

Venous return

From physiology to the bedside

Prof. Xavier MONNET

Medical Intensive Care Unit

Paris-Sud University Hospitals

xavier.monnet@aphp.fr



Venous return

From physiology to the bedside

What is the basic physiology ?

How do we assess it at the bedside ?

How is it useful in practice ?

Prof. Xavier MONNET

Medical Intensive Care

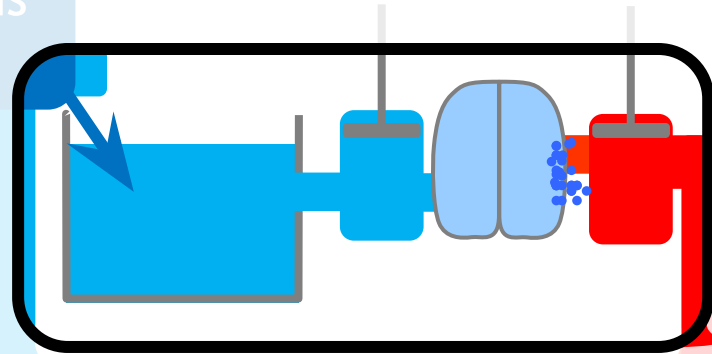
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Antoine Béclère Bichat Paul Brousse

The physiology of venous return

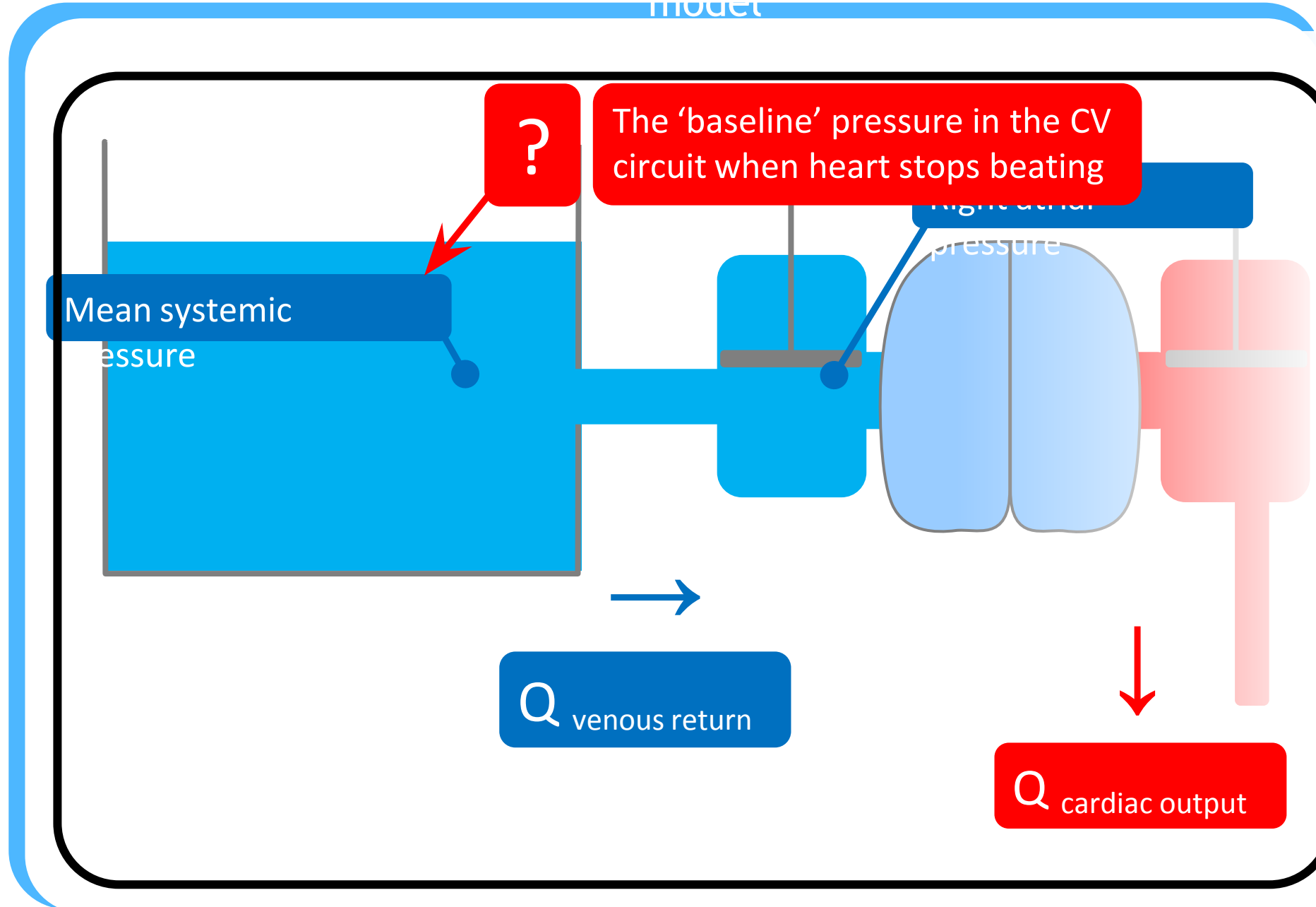
Large venous
reservoir



The physiology of venous return

The Guytonian

model



The physiology of venous return

The Guytonian

Am J Physiol Heart Circ Physiol 285: H2510–H2515, 2003.
First published August 7, 2003; 10.1152/ajpheart.00604.2003.

Static filling pressure in patients during induced ventricular fibrillation

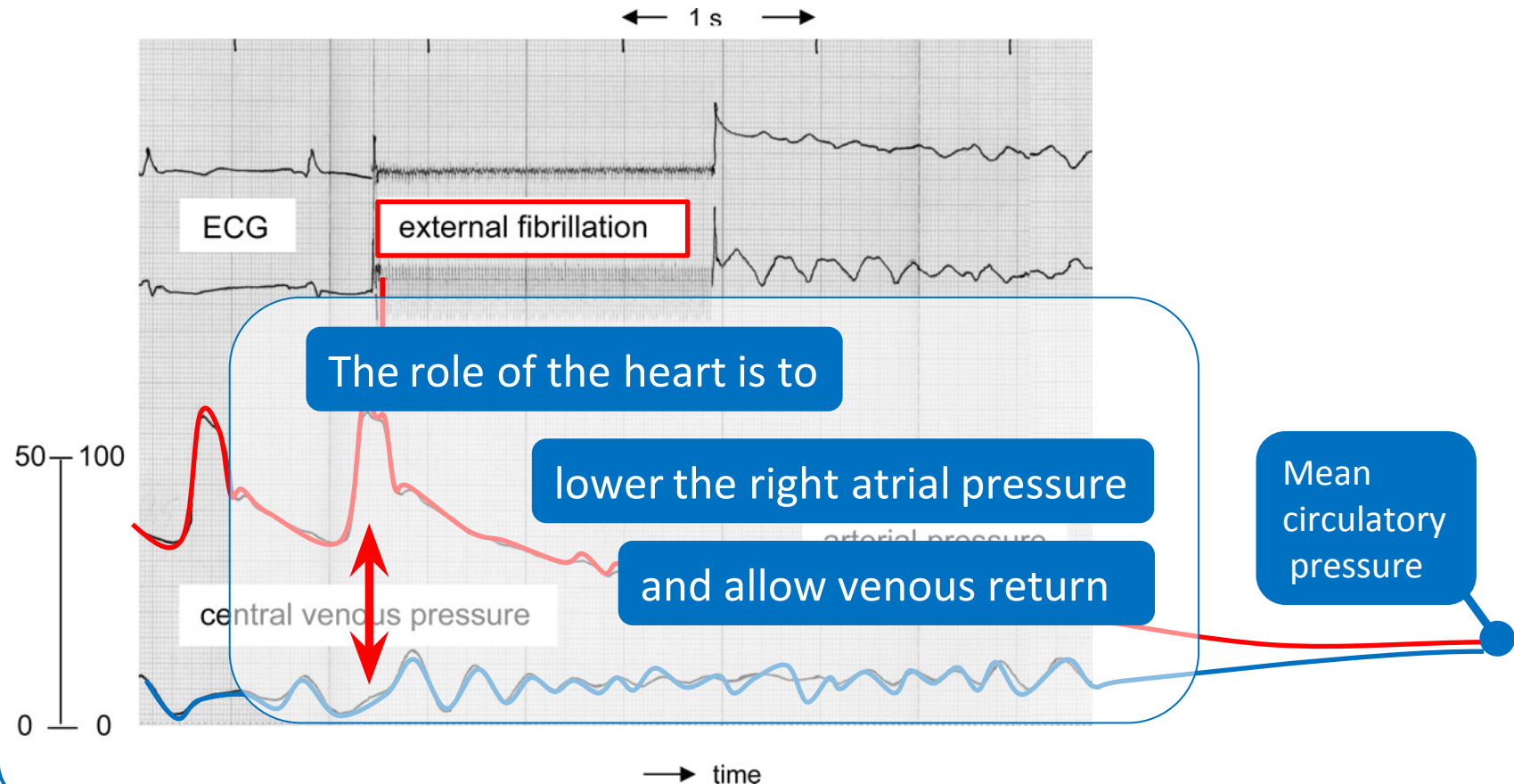
J. D. Schipke,¹ G. Heusch,² A. P. Sanii,⁴ E. Gams,² and J. Winter²

