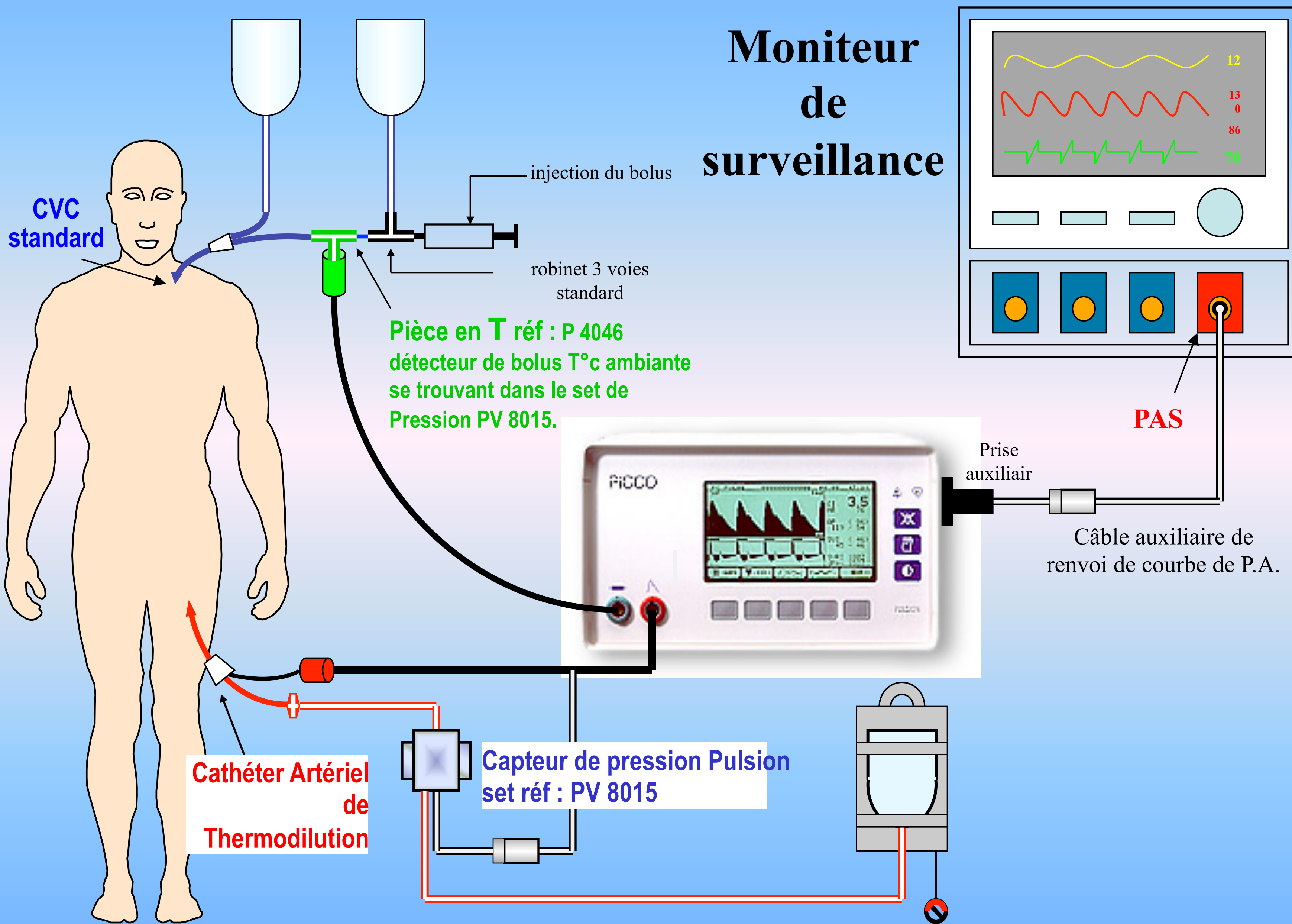
Transpulmonary thermodilution monitors allow measurements of cardiac output


Central Venous Catheter *(cold bolus injection)*
PCCI 4.52
GEDI 815
ELWI 14
ScvO2 75
11
SVV
3.6
CI
73
ScvO2
1668
SVRI
PiCCO
VolumeView
Thermodilution femoral arterial catheter

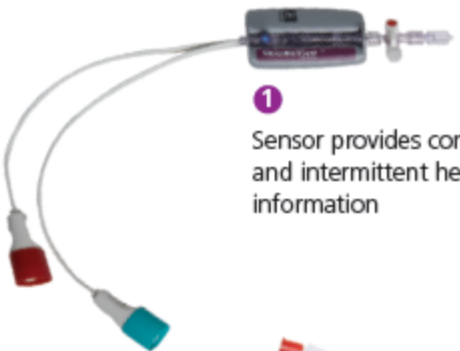
PiCCO Plus


PiCCO plus
PULSION
Medical Systems
13.03 16:28 TB37.0
AP 180
AP 140
117 92
(CVP) 5
SVRI 2762
PC
CI 3.24
HR 78
SVI 42
SVV 5%
dPmx 1140
(GEDI) 625
PCCI 5
1h
ABS
INP
INFO

SCHEMA D'INSTALLATION du PiCCO



The VolumeView set is comprised of the VolumeView sensor, the VolumeView femoral arterial catheter and the VolumeView thermistor manifold.

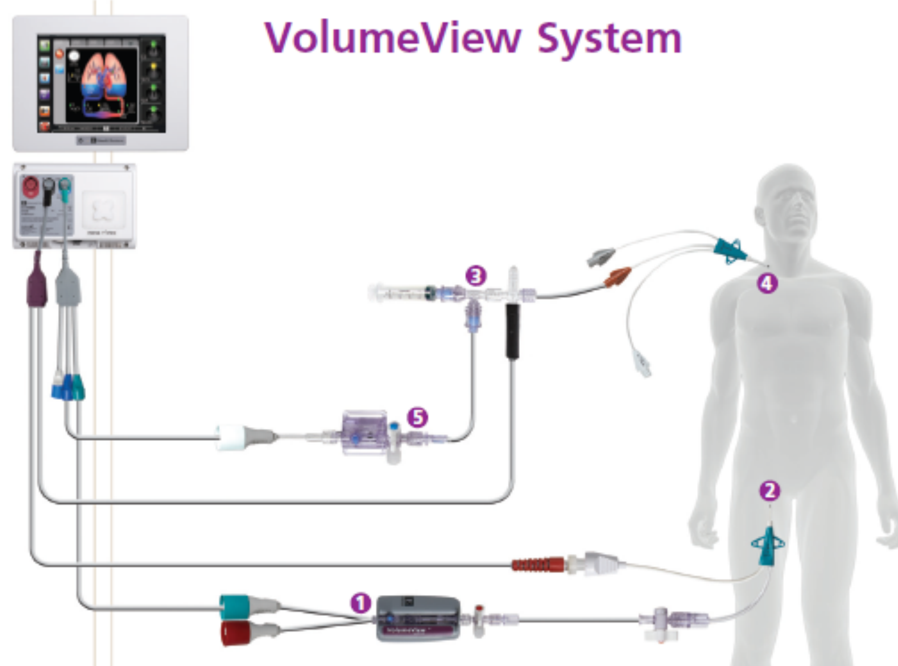


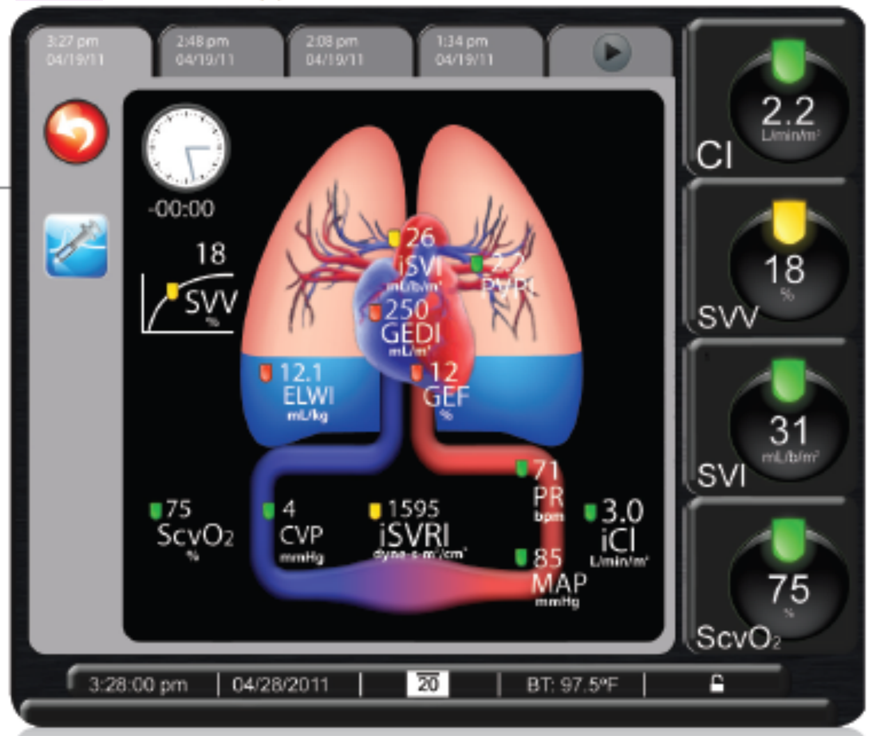
1 Sensor provides continuous and intermittent hemodynamic information

2 Femoral arterial catheter provides volumetric parameters through intermittent TPTD

3 The thermistor manifold enables safe bolus injection (closed system) to record injectate temperature and to record start of injection

VolumeView System





PiCCO or VolumeView monitoring

useful tools to deal with **fluid loading** and/or **depletion**

… especially if associated **respiratory** and **circulatory failures**

- **SVV** and **PPV** to **predict** fluid responsiveness
- **PLR** and **EOT** to **predict** fluid responsiveness
- **GEDV** to check that **preload** actually **increases** with fluid loading
- **CO** to assess the **real** hemodynamic **response** to **fluid infusion**
- **EVLW** and **PVPI** to assess **lung tolerance** to fluid infusion

