Should we **continue** to measure **CVP**?

Prof. Jean-Louis TEBOUL

Medical ICU
Bicetre hospital
University Paris-Saclay
France

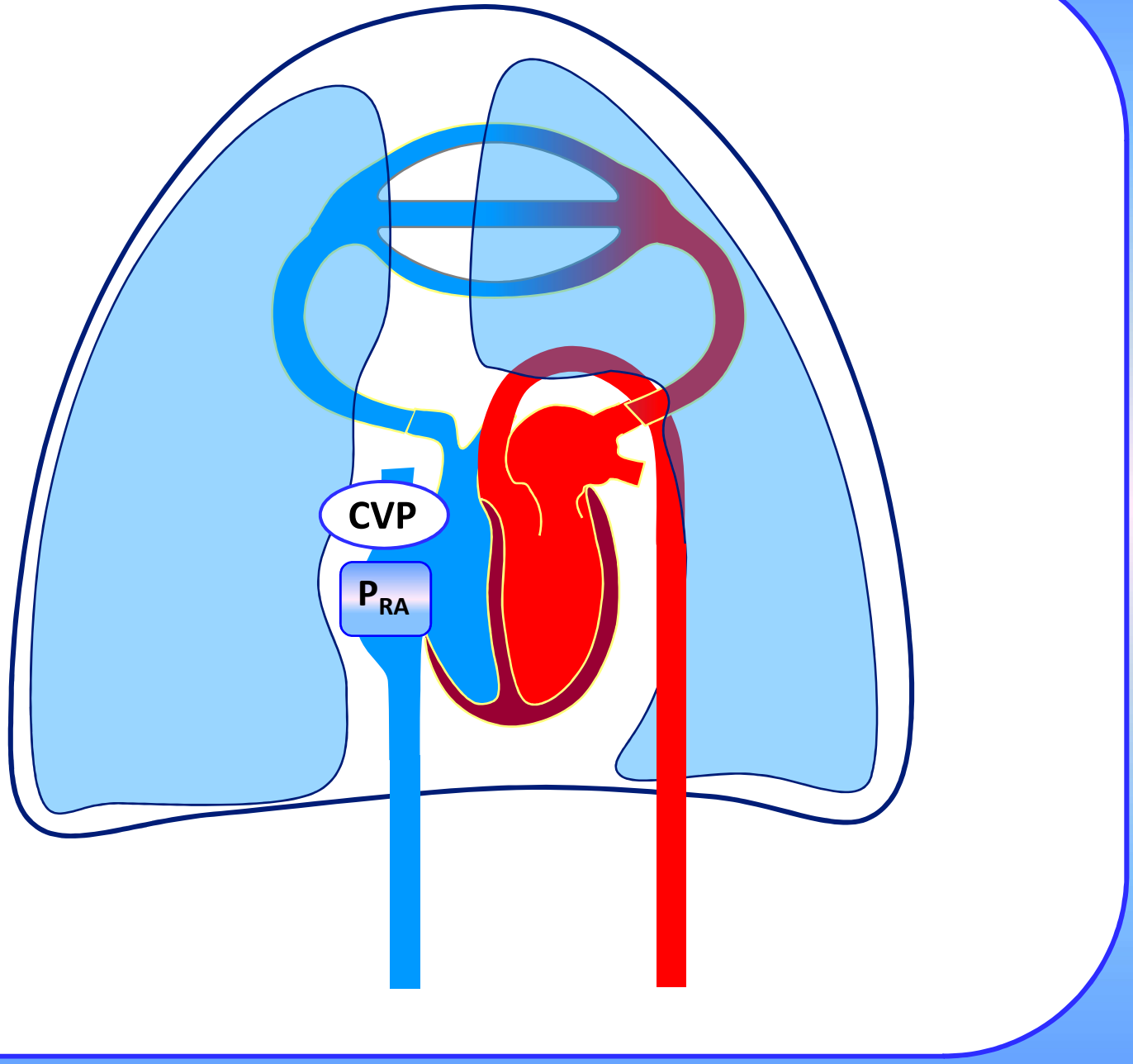
No conflict of Interest for this presentation

What is **CVP**?

CVP is the **pressure** in the **superior vena cavae**

and **reflects** the **right atrial pressure**

- reflects the **right ventricular filling pressure**

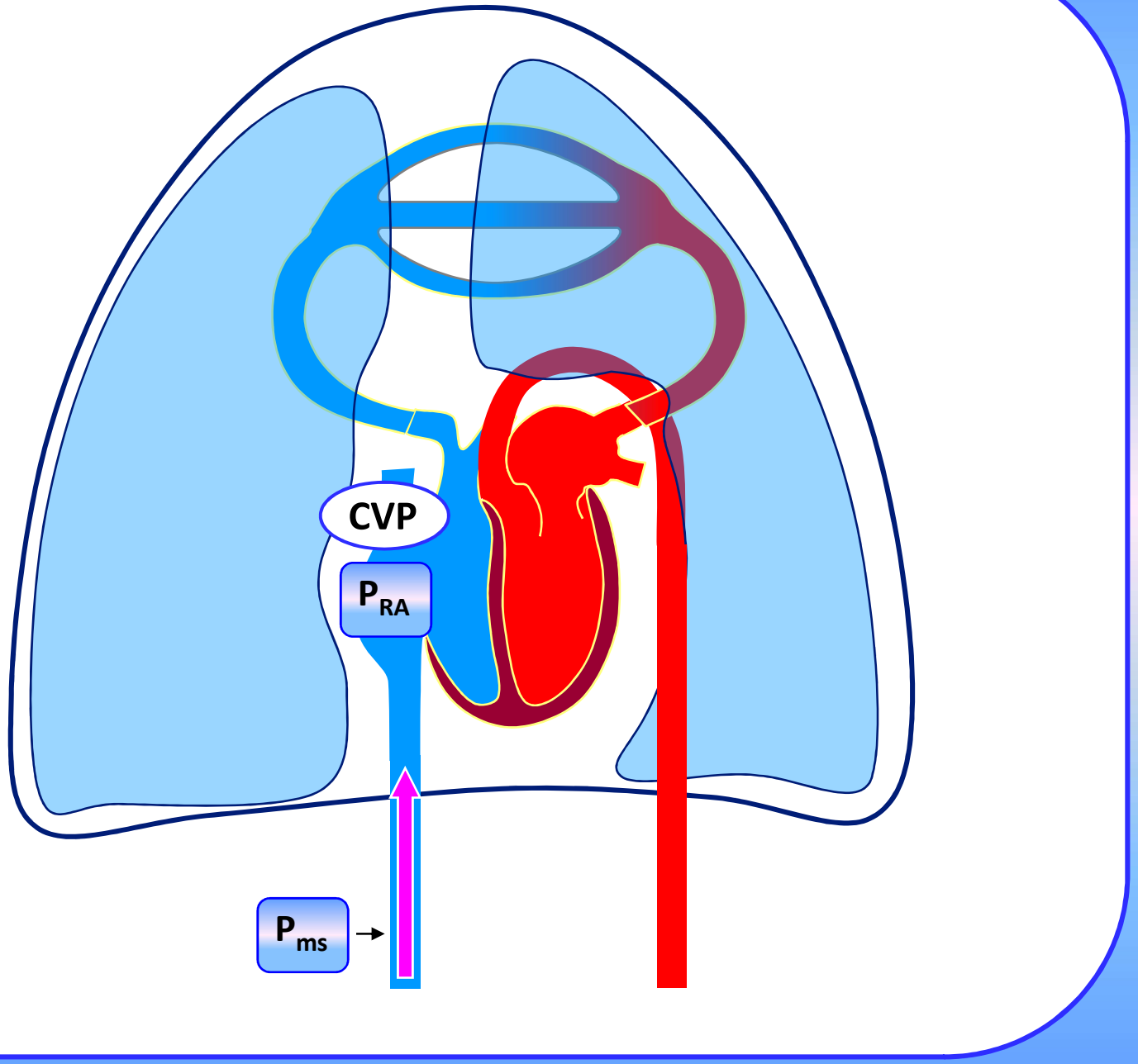

CVP
P_{RA}

What is **CVP**?

CVP is the **pressure** in the **superior vena cavae**

and **reflects** the **right atrial pressure**

- reflects the **right ventricular filling pressure**
- reflects the **backpressure** for **venous return**