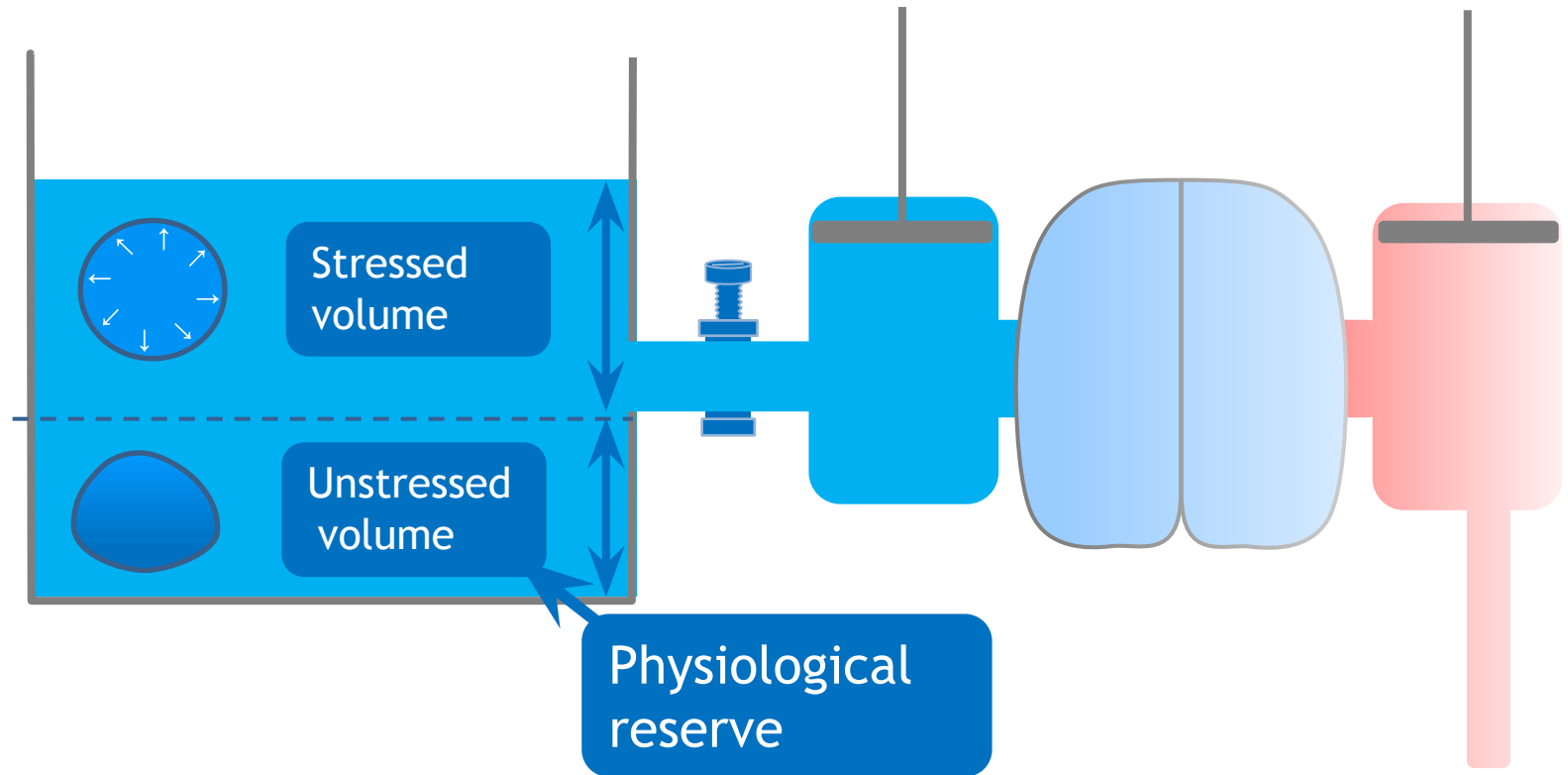
¹Research Group Experimental Surgery and ²Clinic of Thoracic and Cardiovascular Surgery, Department of Surgery I, University Hospital Düsseldorf, Düsseldorf D 40225;