- **PLR/EOT**
- **GEDV**
- **CO**
- **EVLW**

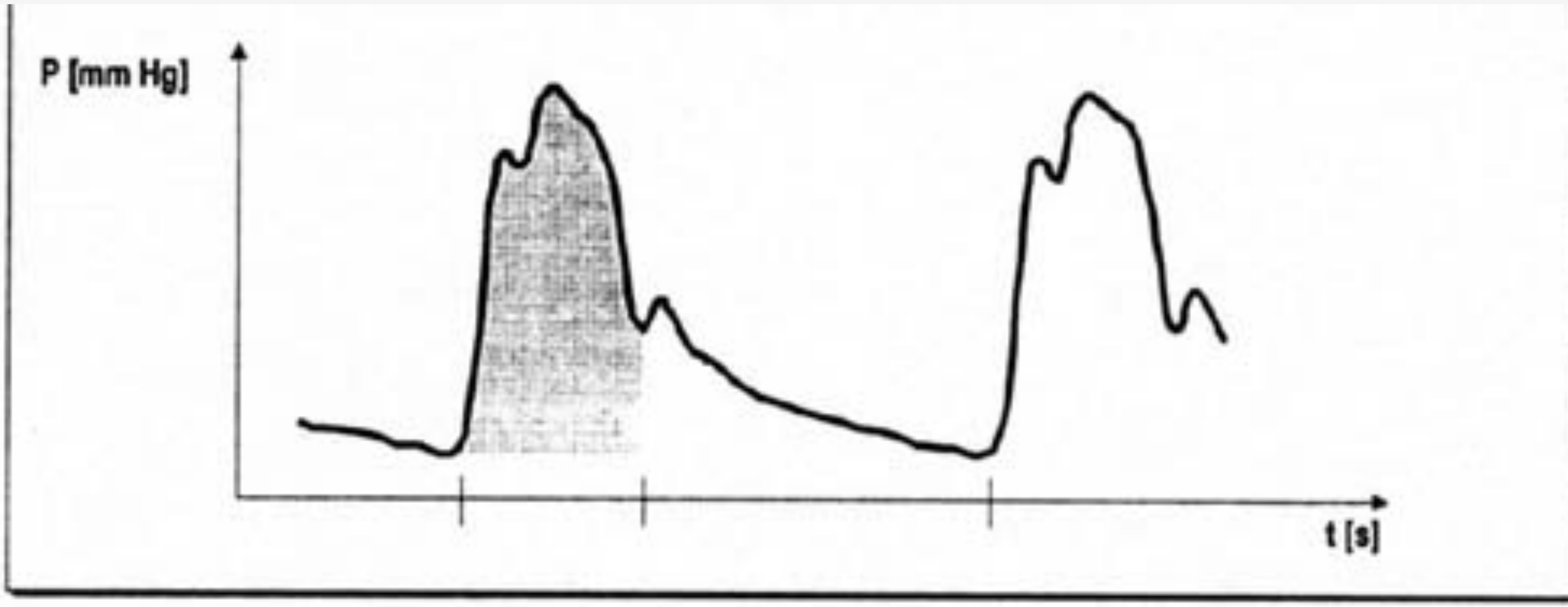
to help to decide

To **start** fluid infusion

To **continue** fluid infusion

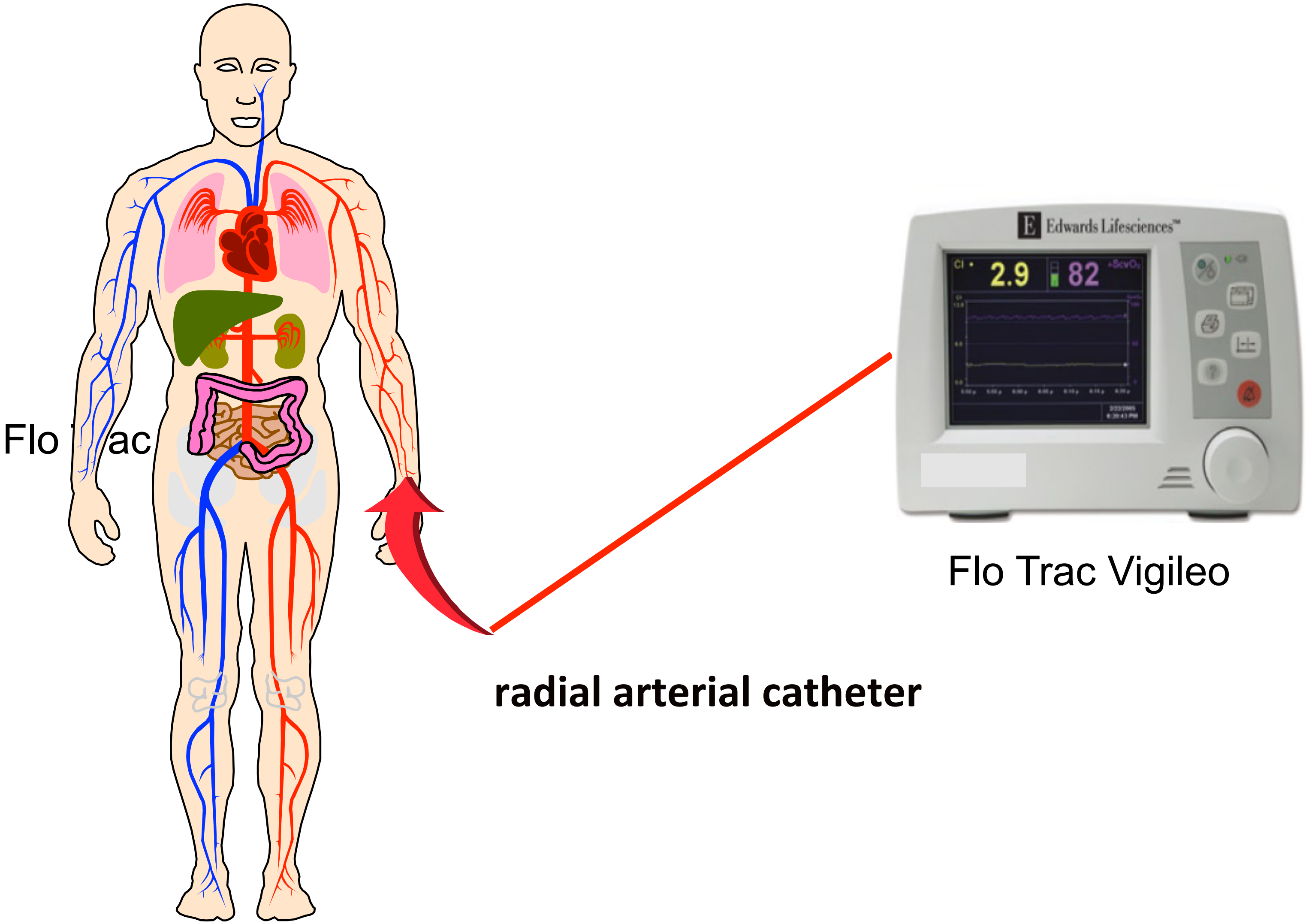
To **stop** fluid infusion

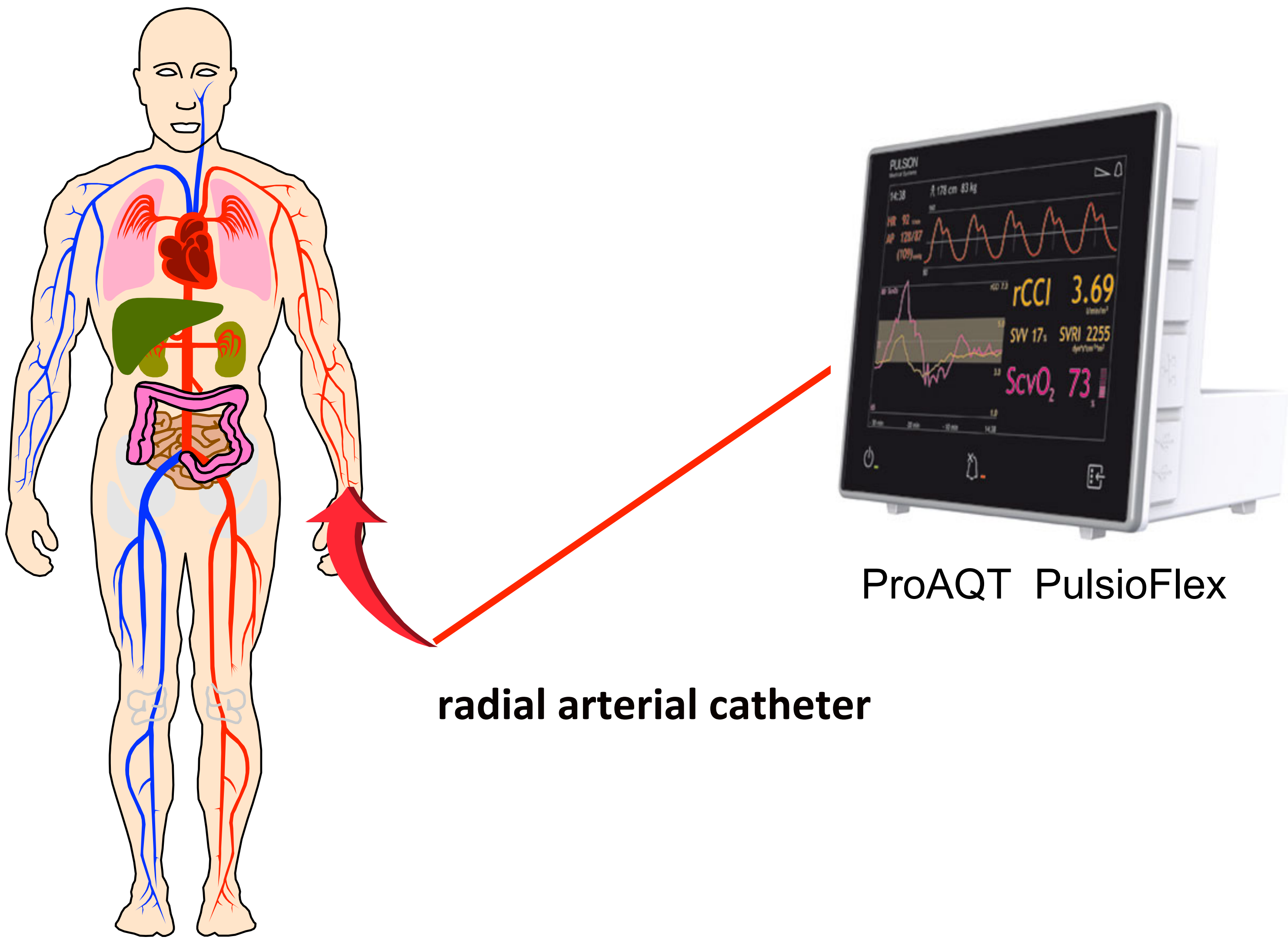
Pulse Contour Method



$$PCCO = cal \cdot HR \cdot \int_{Systole} \left(\frac{P(t)}{SVR} + C(p) \cdot \frac{dP}{dt} \right) dt$$

- cal: Patient-specific calibration factor (determined with thermodilution)
- HR: Heart rate
- $\frac{P(t)}{SVR}$: Area of pressure curve
- $C(p)$: Compliance
- $\frac{dP}{dt}$: Shape of pressure curve


Edwards Lifesciences
CI
2.9
82
Flo Trac Vigileo
radial arterial catheter



ProAQT PulsioFlex
radial arterial catheter

FloTrac/Vigileo™ Technology

- Real-time CO monitoring from AP waveform
- Complex algorithm based on statistical analysis of the AP signal
- **No need for calibration**
- Any type of arterial catheter and any site including the radial site
- Validation studies?