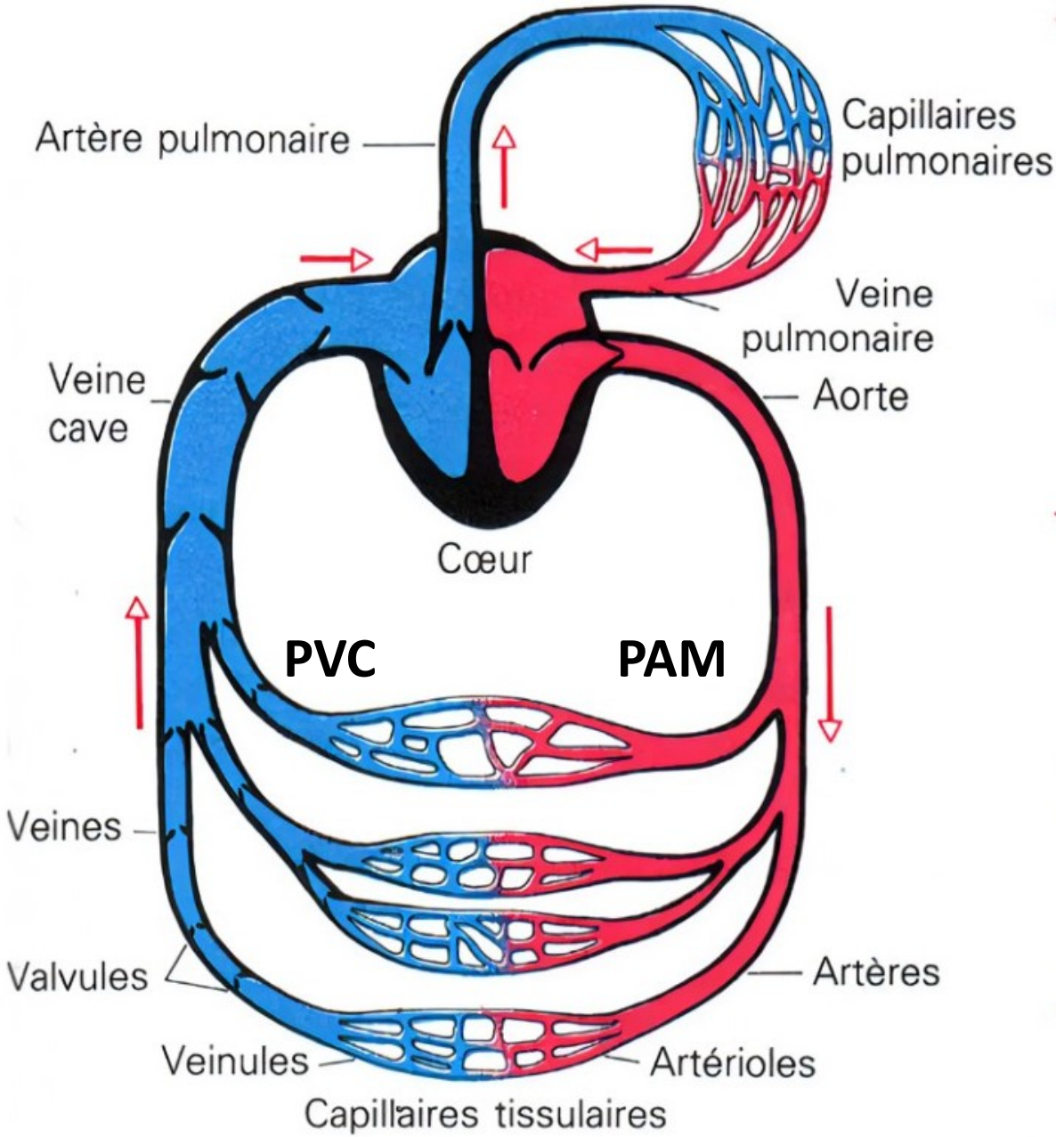

CVP
P_{RA}
P_{ms}

What is **CVP**?

CVP is the **pressure** in the **superior vena cavae**

and **reflects** the **right atrial pressure**

- reflects the **right ventricular filling pressure**
- reflects the **backpressure** for **venous return**
- **reflects** the **downstream pressure** for **organ perfusion**


Artère pulmonaire
Capillaires pulmonaires
Veine pulmonaire
Aorte
Veine cave
Cœur
PVC
PAM
Veines
Valvules
Artères
Veinules
Artérioles
Capillaires tissulaires

Is CVP dead?

- **CVP alive before** the **emergence** of the **PAC**

The patient in shock
Part I

Lloyd D. MacLean, M.D
A. P. H. McLean, M.D.,
C.

JULY 10, 1971

TABLE III

Hemodynamic and metabolic differences in various types of shock

	Blood pressure	*Pulse rate*	*Central venous pressure*	*Cardiac index*	*Urine flow*	*Response to volume load*	*Arterial Po_2*	*Arteriovenous O_2 difference*	*Arterial blood lactate*
Hypovolemic shock	↓	↑	↓	↓	↓	↑→	↓	↑	↑
Cardiogenic shock	↓	↓↑	↑	↓	↓	↓	↓	↑	↑
Peripheral pooling	↓	↑	↓	↓	↓	↓	↓	↑	↑
Cellular defect	↓	↑→	↑	↑	↓	↓	↓	↓→	↑

Is CVP dead?

- CVP alive before the emergence of the PAC
- **CVP almost died in the 80's**

The 80's

… the cult of the **Swan-Ganz** catheter

In USA: 1.5 millions PACs inserted/year

1 PAC/… 170 Americans

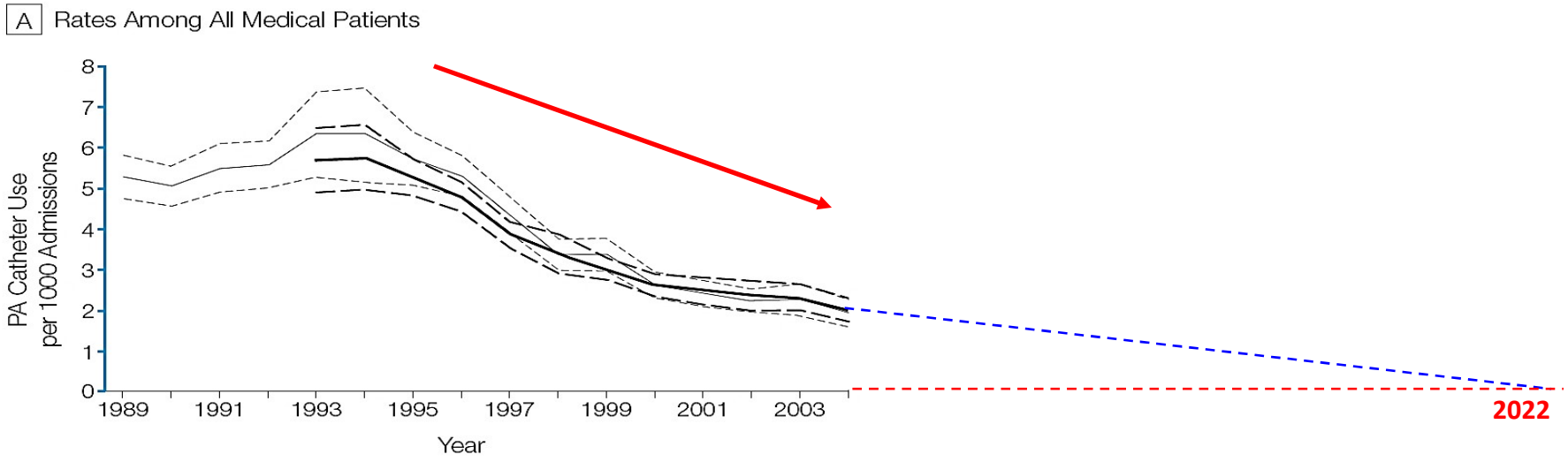
Is CVP dead?

- CVP alive before the emergence of the PAC
- CVP almost died in the 80's
- **CVP revived in the beginning of the 21th century**
  - **Decline of the PAC**

Trends in the Use of the Pulmonary Artery Catheter in the United States, 1993-2004

Renda Soylemez Wiener, MD
H. Gilbert Welch, MD, MPH

JAMA. 2007;298(4):423-429



The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 MAY 25, 2006 VOL. 354 NO. 21

Pulmonary-Artery versus Central Venous Catheter to Guide Treatment of Acute Lung Injury

The National Heart, Lung, and Blood Institute Acute Respiratory Distress Syndrome (ARDS) Clinical Trials Network*

PAC-guided therapy did **not improve survival**

or organ function

but was associated with **more complications**

than **CVC-guided** therapy

Is CVP dead?

- **CVP alive before** the **emergence** of the **PAC**
- **CVP almost died in the 80's**
- **CVP revived in the beginning of the 21th century**
  - **Decline of the PAC**
  - **Emergence** of the **EGDT** using **CVP** (Rivers study)

Intensive Care Med (2013) 39:165–228

GUIDELINES

R. P. Dellinger
Mitchell M. Levy
Andrew Rhodes
Djillali Annane
Herwig Gerlach
Steven M. Opal
Jonathan E. Sevransky

Surviving Sepsis Campaign: International Guidelines for Management of Severe Sepsis and Septic Shock, 2012

Initial resuscitation

1. Protocolized, quantitative resuscitation of patients with sepsis-induced hypoperfusion (defined as hypotension persisting after initial fluid challenge or blood lactate ≥ 4 mmol/L).

Goals during the first 6h of resuscitation:

Central venous pressure 8-12 mmHg

(c) **Urine output ≥ 0.5 mL.kg^{-1} h**

(d) **Central venous or mixed venous oxygen saturation 70 or 65%, respectively (grade 1C)**

Is CVP dead?

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  - **Decline of the PAC**
  - **Emergence** of the **EGDT** using **CVP** (Rivers study)
  - The **fluid challenge revisited**

Fluid challenge revisited

Jean-Louis Vincent, MD, PhD, FCCM; Max Harry Weil, MD, PhD, ScD (Hon), FCCM

Crit Care Med 2006; 34:1333-1337

- Rate of infusion: **500-1000 mL** crystalloids over 30 mins
- Goal: **reversal** of the **marker of hypoperfusion** that prompted the fluid challenge
- **Safety limit**: **increase** in **CVP** above a predefined value (measured every 10 mins)

Is CVP dead?

- **CVP alive before** the **emergence** of the **PAC**
- **CVP almost died in the 80's**
- **CVP revived in the beginning of the 21th century**
  - **Decline of the PAC**
  - **Emergence** of the **EGDT** using **CVP** (Rivers study)
  - The **fluid challenge revisited**

→ **Large use** of **CVP** to guide **fluid therapy**

Maurizio Cecconi
Christoph Hofer
Jean-Louis Teboul
Ville Pettila
Erika Wilkman
Zsolt Molnar
Giorgio Della Rocca
Cesar Aldecoa
Antonio Artigas
Sameer Jog
Michael Sander
Claudia Spies
Jean-Yves Lefrant
Daniel De Backer
on behalf of the FENICE Investigators
and the ESICM Trial Group

Fluid challenges in intensive care: the FENICE study

A global inception cohort study

Intensive Care Med (2015) 41:1529–1537

Hemodynamic variable used to predict fluid responsiveness	n	%
No variable used	945	
Any variable used	1268	
CVP	572	25.8
PAOP	31	1.4
GEDVI	33	1.5
Other	149	6.7
PPV	88	4.0
SVV	88	4.0
PPV + SVV	24	1.1
PLR	238	10.7
Echo variables	45	2.0

Is CVP dead?