³Institute of Pathophysiology, University Hospital Essen, D 45147 Essen, Germany; and ⁴Department of Radiology, Tulane University, New Orleans, Louisiana 70118

Submitted 26 June 2003; accepted in final form 30 July 2003

10 patients
External cardioverter

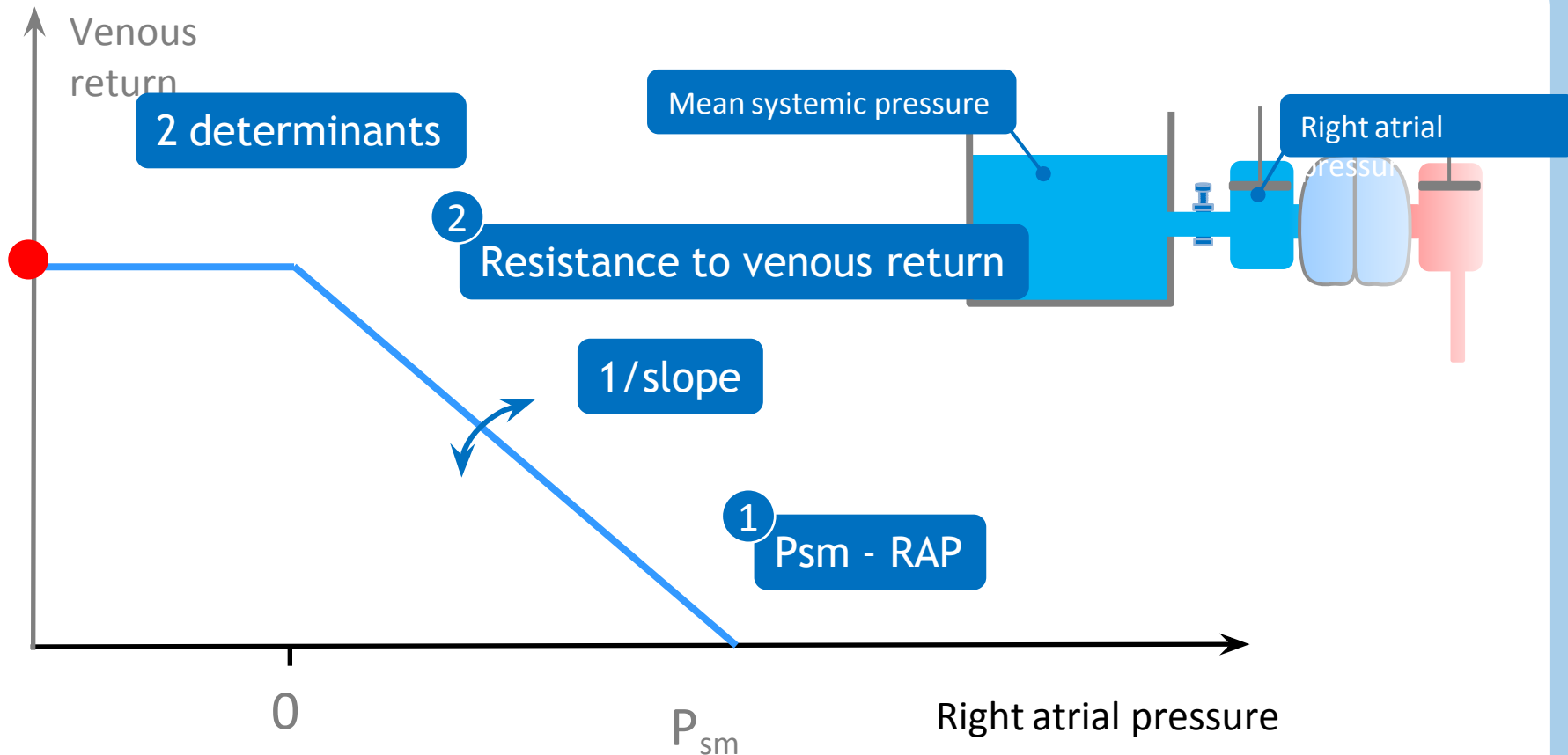




Determination of Cardiac Output By Equating Venous Return Curves With Cardiac Response Curves¹