FloTrac/Vigileo™ Technology

- Validation studies

- 70 validation studies

- Systematic review : BJA 2014 112 626-637

  ERROR 25 – 30% in normo and hypovolemia

  ERROR 51% in hyperdynamic citculation

  New algotithm 4.0 , concordance 90%

ProAQT / PulsioFlex
Pulsion / MAQUET

- **In the ICU contradicting results**

- **ERROR 31 – 59 %**

- **Trend ability 72 -89 %**

Monnet BJA 2015 114 235 -243

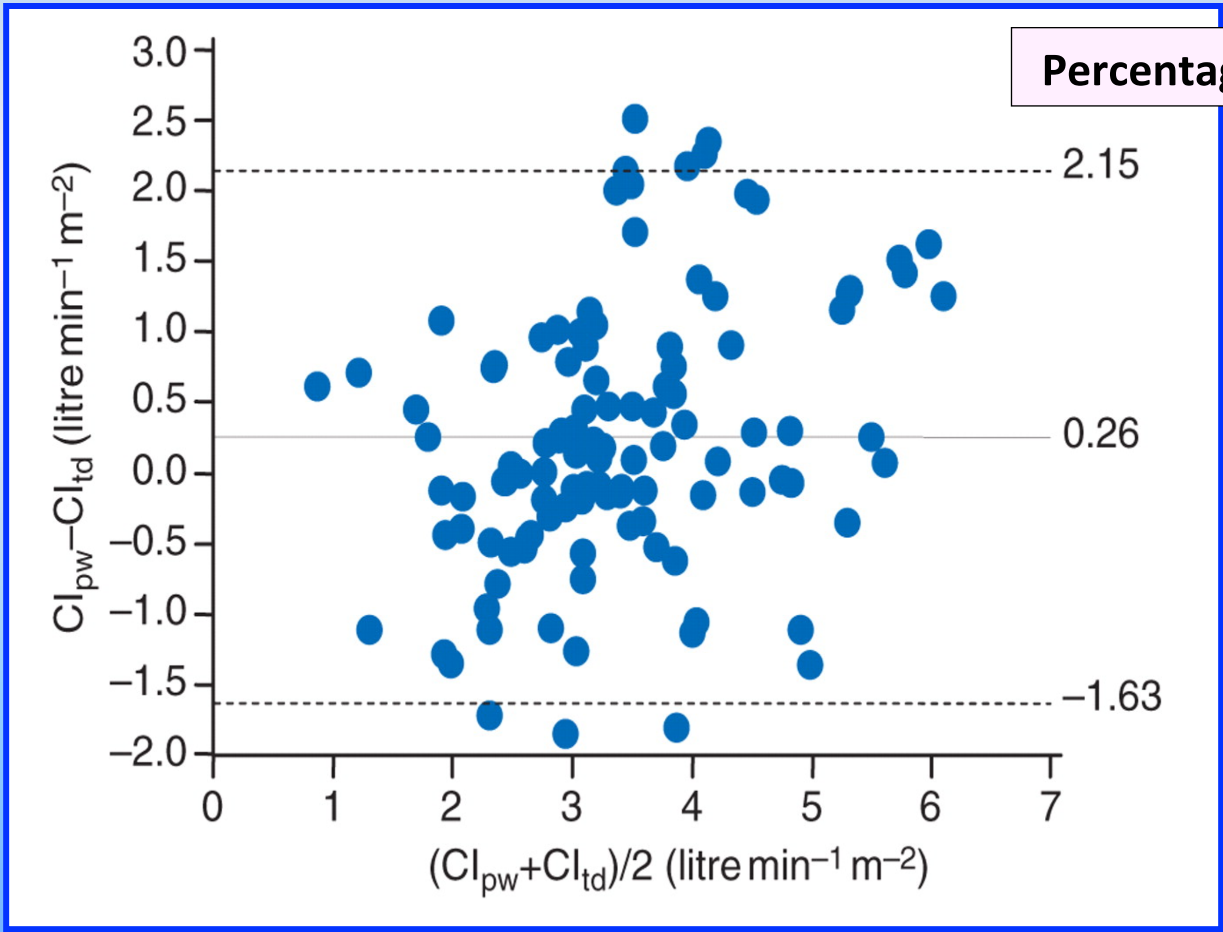
Third-generation FloTrac/Vigileo does not reliably track changes in cardiac output induced by norepinephrine in critically ill patients

X. Monnet[1,2*], N. Anguel[1,2], M. Jozwiak[1,2], C. Richard[1,2] and J.-L. Teboul[1,2]

British Journal of Anaesthesia **108** (4): 615–22 (2012)

3rd generation

Percentage Error = 54%



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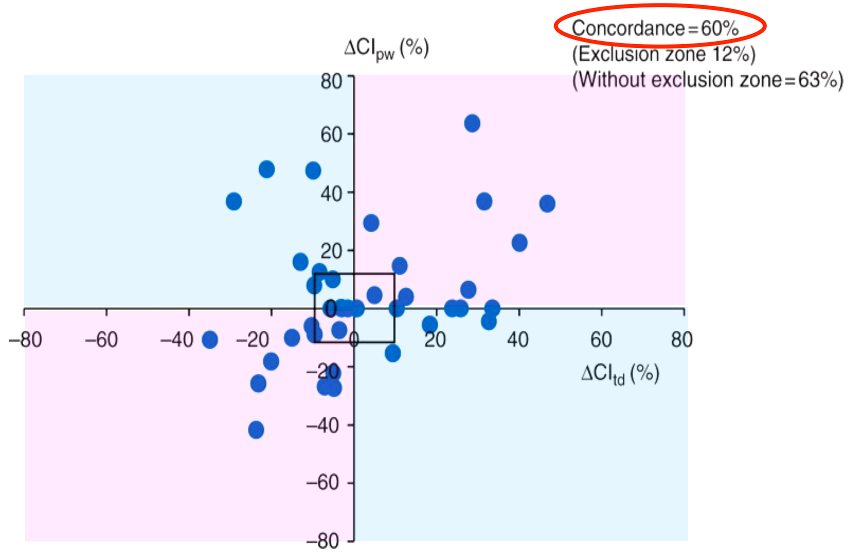
British Journal of Anaesthesia **108** (4): 615–22 (2012)

3rd generation



Changes in CI (%)

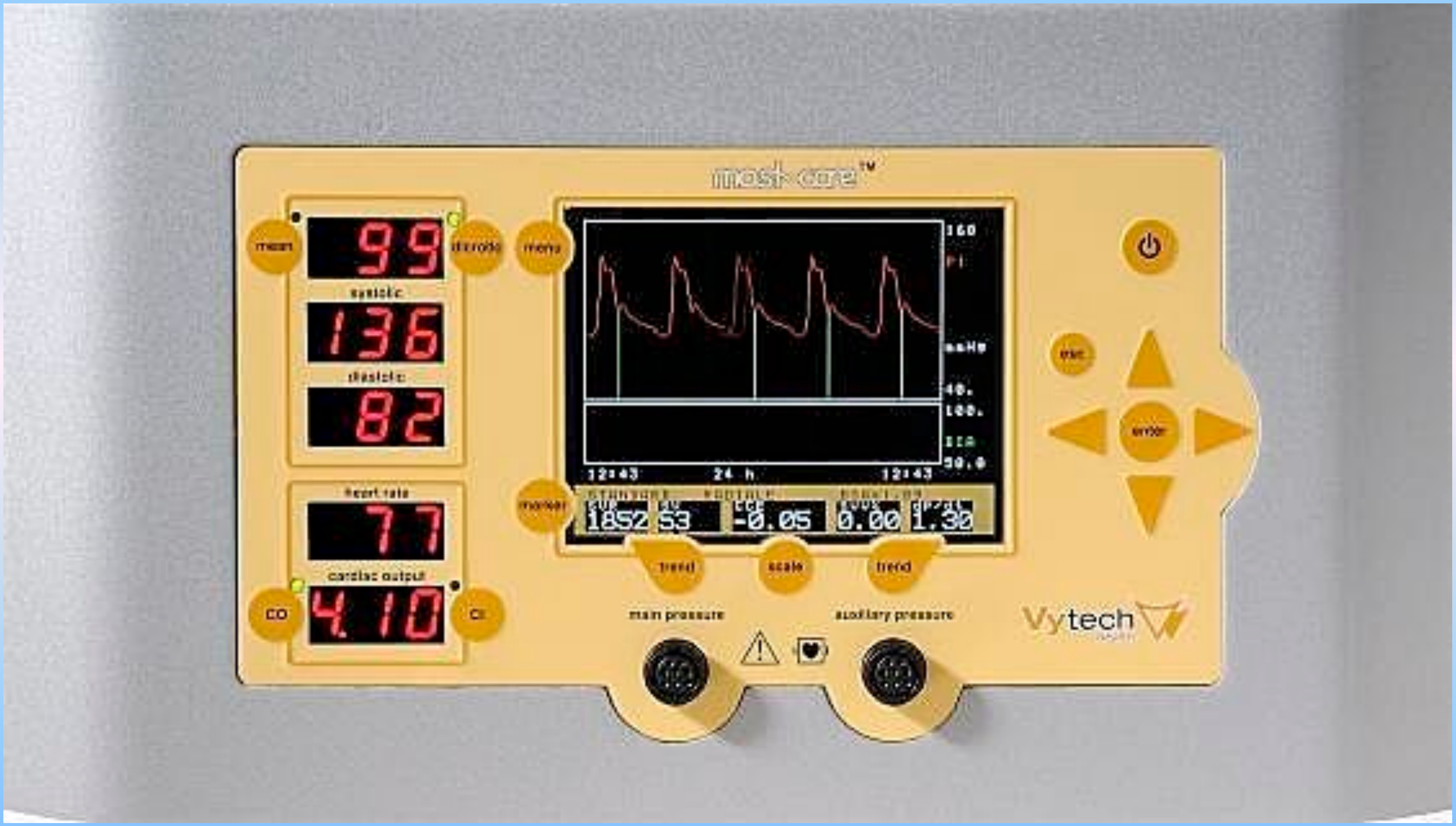
induced by norepinephrine

FloTrac/Vigileo™ Technology

- **Real-time CO monitoring from AP waveform**
- **Complex algorithm based on statistical analysis of the AP signal**
- **No need of calibration**
- **Any type of arterial catheter and any site including the radial site**
- **Validation studies?**

- seems **valid** in the absence of changes in vascular tone
- serious **doubts** on its validity in cases of **changes in vascular tone** (sepsis, vasopressor use)