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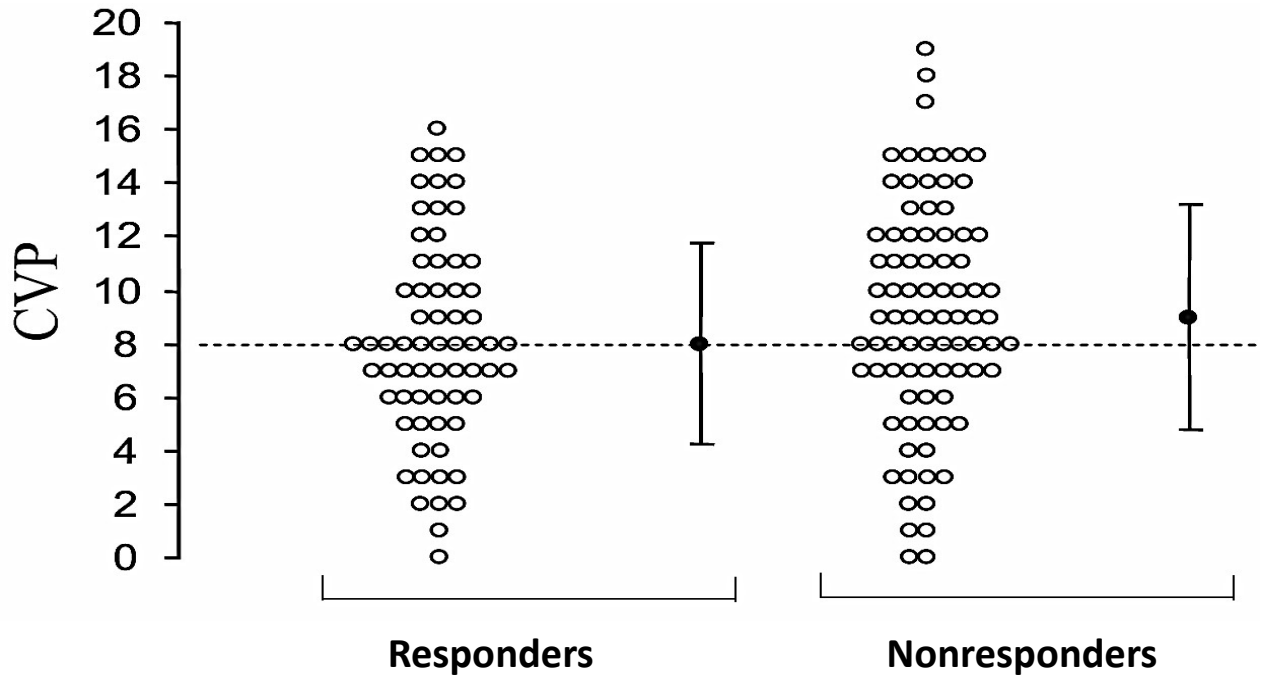
- **CVP revived in the beginning of the 21th century**
  - **Decline of the PAC**
  - **Emergence** of the **EGDT** using **CVP** (Rivers study)
  - The **fluid challenge revisited**

→ **Overuse** of **CVP** to guide **fluid therapy**

Cardiac filling pressures are not appropriate to predict hemodynamic response to volume challenge*

David Osman, MD; Christophe Ridel, MD; Patrick Ray, MD; Xavier Monnet, MD, PhD; Nadia Anguel, MD; Christian Richard, MD; Jean-Louis Teboul, MD, PhD

Crit Care Med 2007; 35:64–68



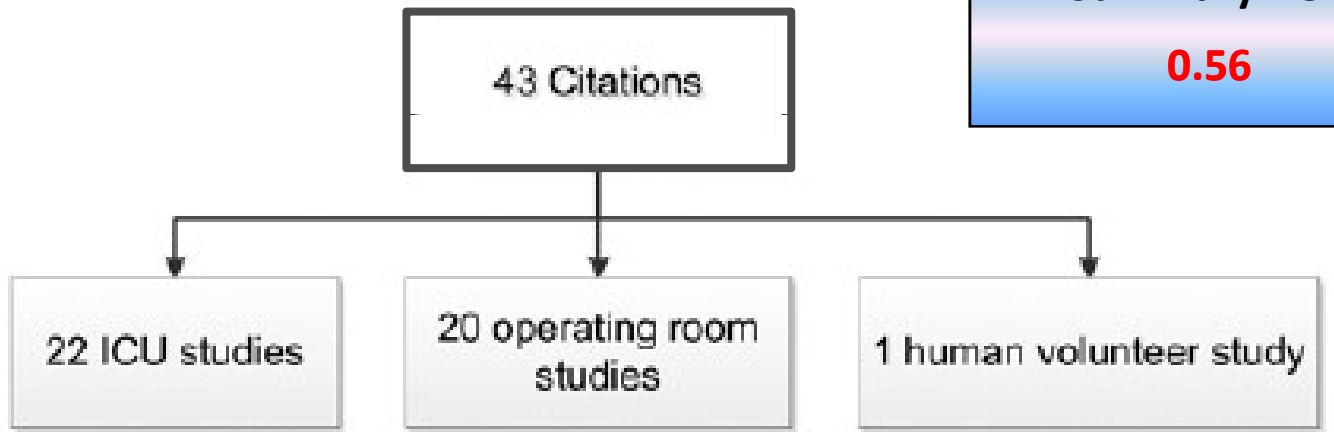
Does the Central Venous Pressure Predict Fluid Responsiveness? An Updated Meta-Analysis and a Plea for Some Common Sense*

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

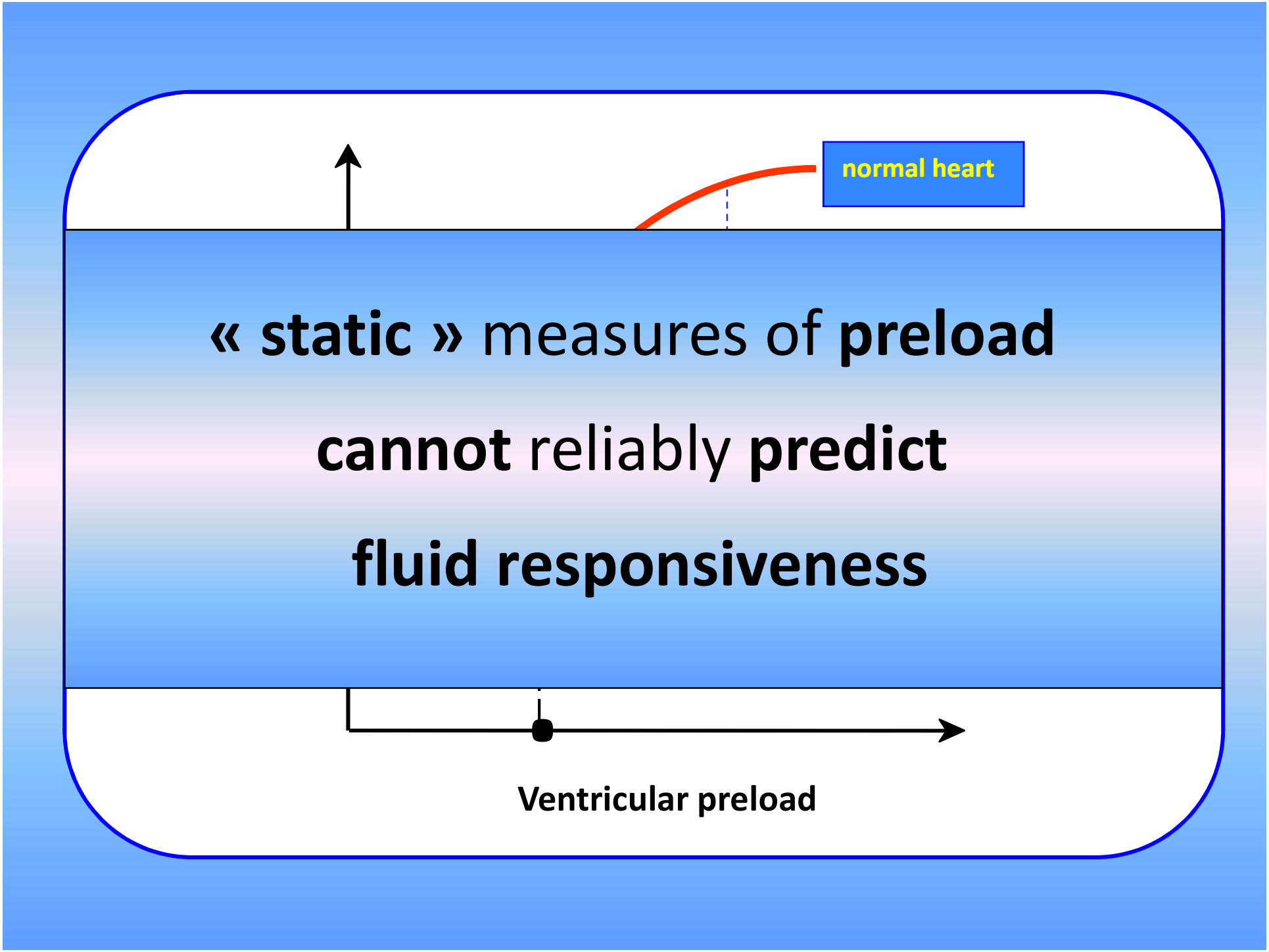
Crit Care Med 2013; 41:1774-81

Summary AUC

0.56



Predicting fluid responsiveness with **CVP** is like

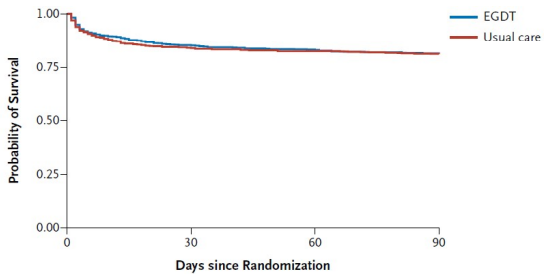

normal heart
« static » measures of preload
cannot reliably predict
fluid responsiveness
Ventricular preload

Arise

Goal-Directed Resuscitation for Patients with Early Septic Shock

The ARISE Investigators and the ANZICS Clinical Trials Group*

N Engl J Med 2014;371:1496-506.

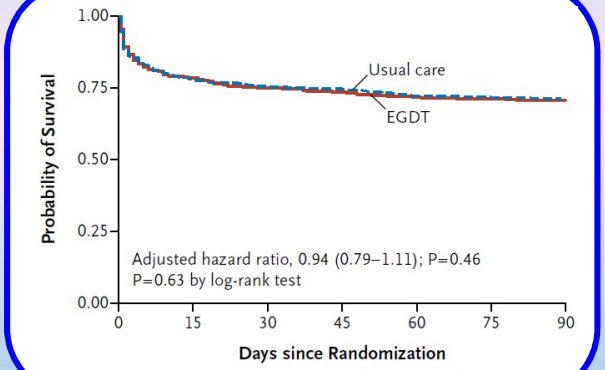


Promise

Trial of Early, Goal-Directed Resuscitation for Septic Shock

Paul R. Mouncey, M.Sc., Tiffany M. Osborn, M.D., G. Sarah Power, M.Sc., David A. Harrison, Ph.D., M. Zia Sadique, Ph.D., Richard D. Grieve, Ph.D., Rahi Jahan, B.A., Sheila E. Harvey, Ph.D., Derek Bell, M.D., Julian F. Bion, M.D., Timothy J. Coats, M.D., Mervyn Singer, M.D., J. Duncan Young, D.M., and Kathryn M. Rowan, Ph.D., for the ProMISe Trial Investigators*

N Engl J Med 2015;372:1301-11.