ARTHUR C. GUYTON

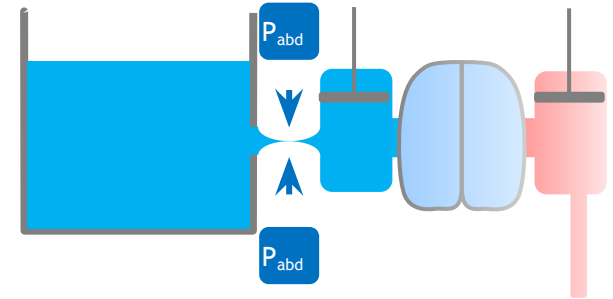
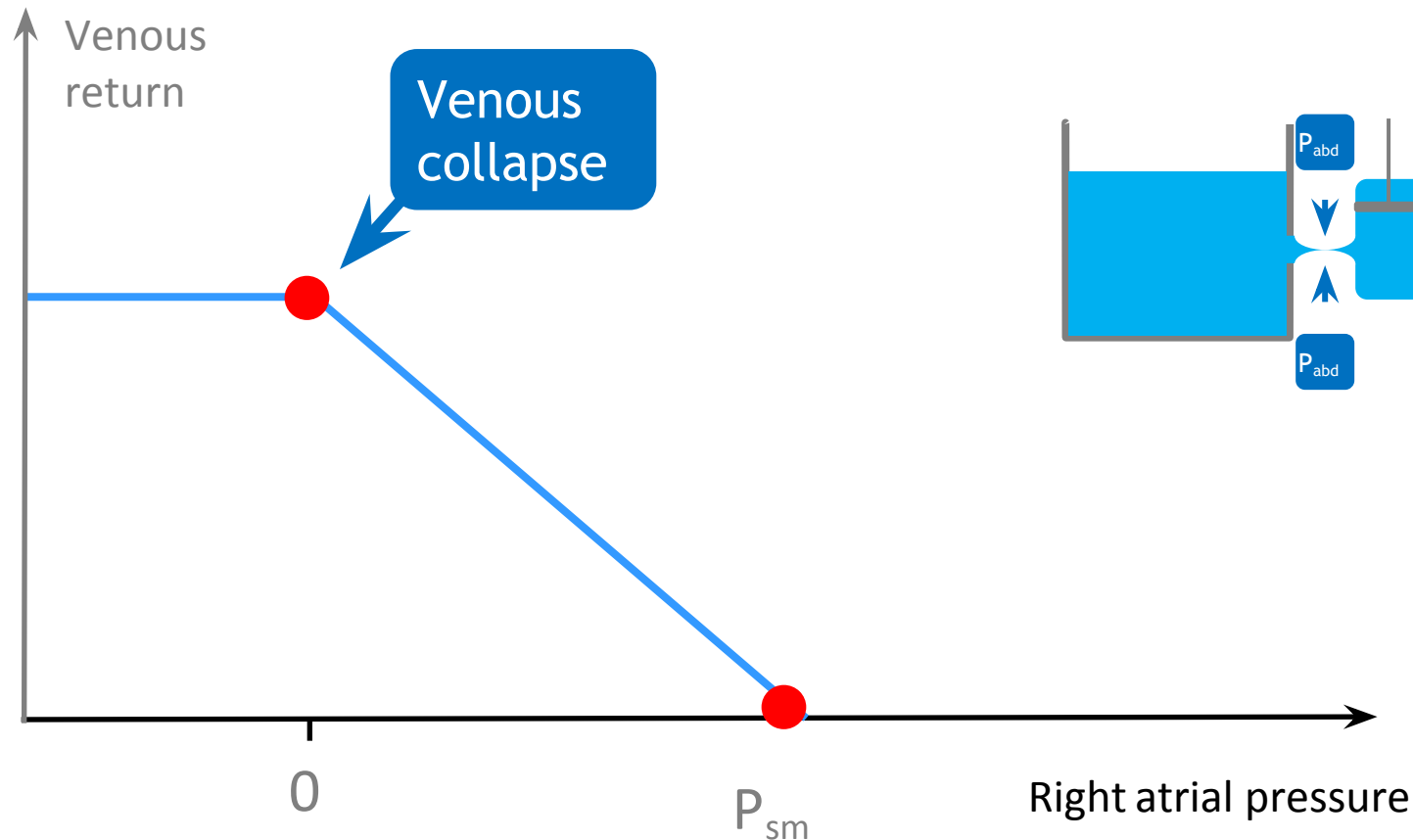
January 1955