Most Care Vytech



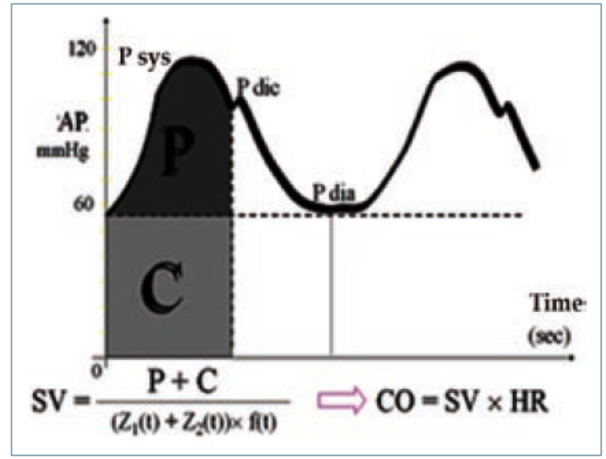


Figure 2 - *Basic algorithm of the PRAM system* (14). *See text.*

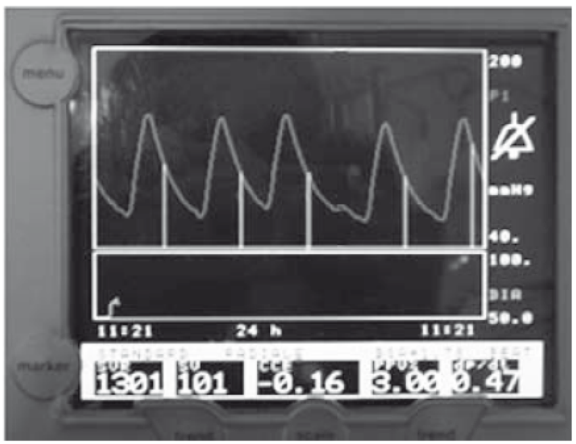


Figure 4 - *Over-damped arterial signal. Note the loss of evidence of the details.*

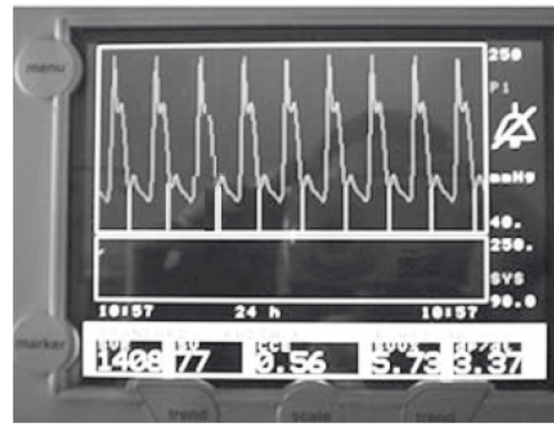


Figure 3 - *Under-damped resonating arterial–signal. Note steep systolic upstroke and narrow systolic peak.*

Limitations

A primary concern about PCMs reliability is related to the *quality of the recorded arterial pressure signal.*

The signal can be inadequate for *patient-related* and *technical-related* reasons.

MostCare
Vygon, Vytech in the OR

- **Alonso Inigo Pediat Anaesth 2016**
  /Fick error 17% r(2) 0.87 Catheterism

- **Favia Interact Cardiovasc Thor Surg 2016**
  prediction of various complications

- **Romagnoli J Card Vasc Anesth 2013**
  /echo error 22%   r(2) 0.76 vascular surgery

MostCare
Vygon, Vytech in the ICU

- **Scolletta CCM 2016**
  /Döppler error 27% r(2) O.85
- **Franchi Minerca Anaesth 2013**
  /echo error 18% r(2) 0.94
- **Scolletta Anesth Analg 2011**
  /PAC error 24% r(2) O.90
- **Franchi BJA 2011**
  /PAC error 25% r(2) O.93

MostCare
Vygon, Vytech in the ICU

Gopal Minerva Anaesth 2014

/PAC error 62.5% Sepsis

NEXFIN

Now ClearSight
(Edwards Life-Sciences)

BM

Contin

The Nex

continuous blood pressure monitoring for adult patients.

- The **Nexfin** monitor measures and displays arterial blood pressure (systolic, diastolic, mean) continuously in real-time.
- The **Nexfin HD** monitor, in addition, measures and displays beat-to-beat cardiac output and derived hemodynamics (HR, SV, SVR, dP/dt).

Both models of the Nexfin monitor feature all data displayed in real-time, trended continuously, and readily accessible for review.

BMEYE's unique monitoring features

- Continuous Non-Invasive Blood Pressure
- Continuous Non-Invasive Cardiac Output
- Advanced hemodynamic profiles and reports
- Nexfin HD: Capable of providing both continuous non-invasive blood pressure, and continuous non-invasive cardiac output with a single sensor

FIGURE 1. The ClearSight device with wrist unit connected to the finger cuff with screenshot of arterial blood pressure curve and trending analysis (circle).

Nexfin 15 studies 2012 - 2017

Intensive care — 5 studies

Aneshesia — 10 studies

Evaluated : AP and/or CO

Comparators : invasive AP

PiCCO PAC

FIGURE 1. The ClearSight device with wrist unit connected to the finger cuff with screenshot of arterial blood pressure curve and trending analysis (circle).

Nexfin in the ICU

Globaly not or poorly reliable for CO variations

Taton Anaesthesia 2013: sensitivity 47 %

Amelook Scien World J 2013: error 37 %

Amelook Minerv Anesth 2014: r(2) 0.88

Hohn BJA 2013: r(2) 0.28

norepinephrine

Monnet Crit Care 2012: error 57%

FIGURE 1. The ClearSight device with wrist unit connected to the finger cuff with screenshot of arterial blood pressure curve and trending analysis (circle).

Nexfin in the OR
Arterial pressure +/- YES

Amelook Minerv Anesth 2014: r(2) 0.88

Balzer J Int Med Res 2014: r(2) O.75

De Wilde Anasthesia 2016: r(2) 0.84

Martina Anesthesiology 2012: r(2) 0.96

Fisher BJA 2012: error 50%

Pouwels J Clin Anesth 2016: Difference 7.8+/-6.9

FIGURE 1. The ClearSight device with wrist unit connected to the finger cuff with screenshot of arterial blood pressure curve and trending analysis (circle).

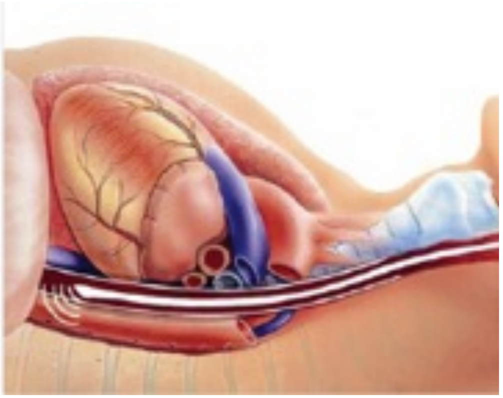
Nexfin in the OR
Cardiac Output ????

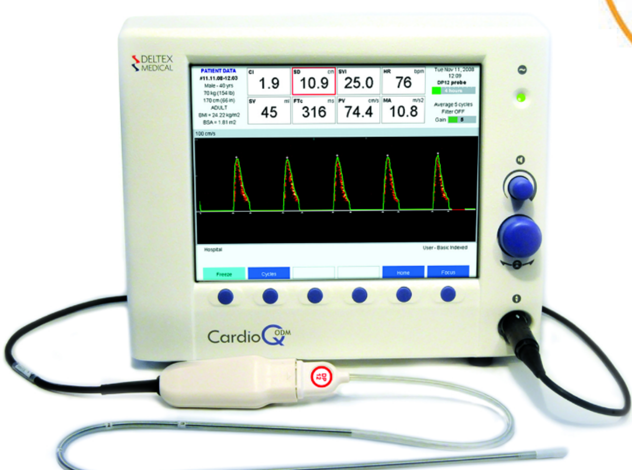
Schraverus Anasthesia 2016: error 46% O Obese

Chen J Clin Anesth 2012: r(2) 0.82

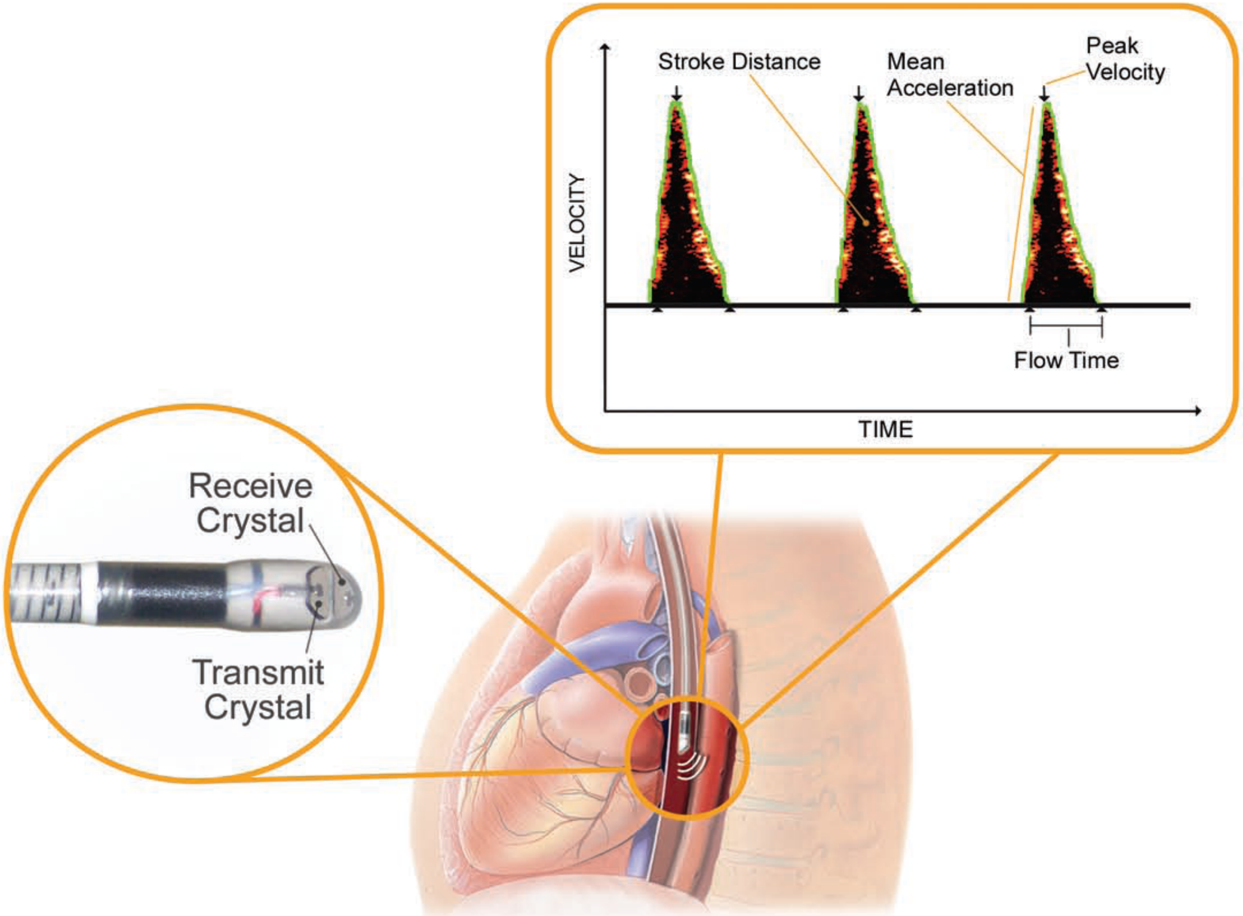
Bubenek Anesth Analg 2013: r(2) O.71

Fisher Acta Anesth Scand 2013: error 55-58%





DELTEX MEDICAL
1.9
10.9
25.0
76
45
316
74.4
10.8
CardioQ ODM



Stroke Distance
Mean Acceleration
Peak Velocity
VELOCITY
Flow Time
TIME
Receive Crystal
Transmit Crystal

Cioccari *et al. Critical Care* 2013, **17**:R121
http://ccforum.com/content/17/3/R121

CRITICAL CARE

RESEARCH Open Access

Hemodynamic assessment of critically ill patients using a miniaturized transesophageal echocardiography probe

Luca Cioccari[1], Hans-Rudolf Baur[2], David Berger[1], Jan Wiegand[1], Jukka Takala[1] and Tobias M Merz[1*]

patients. Inter-rater reliability between assessment by ICU mTEE operators and a trained cardiologist was substantial. Hemodynamic assessment using mTEE might, therefore, provide a valuable alternative to standard TTE or TEE-examination or conventional hemodynamic monitoring for a rapid, semi-quantitative assessment of LV and RV function and volume status.