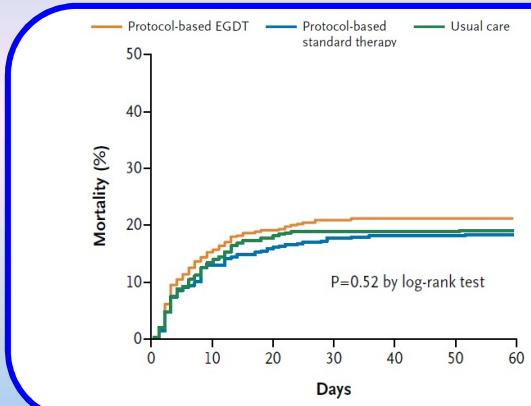


Process

A Randomized Trial of Protocol-Based Care for Early Septic Shock

The ProCESS Investigators*

N Engl J Med 2014;370:1683-93.



No improved survival with **EGDT**

No mention to CVP anywhere

in the **guidelines**….!!!!

GUIDELINES

Surviving sepsis campaign: international guidelines for management of sepsis and septic shock 2021

Laura Evans[1*], Andrew Rhodes[2], Waleed Alhazzani[3], Massimo Antonelli[4], Craig M. Coopersmith[5], Craig French[6], Flávia R. Machado[7], Lauralyn Mcintyre[8], Marlies Ostermann[9], Hallie C. Prescott[10],

Intensive Care Med

Is CVP dead?

- CVP alive before the emergence of the PAC
- CVP almost died in the 80's
- CVP was revived in the beginning of the 2000's
- **Should we still use CVP today?**
  - **NO** for **predicting fluid responsiveness**

Intensive Care Med (2014) 40:1795–1815

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

We recommend using **dynamic** over static variables to predict **fluid responsiveness**, when applicable

CONFERENCE REPORTS AND EXPERT PANEL

Surviving Sepsis Campaign: International Guidelines for Management of Sepsis and Septic Shock: 2016

Andrew Rhodes[1*], Laura E. Evans[2], Waleed Alhazzani[3], Mitchell M. Levy[4], Massimo Antonelli[5], Ricard Ferrer[6], Anand Kumar[7], Jonathan E. Sevransky[8], Charles L. Sprung[9], Mark E. Nunnally[2], Bram Rochwerg[3], Gordon D. Rubenfeld[10], Derek C. Angus[11], Djillali Annane[12], Richard J. Beale[13], Geoffrey J. Bellinghan[14],

Intensive Care Med (2017) 43:304–377

We suggest that **dynamic** over static variables be used to predict **fluid responsiveness**, when available

GUIDELINES

Surviving sepsis campaign: international guidelines for management of sepsis and septic shock 2021

Laura Evans[1*], Andrew Rhodes[2], Waleed Alhazzani[3], Massimo Antonelli[4], Craig M. Coopersmith[5], Craig French[6], Flávia R. Machado[7], Lauralyn Mcintyre[8], Marlies Ostermann[9], Hallie C. Prescott[10],

Intensive Care Med

We suggest that **dynamic** measures to guide fluid resuscitation over static parameters

GUIDELINES

Surviving sepsis campaign: international guidelines for management of sepsis and septic shock 2021

Laura Evans[1*], Andrew Rhodes[2], Waleed Alhazzani[3], Massimo Antonelli[4], Craig M. Coopersmith[5], Craig French[6], Flávia R. Machado[7], Lauralyn Mcintyre[8], Marlies Ostermann[9], Hallie C. Prescott[10],

Intensive Care Med

6. For adults with sepsis or septic shock, we **suggest** using dynamic measures to guide fluid resuscitation, over physical examination or static parameters alone

Weak recommendation, very low-quality evidence

Is CVP dead?

- **CVP alive before** the **emergence** of the **PAC**
- **CVP almost died in the 80's**
- **CVP was revived in the beginning of the 2000's**
- **Should we still use CVP today?**
  - **NO** for **predicting fluid responsiveness**
  - **NO** for helping to **stop fluid** infusion

Intensive Care Med (2012) 38:422–428

ORIGINAL

Charalampos Pierrakos
Dimitrios Velissaris
Sabino Scolletta
Sarah Heenen
Daniel De Backer
Jean-Louis Vincent

Can changes in arterial pressure be used to detect changes in cardiac index during fluid challenge in patients with septic shock?

CVP (mmHg)	**before**	**after fluid**
Responders	10 ± 3	13 ± 4 *
Nonresponders	12 ± 4	14 ± 4

CVP increased after fluids in **responders** but **not** in **nonresponders**

…. the **opposite** of what was expected in the **« fluid challenge rules »**

The Changes in Pulse Pressure Variation or Stroke Volume Variation After a "Tidal Volume Challenge" Reliably Predict Fluid Responsiveness During Low Tidal Volume Ventilation*

Sheila Nainan Myatra, MD, FCCM[1]; Natesh R Prabu, MD, DM[1]; Jigeeshu Vasishtha Divatia, MD, FCCM[1]; Xavier Monnet, MD, PhD[2]; Atul Prabhakar Kulkarni, MD, FICCM[1]; Jean-Louis Teboul, MD, PhD[2]

Crit Care Med 2017; 45:415–421

CVP (mmHg)	**before**	**after fluid**
Responders	8 ± 4	12 ± 4 *
Nonresponders	9 ± 4	11 ± 4

CVP increased after fluids in **responders** but **not** in **nonresponders**

…. the **opposite** of what was expected in the **« fluid challenge rules »**

Is CVP dead?

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- **CVP almost died in the 80's**
- **CVP was revived in the beginning of the 2000's**
- **Should we still use CVP today?**
  - **NO** for **predicting fluid responsiveness**
  - **NO** for helping to **stop fluid** infusion
  - **YES** for assessing **RV dysfunction** and its response to therapies

→ Take into account the **transmural CVP**
which can be **overestimated** by the **measured CVP** (PEEP, PEEPi)

Is CVP dead?

- **CVP alive before** the **emergence** of the **PAC**
- **CVP almost died in the 80's**
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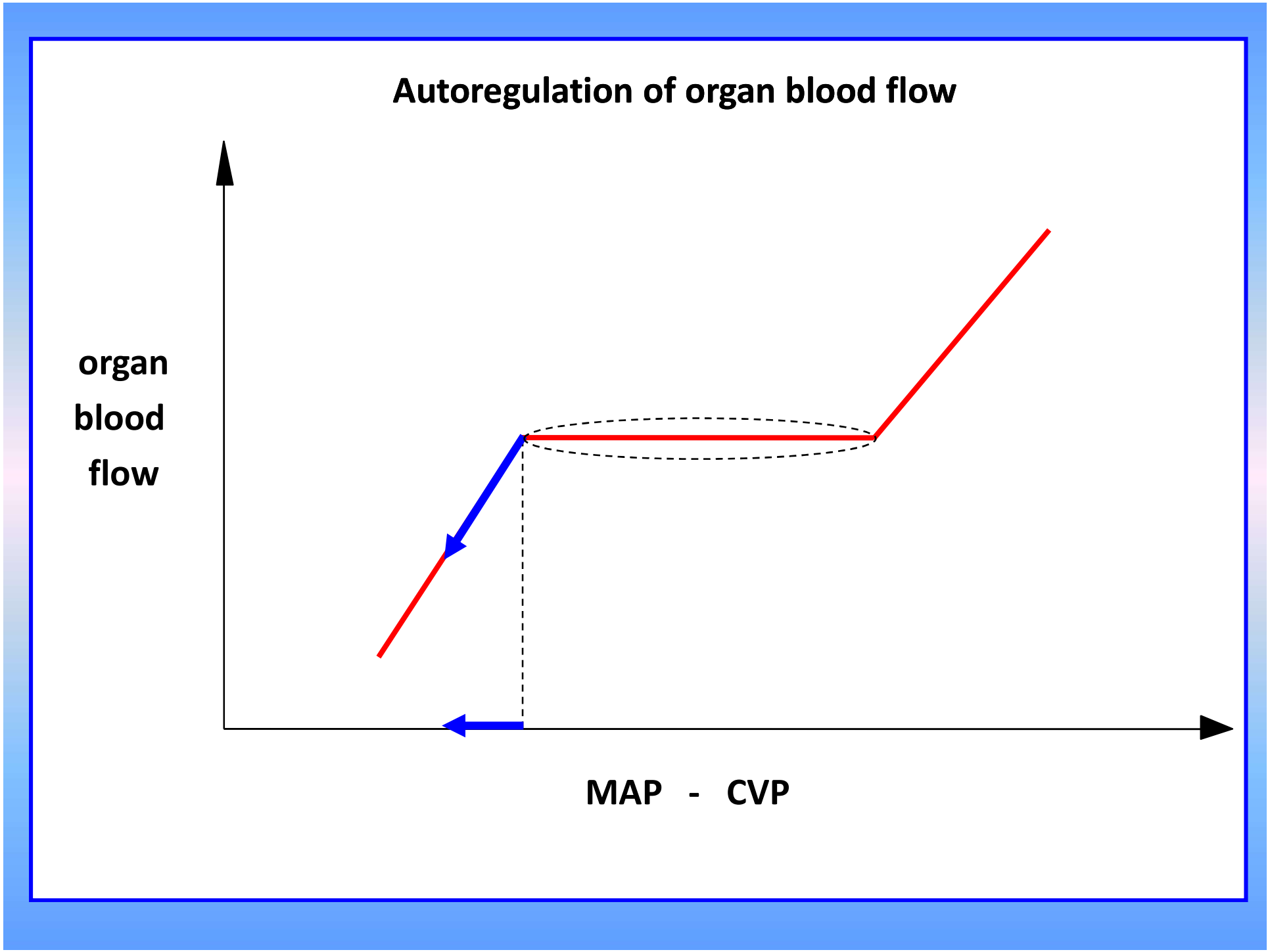
- **Should we still use CVP today?**
  - **NO** for **predicting fluid responsiveness**
  - **NO** for helping to **stop fluid** infusion
  - **YES** for assessing **RV dysfunction** and its response to therapies
  - **YES** for assessing **downstream pressure** for organ **perfusion**

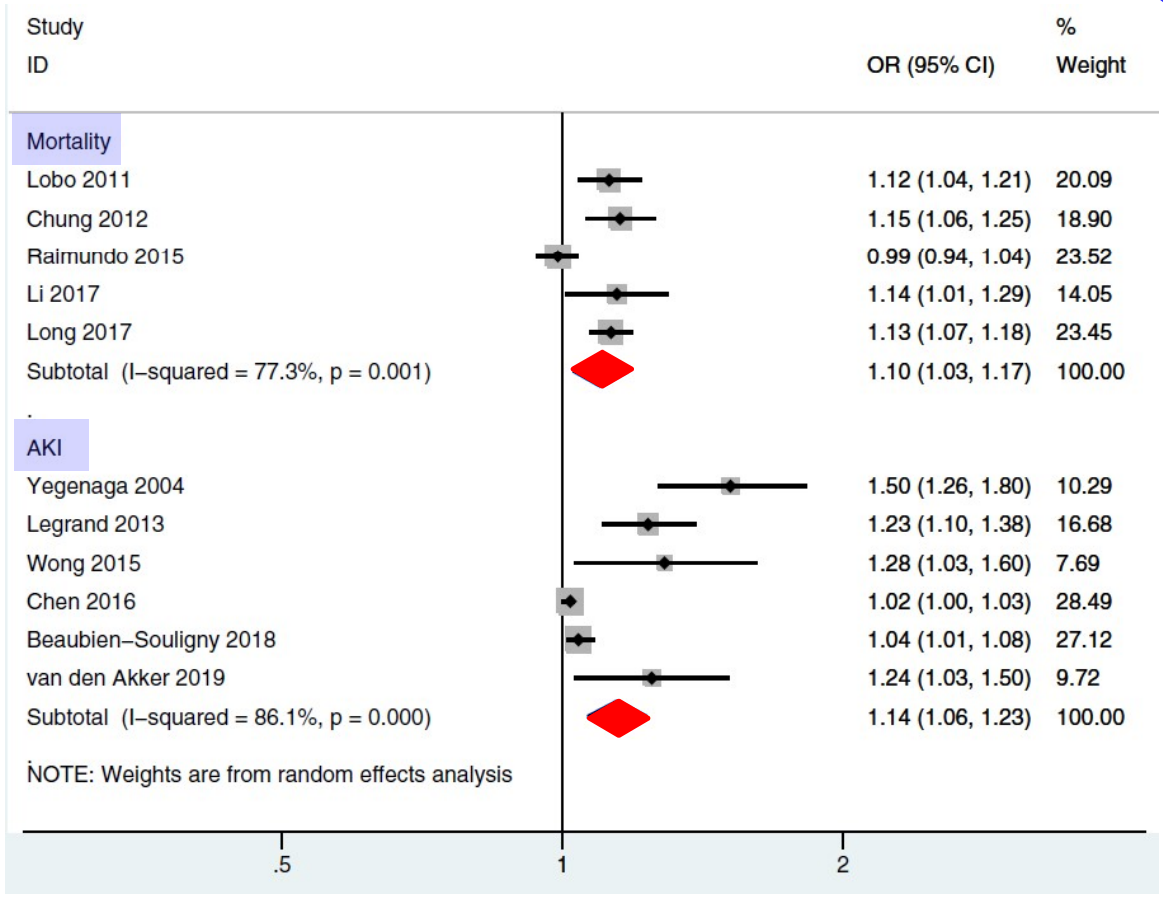
→ Take into account the **measured CVP** and **not** the **transmural CVP**


Autoregulation of organ blood flow
organ
blood
flow
MAP - CVP

Elevated central venous pressure is associated with increased mortality and acute kidney injury in critically ill patients: a meta-analysis

Chuan-Yu Chen[1], Yan Zhou[1], Peng Wang[1], En-Yao Qi[1] and Wan-Jie Gu[2*]

Critical Care (2020) 24:80



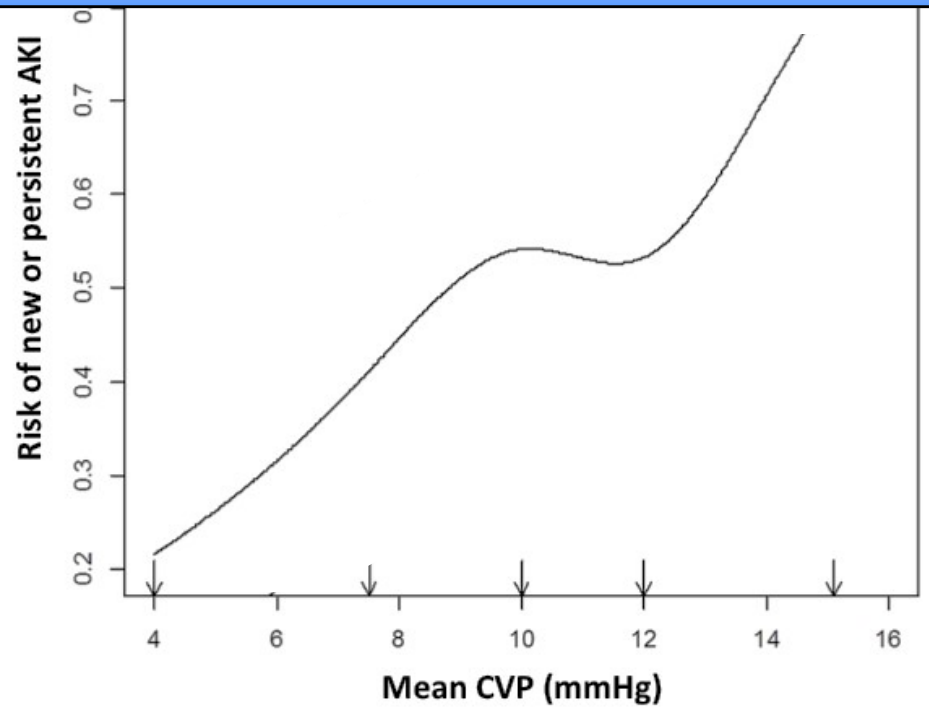
Association between systemic hemodynamics and septic acute kidney injury in critically ill patients: a retrospective observational study

Matthieu Legrand[1,2*], Claire Dupuis[1], Christelle Simon[1], Etienne Gayat[1,3], Joaquim Mateo[1], Anne-Claire Lukaszewicz[1,2,4] and Didier Payen[1,2,4]

Critical Care 2013, **17**:R278

Association between **elevated CVP** and **AKI**

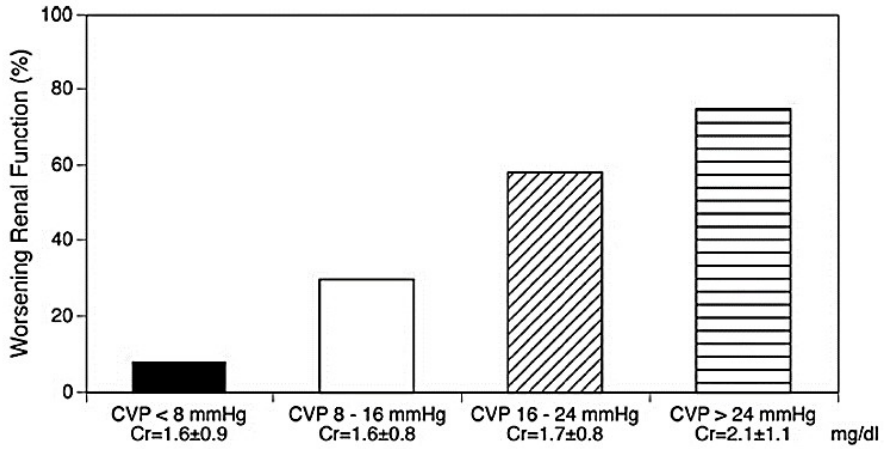
suggests a role of **venous congestion** in the development of AKI

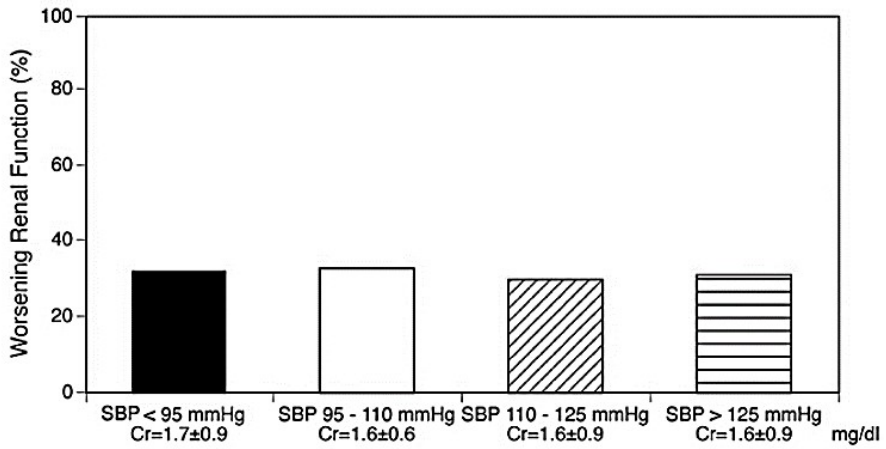


Importance of Venous Congestion for Worsening of Renal Function in Advanced Decompensated Heart Failure

Wilfried Mullens, MD, Zuheir Abrahams, MD, PhD, Gary S. Francis, MD, FACC, George Sokos, DO, David O. Taylor, MD, FACC, Randall C. Starling, MD, MPH, FACC, James B. Young, MD, FACC, W. H. Wilson Tang, MD, FACC

Journal of the American College of Cardiology Vol. 53, No. 7, 2009





Low mean perfusion pressure is a risk factor for progression of acute kidney injury in critically ill patients – A retrospective analysis

Marlies Ostermann[1*], Anna Hall[2] and Siobhan Crichton[3]