We evaluated a monoplane, oral mTEE probe for hemodynamic monitoring in a population of critically ill patients in our ICU. Our data show that after a short

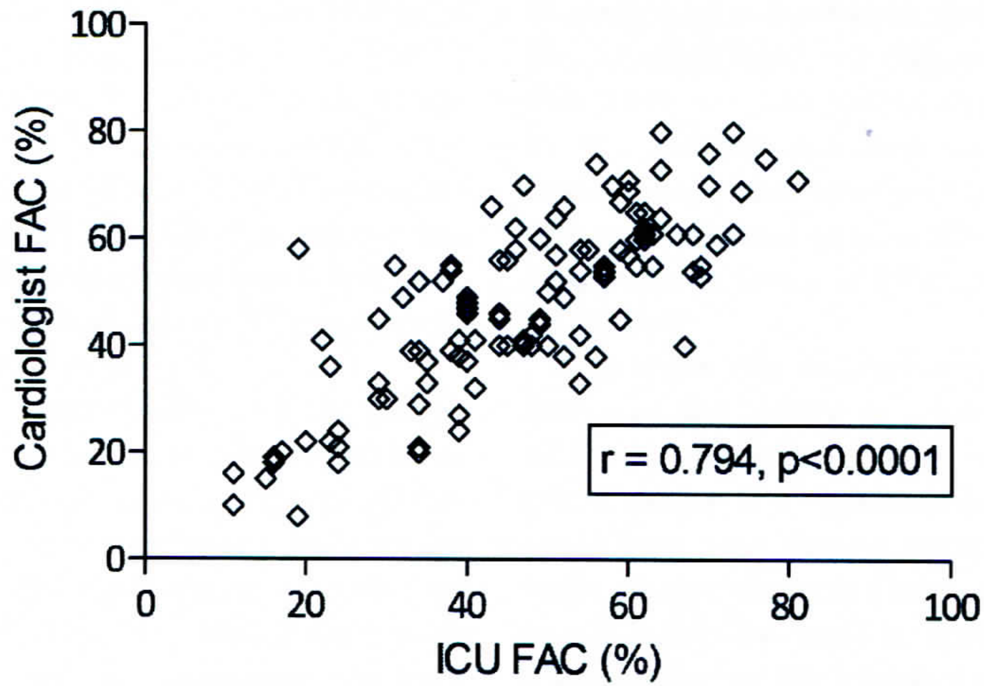
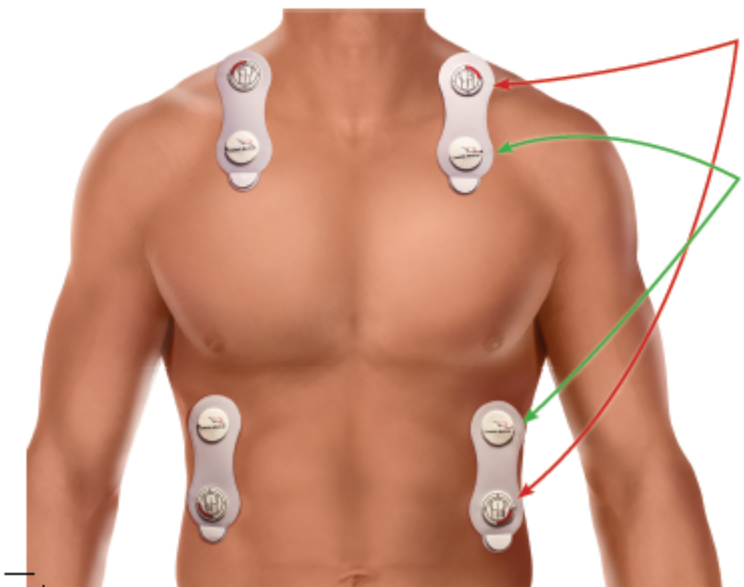


Figure 3 Accuracy of measurements of left ventricular systolic function. Assessment of the accuracy of measurements of left ventricular systolic function using the mTEE probe in 148 examinations of 55 patients with hemodynamic compromise. Measurements of left ventricular function fractional area change (FAC) by ICU operators were repeated by a trained cardiologist blinded to the patients and the mTEE operator's identity and to the results of the operator's examination. Correlation analysis revealed substantial inter-rater reliability of LV FAC measurements ($r = 0.794$, P (one-tailed) < 0.0001). ICU, intensive care unit; LV FAC, fractional area change of left ventricle; mTEE, miniaturized trans-esophageal echocardiography

CHEETAH NICOM Technology

The CHEETAH NICOM's unique, patented Bioreactance® technology takes measurements continuously and precisely. And it requires only four sensors, easily placed on the chest. The sensors can be placed anywhere on the chest or back as long as two are positioned above and two are positioned below the heart.

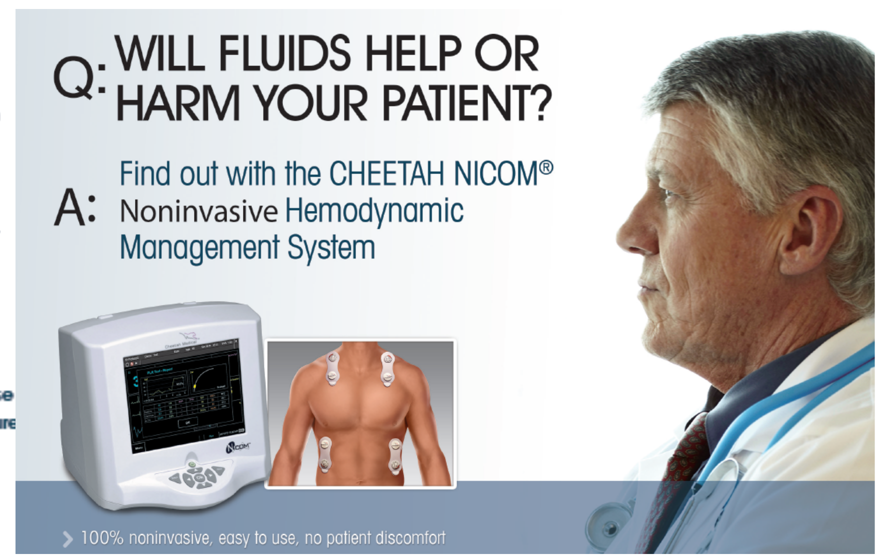


An electric current of known frequency is applied across the thorax between the outer pair of sensors.

A signal is recorded between the inner pair of sensors.

The blood absorbs electrons, causing a delay in the signal. The delay is proportional to the volume of blood, and the information is updated every 60 seconds.

This time delay, called a Phase Shift, is recorded; and the figure is translated to flow.



British Journal of Anaesthesia **111** (6): 961–6 (2013)
Advance Access publication 28 August 2013 · doi:10.1093/bja/aet282

BJA

Bioreactance is not reliable for estimating cardiac output and the effects of passive leg raising in critically ill patients

E. Kupersztych-Hagege[1,2], J.-L. Teboul[1,2], A. Artigas[3], A. Talbot[1,2], C. Sabatier[3], C. Richard[1,2] and X. Monnet[1,2]*

[1] Hôpitaux universitaires Paris-Sud, Hôpital de Bicêtre, service de réanimation médicale, 78, rue du Général Leclerc, F-94270 Le Kremlin-Bicêtre, France
[2] Univ Paris-Sud, Faculté de médecine Paris-Sud, EA4533, 63, rue Gabriel Péri, F-94270 Le Kremlin-Bicêtre, France
[3] Centro de Críticos, Hospital de Sabadell, CIBER de Enfermedades Respiratorias, Corporació Sanitària i Universitària Parc Taulí, Universitat Autònoma de Barcelona, Parc Taulí, s/n, 08208 Sabadell, Spain

* Corresponding author: Service de réanimation médicale, Centre Hospitalier Universitaire de Bicêtre, 78, rue du Général Leclerc, 94270 Le Kremlin-Bicêtre, France. E-mail: xavier.monnet@bct.aphp.fr