BMC Nephrology (2017) 18:151

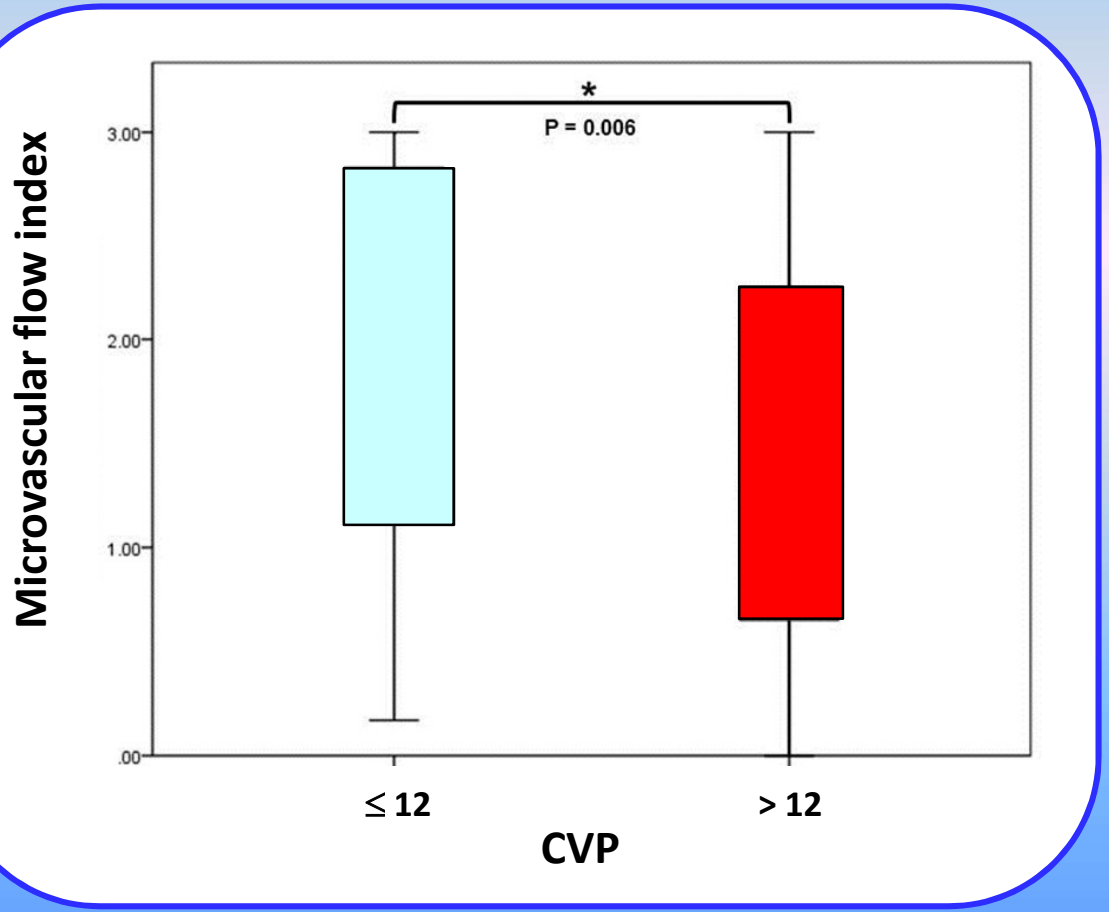
Mean perfusion pressure (MPP = MAP-CVP) but **not MAP** was an independent factor associated with **AKI progression**.

A value of **MPP** of **60 mmHg** was found as a cutoff.

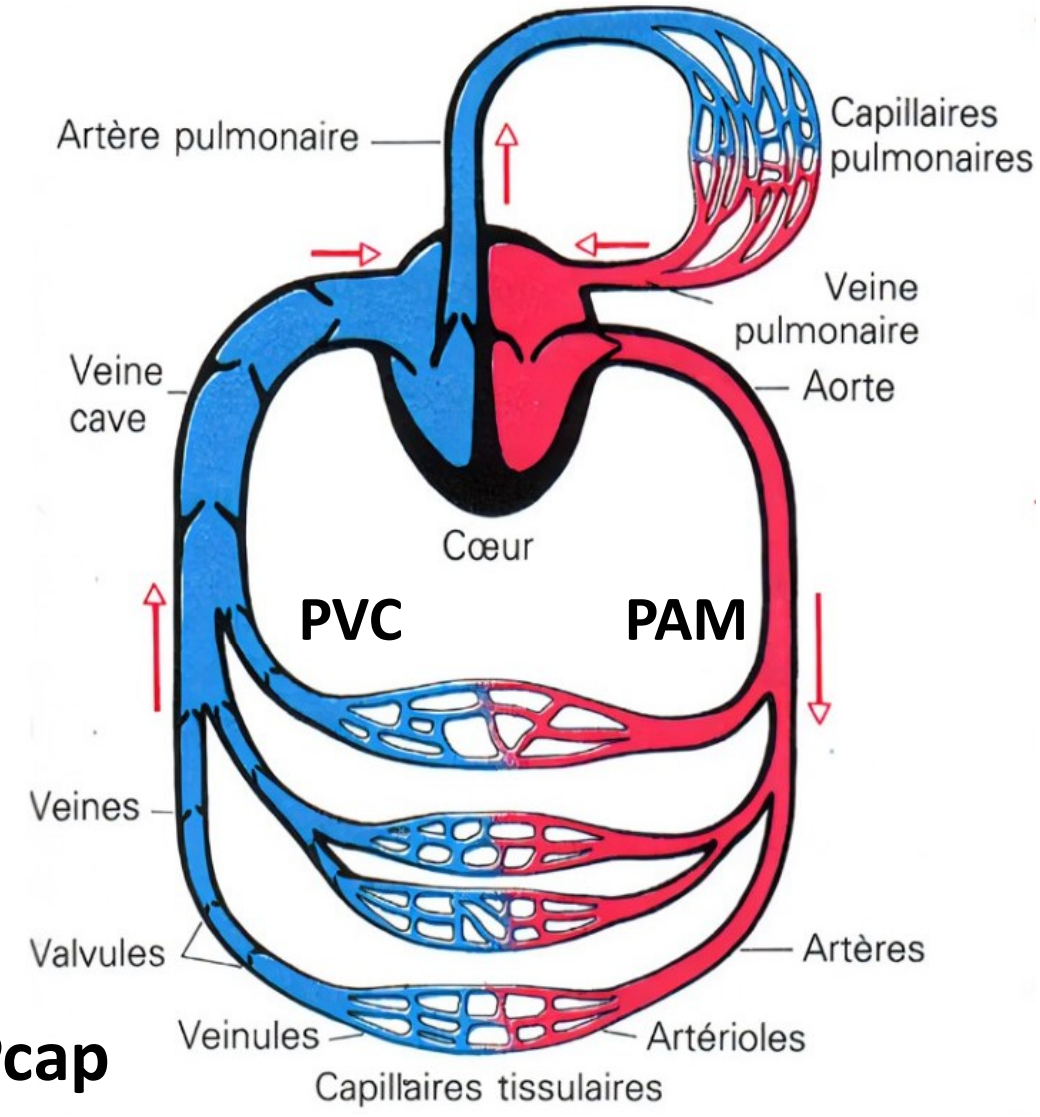
Elevated central venous pressure is associated with impairment of microcirculatory blood flow in sepsis: a hypothesis generating post hoc analysis

Namkje AR Vellinga[1,2*], Can Ince[1] and E Christiaan Boerma[2,3]

BMC Anesthesiology 2013, **13**:17



↑ **PVC**



↑ **Pcap**

œdème tissulaire

SPECIAL ISSUE INSIGHT

Central venous pressure (CVP)

Olfa Hamzaoui[1*] and Jean-Louis Teboul[2,3]

Intensive Care Med (2022) 48:1498–1500

Take home messages

Central venous pressure is a **pivotal** hemodynamic **variable**, since it provides important **information** on the **RV function** and on the **mean organ perfusion pressure**

SPECIAL ISSUE INSIGHT

Central venous pressure (CVP)

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Intensive Care Med (2022) 48:1498–1500

Take home messages

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SPECIAL ISSUE INSIGHT

Central venous pressure (CVP)

Olfa Hamzaoui[1*] and Jean-Louis Teboul[2,3]

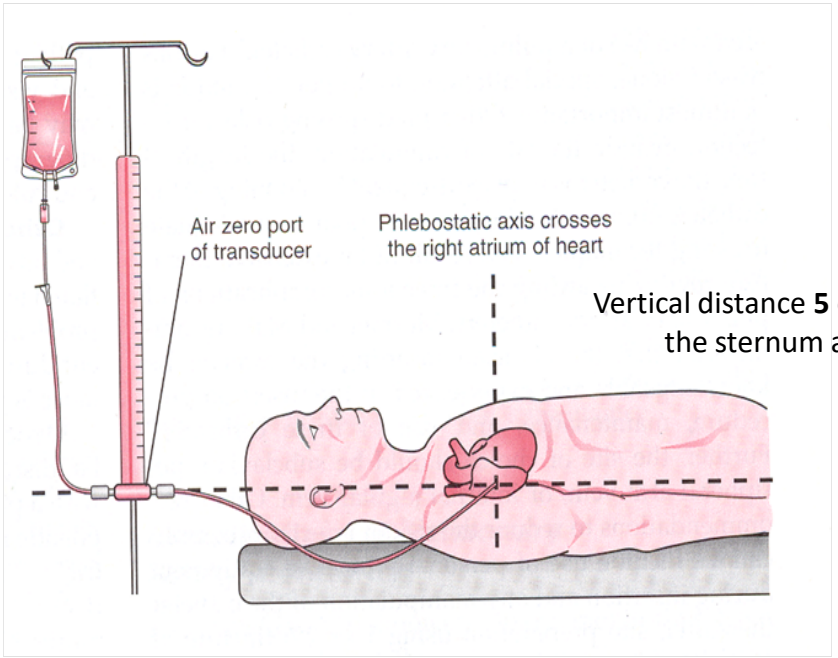
Intensive Care Med (2022) 48:1498–1500

Take home messages

Central venous pressure is a **pivotal** hemodynamic **variable**, since it provides important **information** on the **RV function** and on the **mean organ perfusion pressure**. **CVP cannot** be used to **predict fluid responsiveness**

Many sources of errors of measurements

- problem of the anatomic « **zero** » level



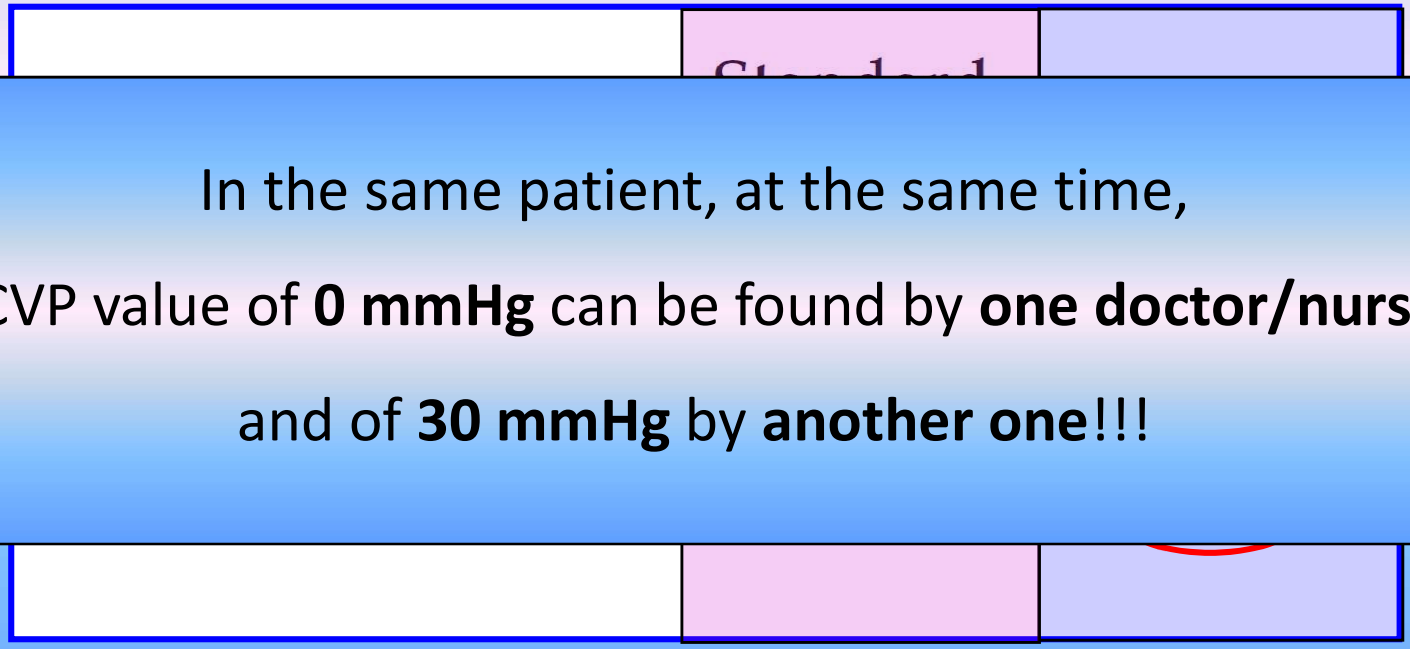
Vertical distance **5 cm below** the sternum angle