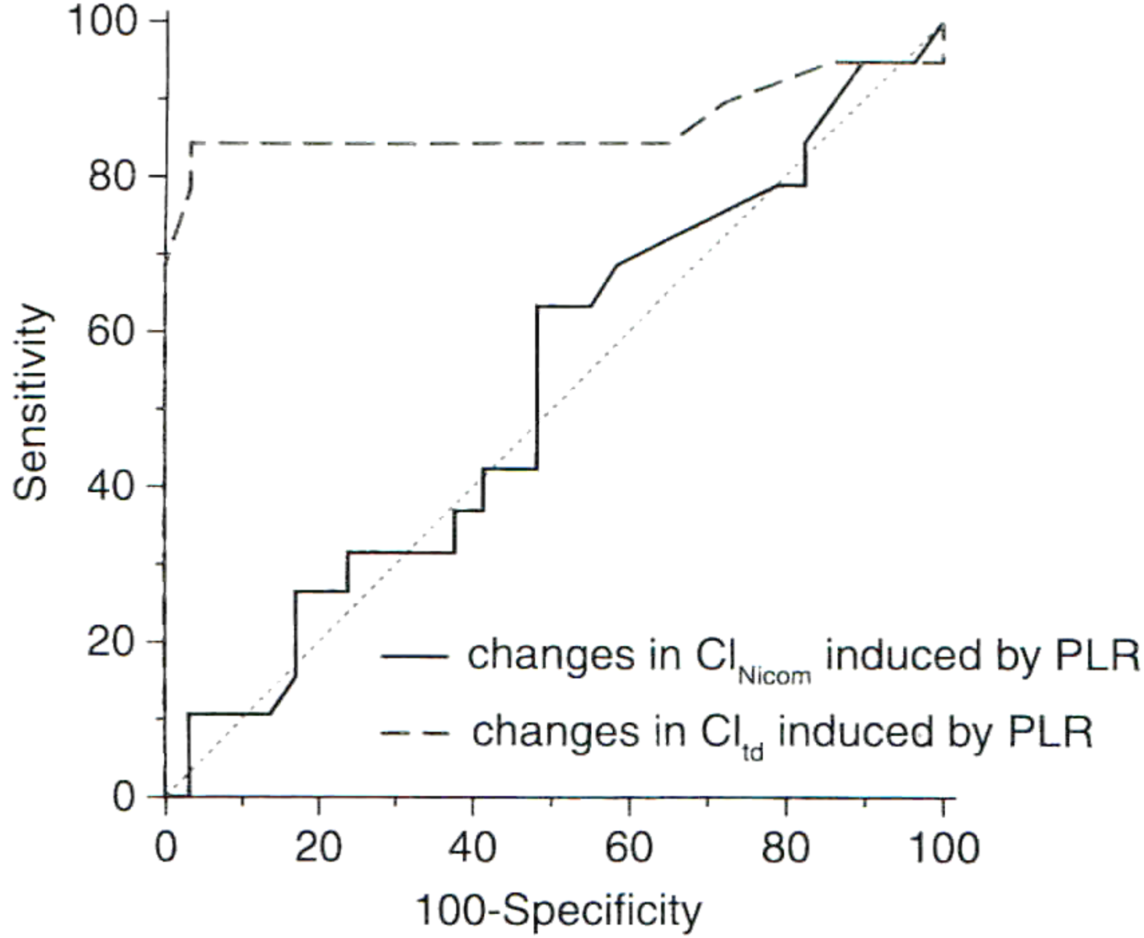


Fig 3 ROC curves testing the ability of the percentage changes in CI measured by transpulmonary thermodilution (CI_{td}) and by the NICOM® device (CI_{Nicom}) induced by the PLR test to predict fluid responsiveness.

Patient with circulatory failure

First, try to perform **echocardiography** to assess cardiac function

Lung injury ?

ABG, Chest X-ray

no

Basic monitoring

only

CVC + Art cath

CVP

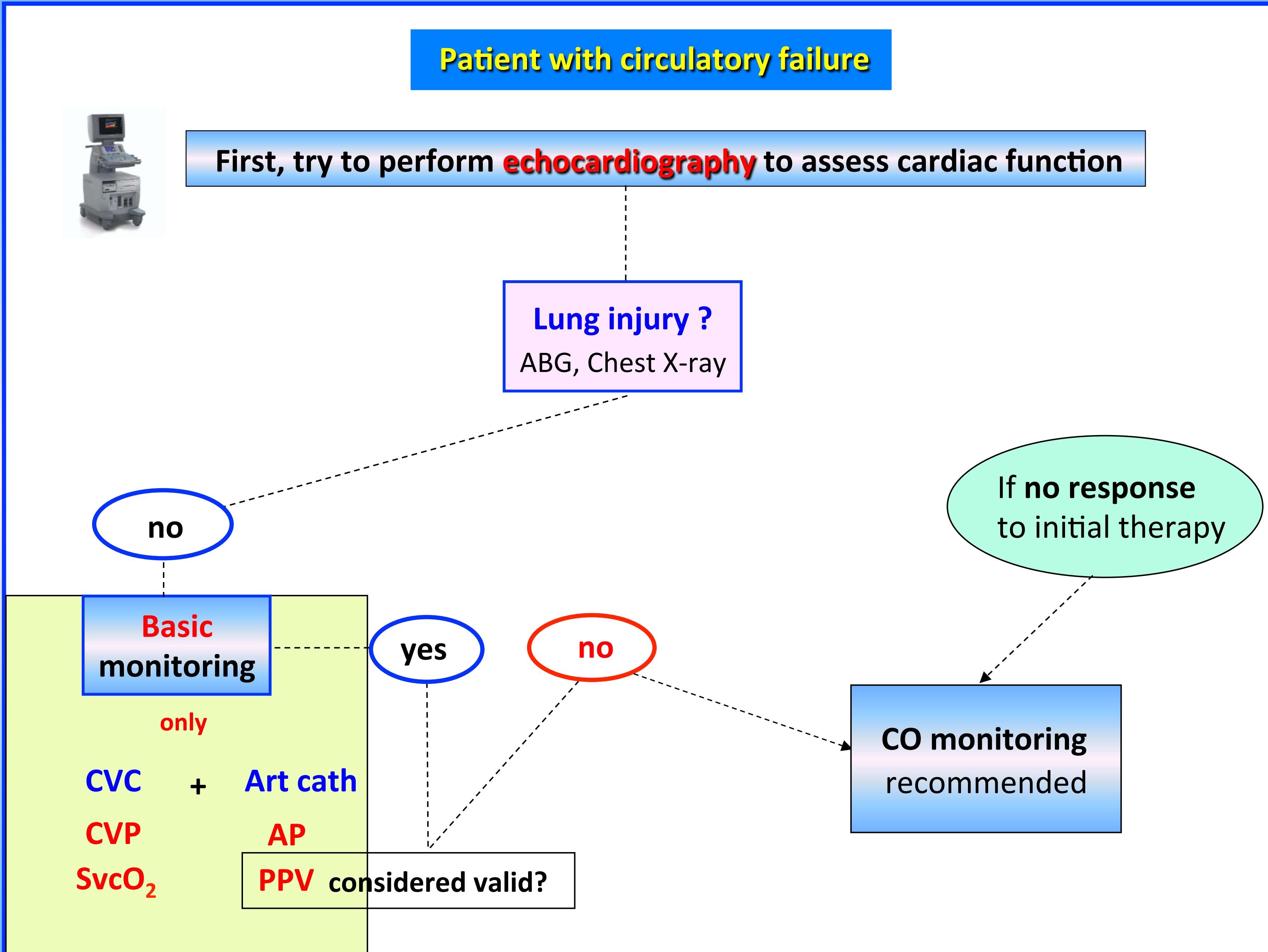
$SvcO_2$

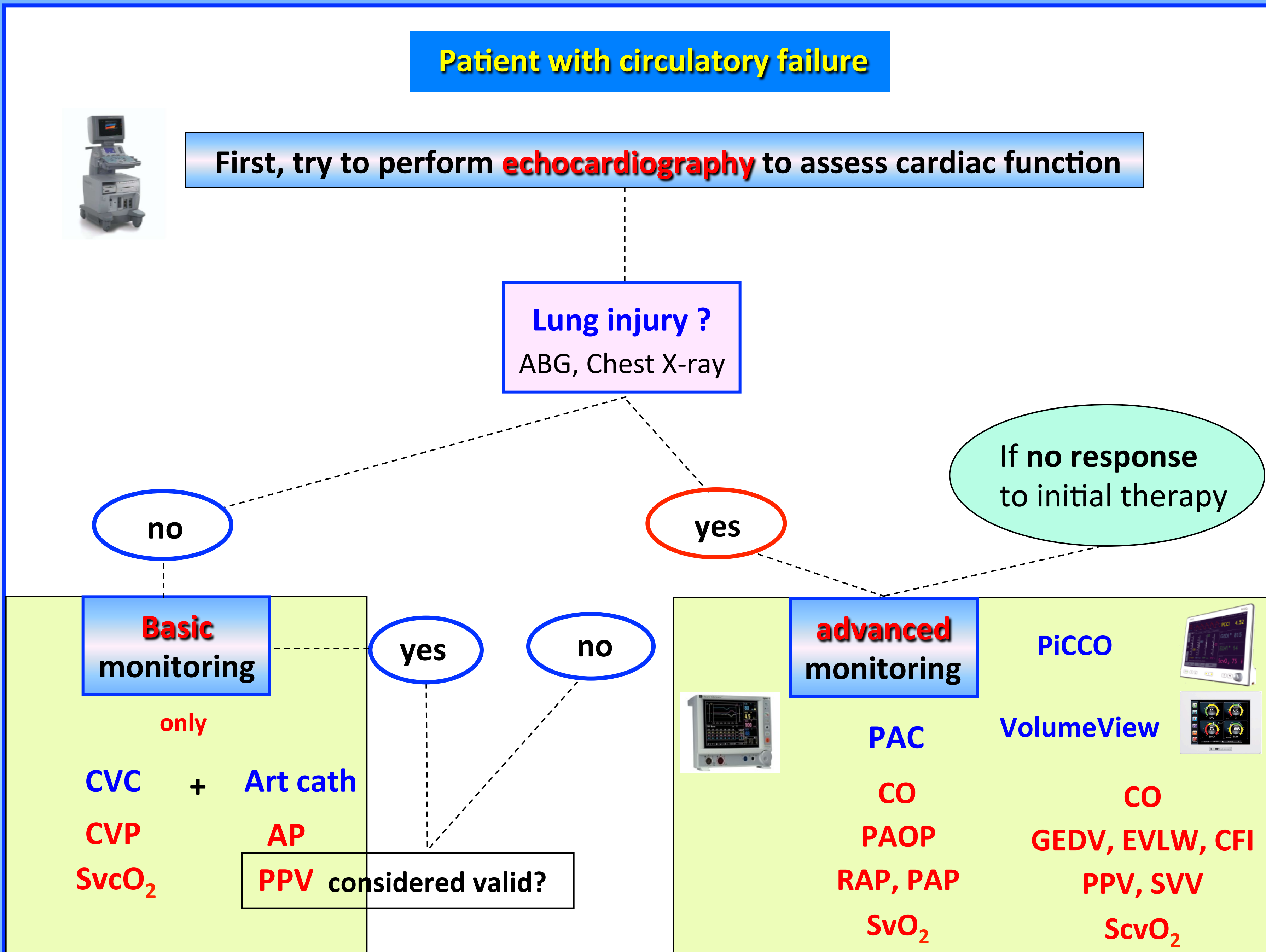
AP

yes

PPV considered valid?

Minimal monitoring could be **sufficient**


Patient with circulatory failure
First, try to perform echocardiography to assess cardiac function
Lung injury ?
ABG, Chest X-ray
no
If no response to initial therapy
Basic monitoring
yes
no
only
CVC
+
Art cath
CVP
AP
$SvcO_2$
PPV considered valid?
CO monitoring recommended


Patient with circulatory failure
First, try to perform echocardiography to assess cardiac function
Lung injury ?
ABG, Chest X-ray
If no response to initial therapy
no
yes
Basic monitoring
only
CVC
+
Art cath
CVP
AP
$SvcO_2$
PPV considered valid?
yes
no
advanced monitoring
PAC
PiCCO
VolumeView
CO
PAOP
RAP, PAP
SvO_2
CO
GEDV, EVLW, CFI
PPV, SVV
$ScvO_2$

Vincent et al. Critical Care (2015) 19:224
DOI 10.1186/s13054-015-0932-7

CRITICAL CARE

REVIEW Ope

Perioperative cardiovascular monitoring of high-risk patients: a consensus of 12

Jean-Louis Vincent[1*], Paolo Pelosi[2], Rupert Pearse[3], Didier Payen[4], Azriel Perel[5], Andreas Hoeft[6], Stefano R V Marco Ranieri[8], Carole Ichai[9], Patrice Forget[10], Giorgio Della Rocca[11] and Andrew Rhodes[12]

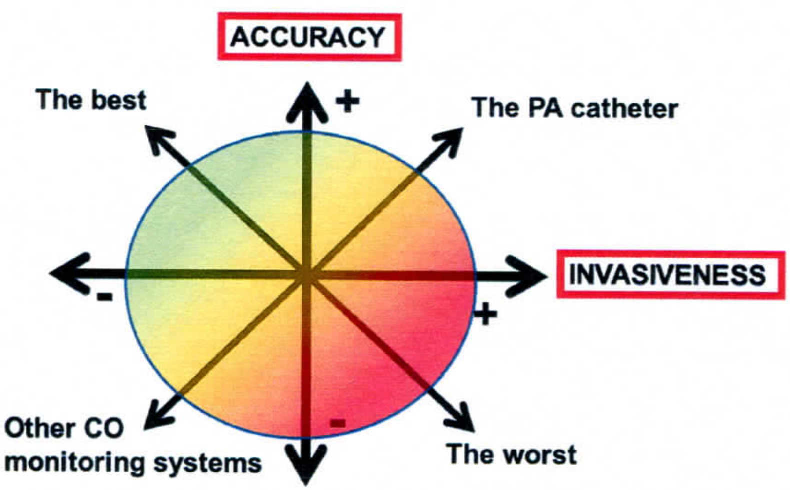


Figure 1 The compromise between accuracy and invasiveness of monitoring systems. CO, cardiac output; PA, pulmonary artery.

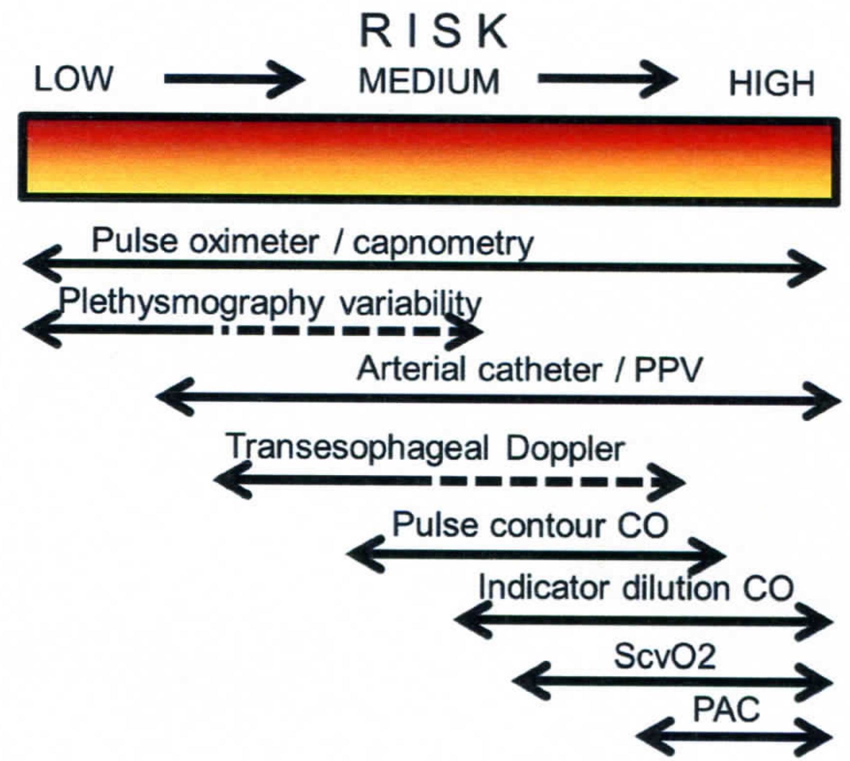


Figure 2 Possible choice of monitoring system in relation to a patient's degree of perioperative risk. CO, cardiac output; PAC, pulmonary artery catheter; PPV, pulse pressure variation; $ScvO_2$, central venous oxygen saturation.

Thankyou

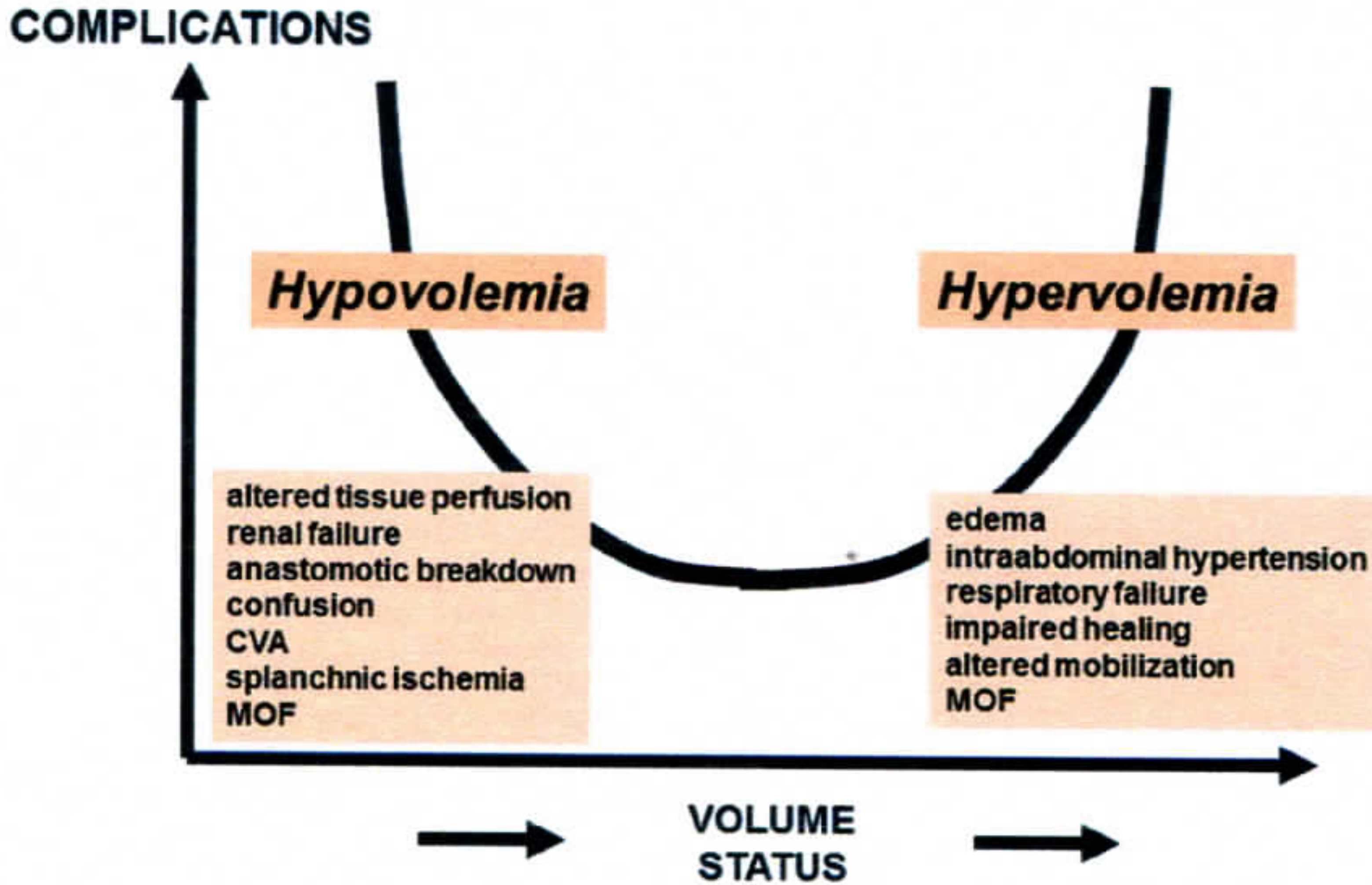


Figure 3 Both hypo- and hypervolemia are associated with more complications. CVA, cerebrovascular accident; MOF, multiple organ failure.

		of use	measurement	other variables than CO
Pulmonary artery catheter	+++	-	+++	+++
Transpulmonary dilution devices (thermodilution, lithium)	++	+	+++	+++
Non-calibrated pulse contour analysis	+	++	+/-	+
Oesophageal doppler	+	+	++	++
Pulse contour analysis of noninvasive arterial pressure	0	+++	?	+
Bio-impedance, bioreactance	0	+++	-	+

CO: Cardiac output

Transpulmonary dilution	Non calibrated Pulse contour	Pulse contour Non invasive	Oesophageal Doppler	Bio reactance

	PiCCO (Pulsion Medical Systems, Munich, Germany)	LiDCO (LiDCO Group Plc, London, UK)	VIGILEO (Edwards Lifesciences Corporation, Irvine, CA, USA)	Most Care® PRAM (Vytech Health, Padova, ITALY)
Source of the signal (Artery)	Femoral or Brachial	Radial	Radial	Femoral or Radial
Need of dedicated material	Yes	Yes	Yes	No
External calibration or preloaded data	Yes	Yes	Yes	No

Intensive Care Med (2014) 40:1795–1815
DOI 10.1007/s00134-014-3525-z

CONFERENCE REPORTS AND EXPERT PANEL

Maurizio Cecconi
Daniel De Backer
Massimo Antonelli
Richard Beale
Jan Bakker
Christoph Hofer
Roman Jaeschke
Alexandre Mebazaa
Michael R. Pinsky
Jean Louis Teboul
Jean Louis Vincent
Andrew Rhodes

Consensus on circulatory shock and hemodynamic monitoring. Task force of the European Society of Intensive Care Medicine

Monitoring preload and fluid responsiveness

- Optimal fluid management does improve patient outcome; hypovolemia and hypervolemia are harmful. *Statement of fact*.
- We recommend to assess volume status and volume responsiveness. *Best practice*.
- We recommend that immediate fluid resuscitation should be started in shock states associated with very low values of commonly used preload parameters. *Best practice*.
- We recommend that commonly used preload measures (such as CVP or PAOP or global end diastolic volume or global end diastolic area) alone should not be used to guide fluid resuscitation. *Recommendation*. Level 1; QoE moderate (B).
- We recommend not to target any ventricular filling pressure or volume. *Recommendation*. Level 1; QoE moderate (B).

- We recommend that fluid resuscitation should be guided by more than one single hemodynamic variable. *Best practice*.
- We recommend using dynamic over static variables to predict fluid responsiveness, when applicable. *Recommendation*. Level 1; QoE moderate (B).
- When the decision for fluid administration is made, we recommend to perform a fluid challenge, unless in cases of obvious hypovolemia (such as overt bleeding in a ruptured aneurysm). *Recommendation*, Level 1; QoE low (C).
- We recommend that even in the context of fluid-responsive patients, fluid management should be titrated carefully, especially in the presence of elevated intravascular filling pressures or extravascular lung water. *Best practice*.