Error in Central Venous Pressure Measurement

Katie K. Figg, MD*

Edward C. Nemergut, MD*†

Anesth Analg 2009;108:1209–11



In the same patient, at the same time,

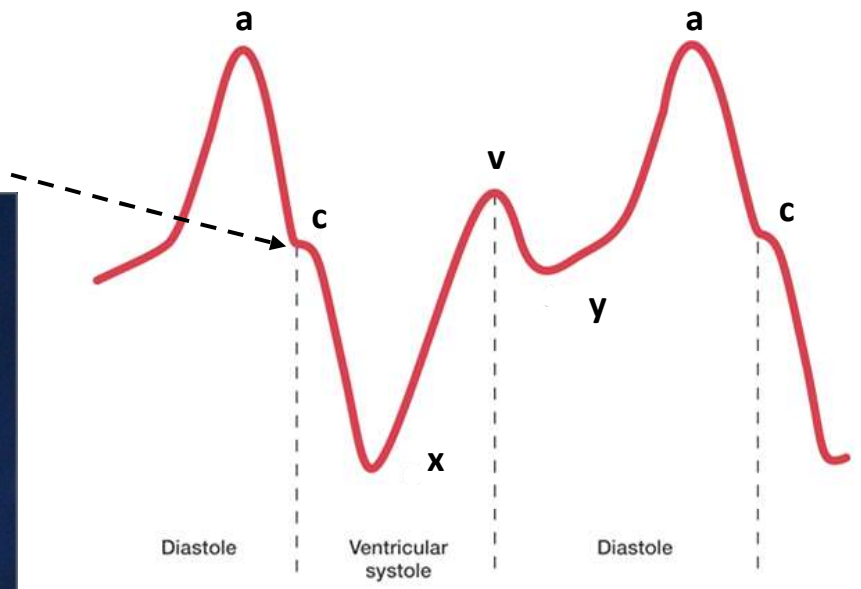
a CVP value of **0 mmHg** can be found by **one doctor/nurse**

and of **30 mmHg** by **another one**!!!

Many sources of errors of measurements

- problem of the anatomic « **zero** » level
- correct value measured at the **foot** of the « **c** » wave

CVP must be measured at the **foot** of "**c**"



Tricuspid valve closure

Tricuspid valve opening

Tricuspid valve closure

Many sources of errors of measurements

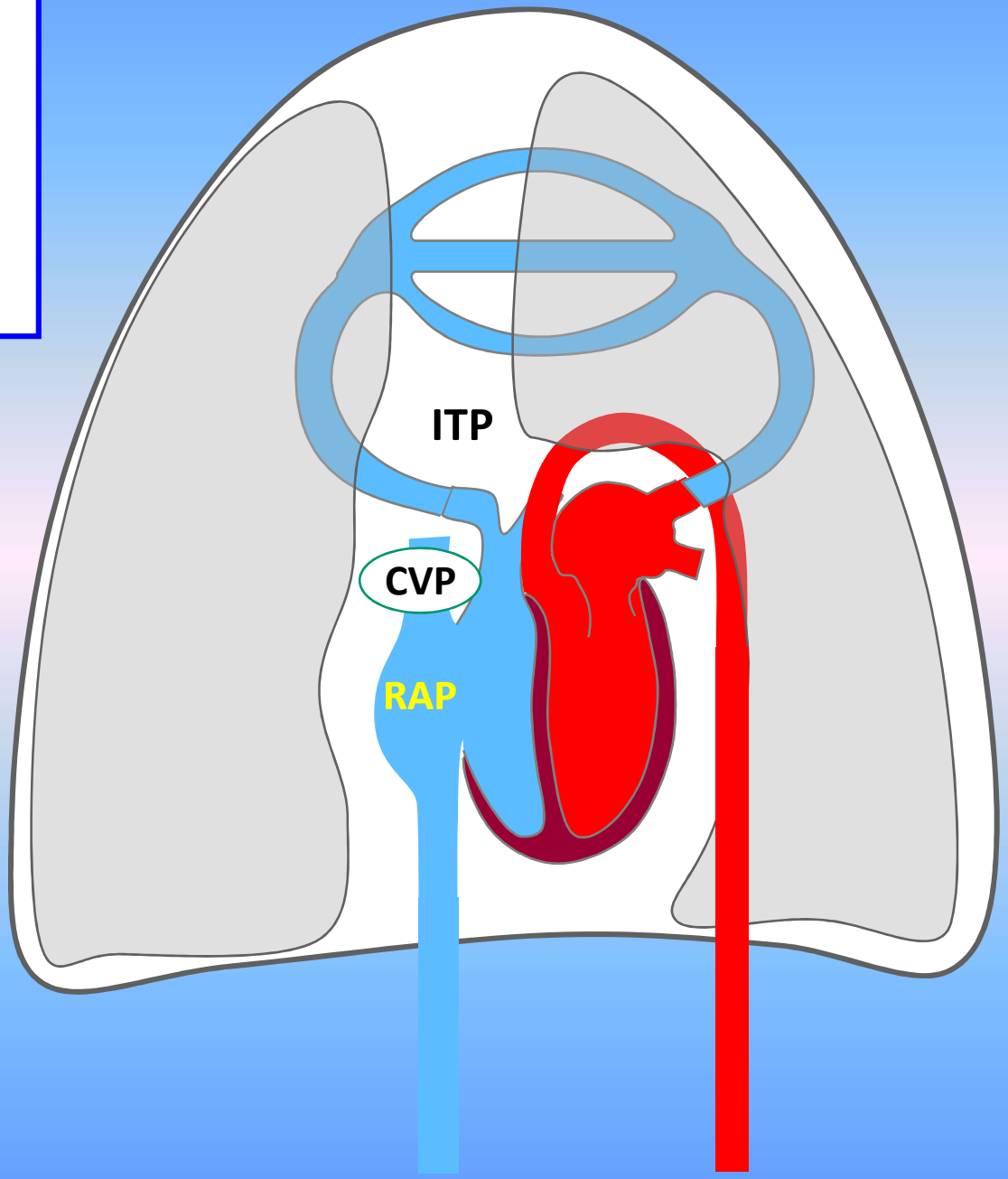
- problem of the anatomic « **zero** » level
- correct value measured at the **foot** of the « **c** » wave
- CVP must be measured at **end-expiration**

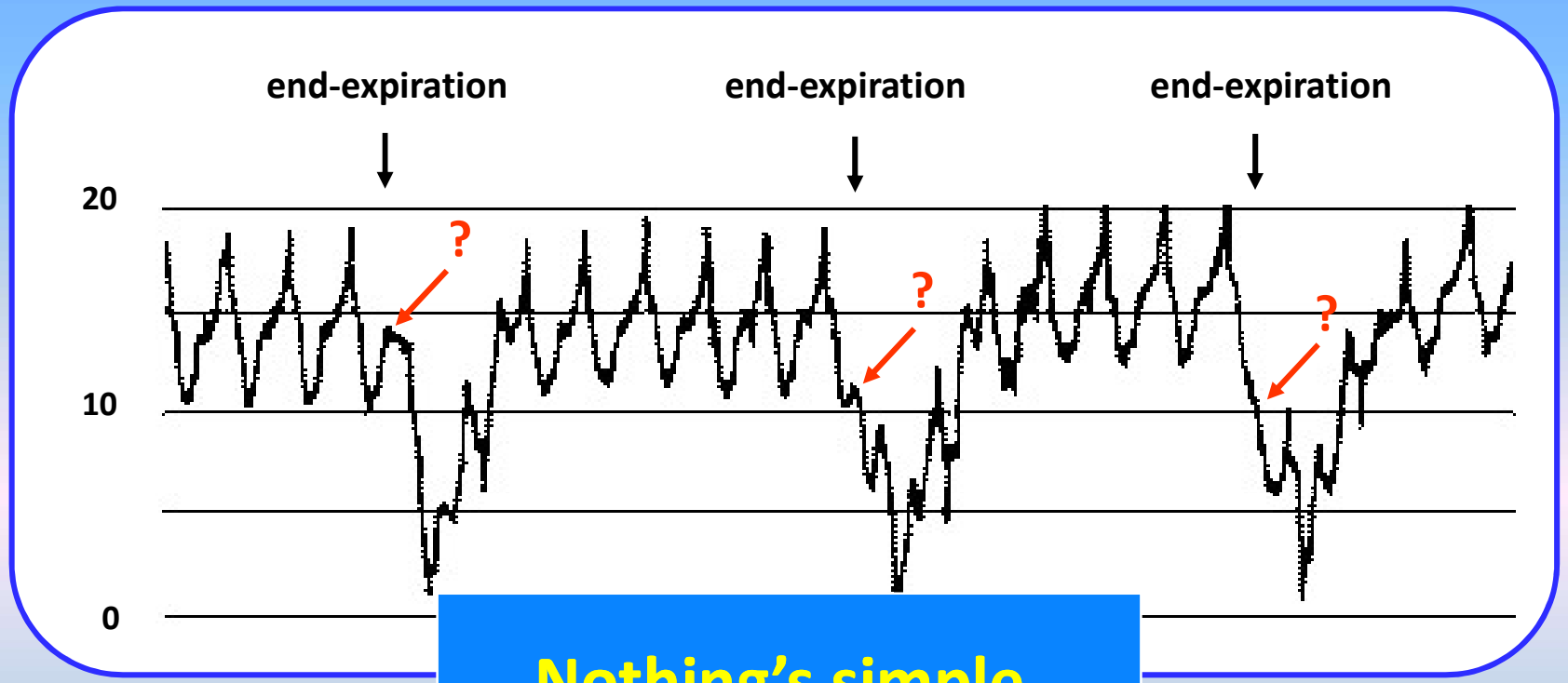
RV filling pressure

≈ **transmural RAP**

≈ **measured CVP - ITP**

close to **0**
at **end-expiration**





Nothing's simple

20 mmHg between **minimal** and **maximal** values

Different end-expiratory CVP value from one cycle to another one

Many sources of errors of measurements

- problem of the anatomic « **zero** » level
- correct value measured at the **foot** of the « **c** » wave
- CVP must be measured at **end-expiration**
- difficult measurement if **active** expiration

The end-expiratory value

overestimates

the true transmural pressure

Many sources of errors of measurements

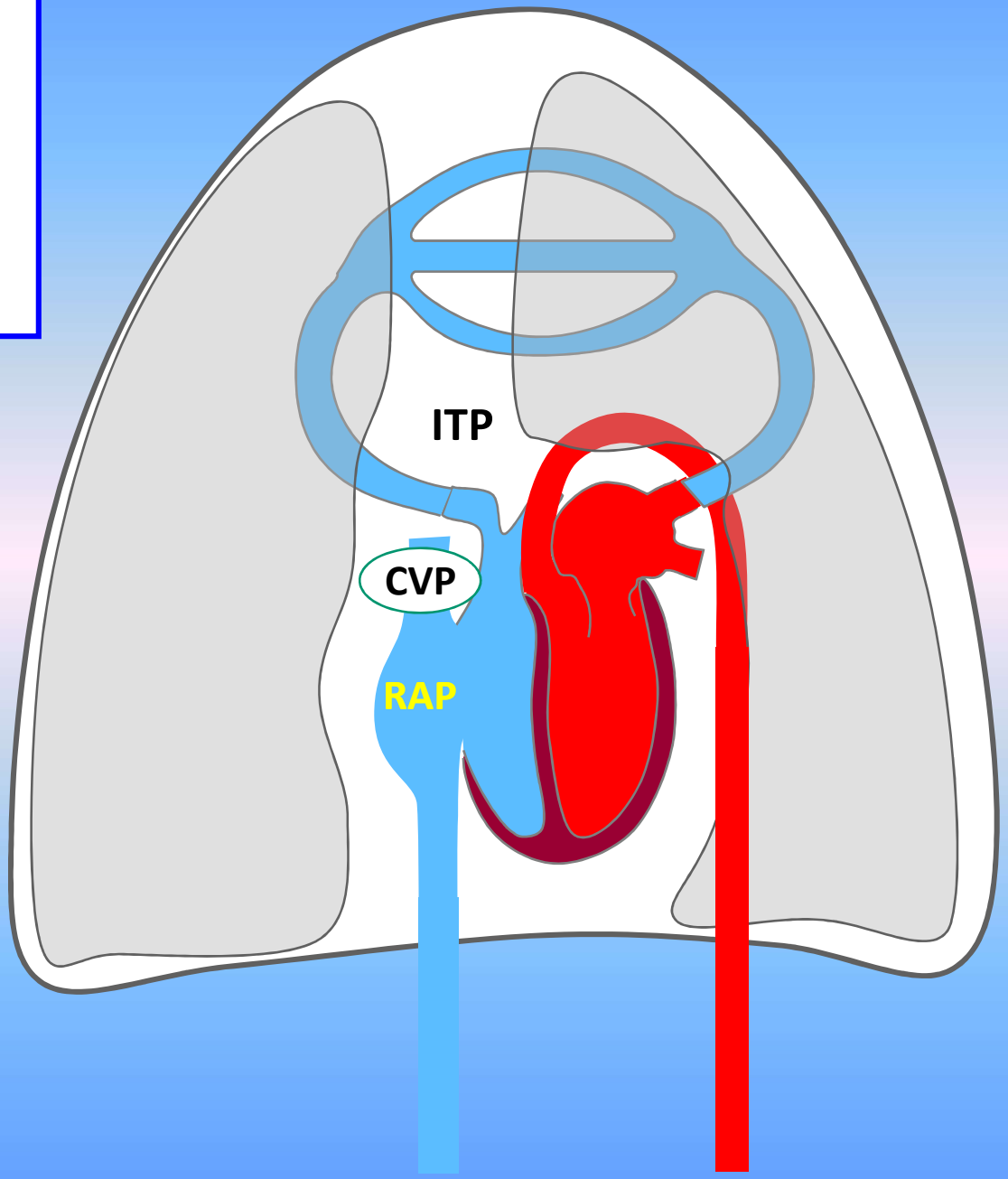
- problem of the anatomic « **zero** » level
- correct value measured at the **foot** of the « **c** » wave
- CVP must be measured at **end-expiration**
- difficult measurement if **active** expiration
- which value in case of **PEEP** or **intrinsic PEEP**?

RV filling pressure

≈ **transmural RAP**

≈ **measured CVP - ITP**

higher than **0**
at **end-expiration**
in case of
PEEP or **PEEPi**



CVP = 12 mmHg
at end-expiration

PEEPi = 12 mmHg

Airway **pressure**
transmission = **50%**

true CVP? **12**? **0**? **6**? **others**?

Estimating cardiac filling pressure in mechanically ventilated patients with hyperinflation

Jean-Louis Teboul, MD, PhD; Michael R. Pinsky, MD, FCCM; Alain Mercat, MD; Nadia Anguel, MD; Gilles Bernardin, MD; Jean-Michel Achard, MD; Thierry Boulain, MD; Christian Richard, MD

Crit Care Med 2000; 28:3631–3636

Estimation of "transmitted" PEEP

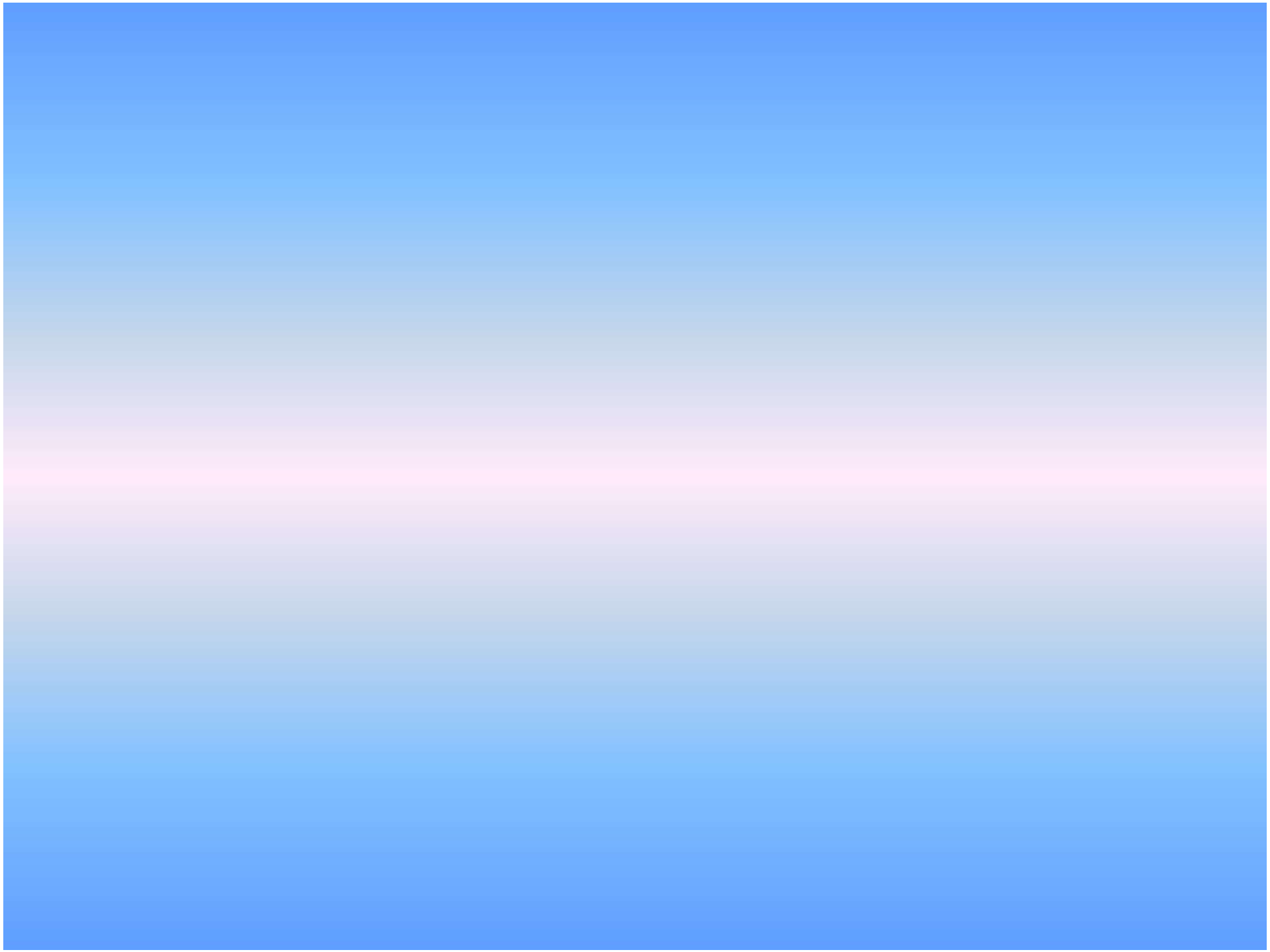
Hypothesis

The changes in PAOP during a respiratory cycle are secondary to changes in Palv

Their magnitude would depend on the degree of transmission of Palv to PAOP

Transmitted PEEP would be: $(\Delta \text{PAOP} / \Delta \text{Palv}) \times \text{PEEP}$

Index of transmission (%)



Conclusion

Should we still use CVP today?

- **NO** for **predicting fluid responsiveness**
- **NO** for helping to **stop fluid** infusion
- **YES** for assessing **RV dysfunction** and its response to therapies
- **YES** for assessing **downstream pressure** for organ **perfusion**

Be aware of the **multiple** sources

of **errors** in **measurements**

Merci

Merci