Monitoring cardiac function and cardiac output

- Echocardiography can be used for the sequential evaluation of cardiac function in shock *Statement of fact.*
- We do not recommend the routine use of the pulmonary artery catheter for patients in shock. *Recommendation*. Level 1; QoE high (A).
- We suggest PAC in patients with refractory shock and RV dysfunction. *Recommendation*. Level 2; QoE low (C).
- We suggest the use of transpulmonary thermodilution or PAC in patients with severe shock especially in the case of associated acute respiratory distress syndrome. *Recommendation*. Level 2; QoE low (C).
- We recommend that less invasive devices are used, instead of more invasive devices, only when they have been validated in the context of patients with shock *Best practice.*

Table 1. 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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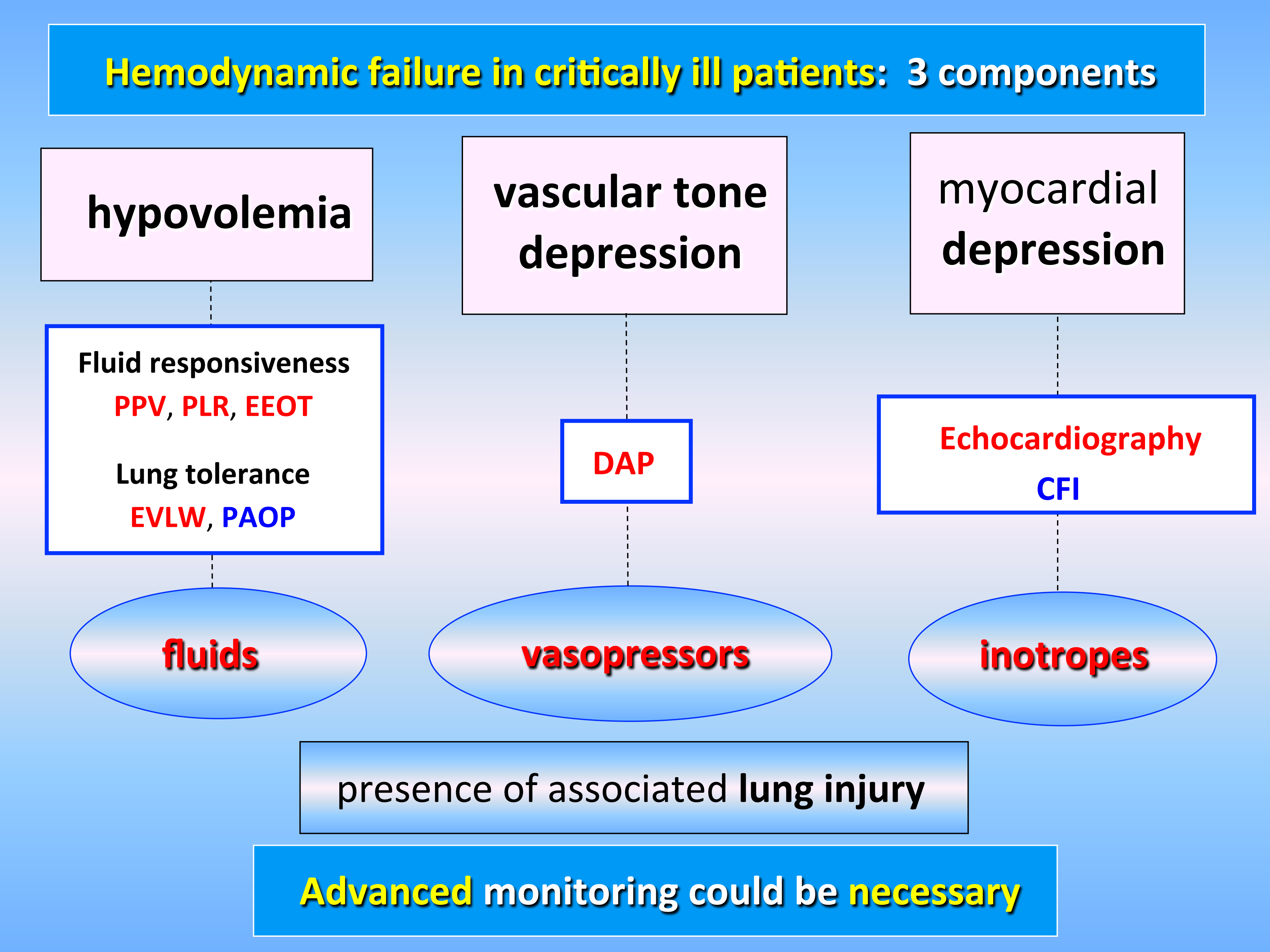

Hemodynamic failure in critically ill patients: 3 components
hypovolemia
vascular tone depression
myocardial depression
Fluid responsiveness
PPV, PLR, EEOT
Lung tolerance
EVLW, PAOP
DAP
Echocardiography
CFI
fluids
vasopressors
inotropes
presence of associated lung injury
Advanced monitoring could be necessary

1) **Detect** the presence of shock/tissue **hypoxia** **lactate**

2) If **yes**, try to **optimize** the **macrocirculation**

Check if **MAP adequate**

MAP – CVP adequate

yes

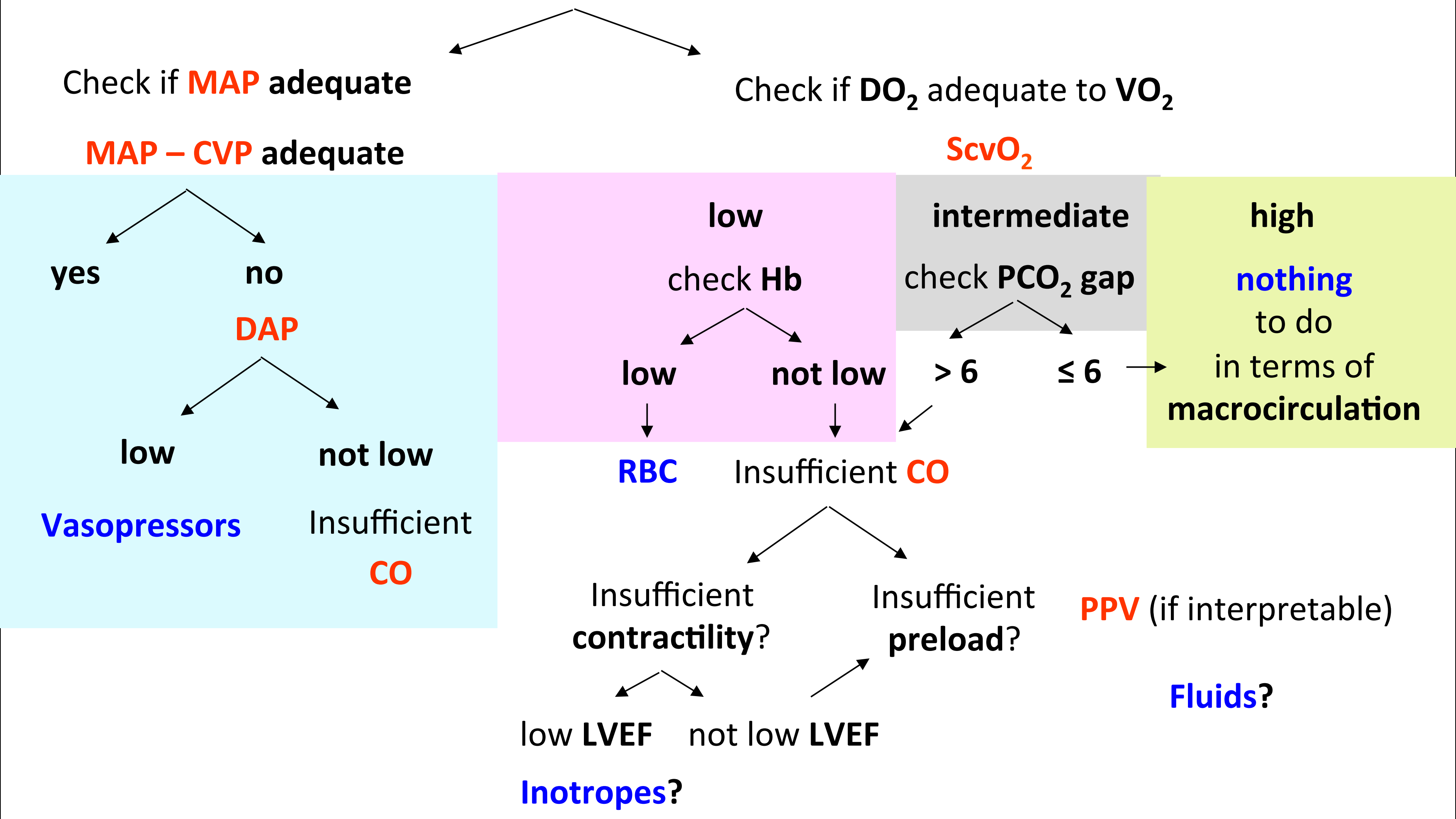
no

DAP

Check if $\mathbf{DO_2}$ adequate to $\mathbf{VO_2}$

1) **Detect** the presence of shock/tissue **hypoxia** lactate

2) If **yes**, try to **optimize** the **macrocirculation**



A Comparison of Third-Generation Semi-Invasive Arterial Waveform Analysis with Thermodilution in Patients Undergoing Coronary Surgery

Ole Broch,[1] Jochen Renner,[1] Matthias Gruenewald,[1] Patrick Meybohm,[1,2] Jan Schöttler,[3] Markus Steinfath,[1] Manu Malbrain,[4] and Berthold Bein[1]

The Scientific World Journal
Volume 2012, Article ID 451081

surgical pts

Table 2: Bland-Altman analysis showing 95% limits of agreement, confidence interval, and percentage error before (T1) and after (T2) cardiopulmonary bypass and during passive leg raising before (PLR 1) and after (PLR 2) bypass.

	T1	T2	PLR 1	PLR 2
$n_{data}/n_{patient}$	$n = 245/n = 50$	$n = 223/n = 50$	$n = 132/n = 47$	$n = 123/n = 42$
	CI_{Wave}	CI_{Wave}	CI_{Wave}	CI_{Wave}
Mean (L/min/m^2)	2.38	2.78	2.26	2.76
Bias (L/min/m^2)	0.01	0.007	0.05	0.03
SD of bias (L/min/m^2)	0.37	0.35	0.34	0.34
CI of LOA (L/min/m^2)	0.17	0.16	0.10	0.11
95% limits of agreement (L/min/m^2)	−0.71 to +0.73	−0.69 to +0.68	−0.63 to +0.72	−0.69 to +0.63
Percentage error (%)	31	25	30	25

Complete picture

of the patient's

hemodynamic status