Determination of Cardiac Output By Equating Venous Return Curves With Cardiac Response Curves¹

ARTHUR C. GUYTON

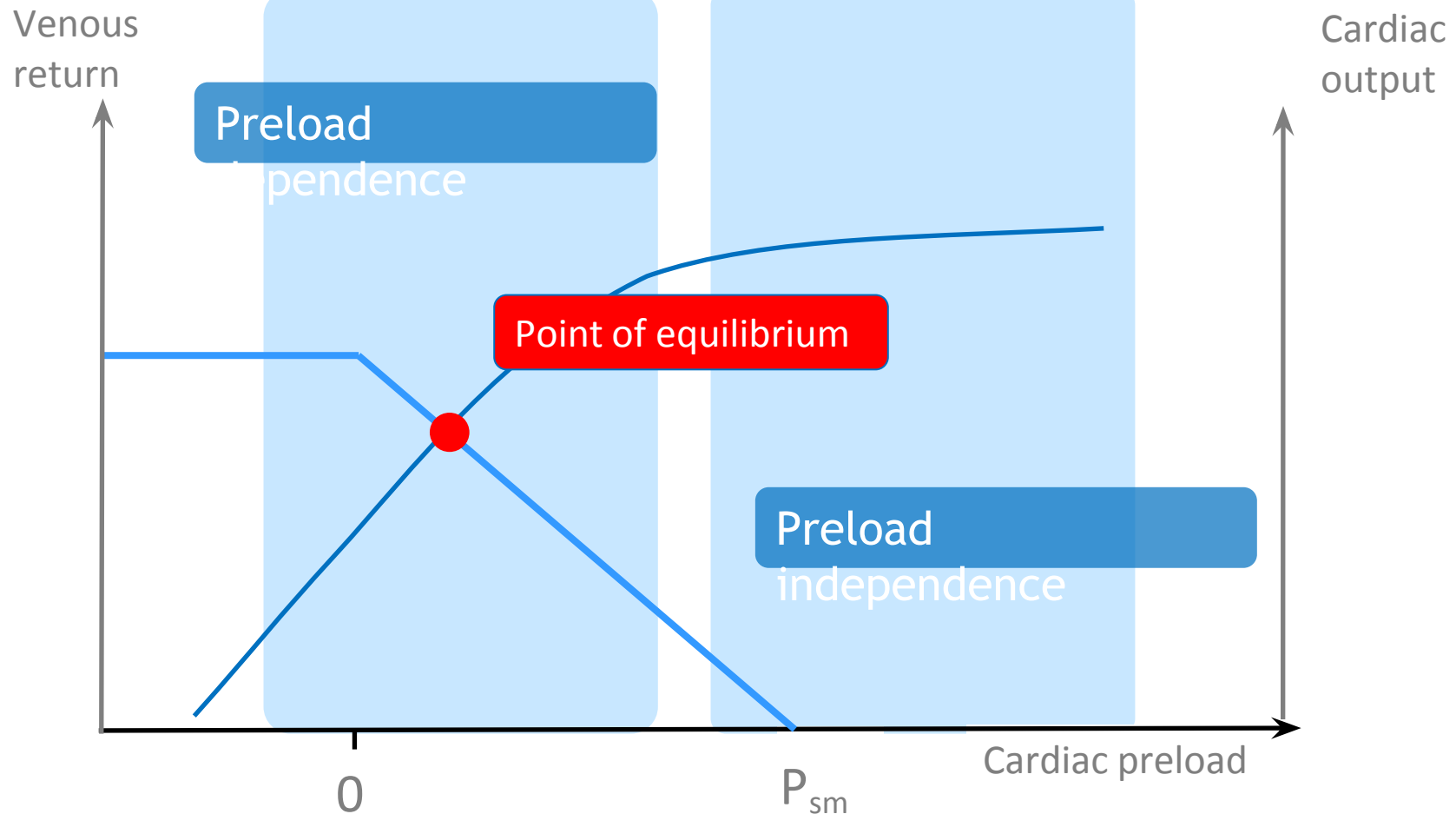
January 1955

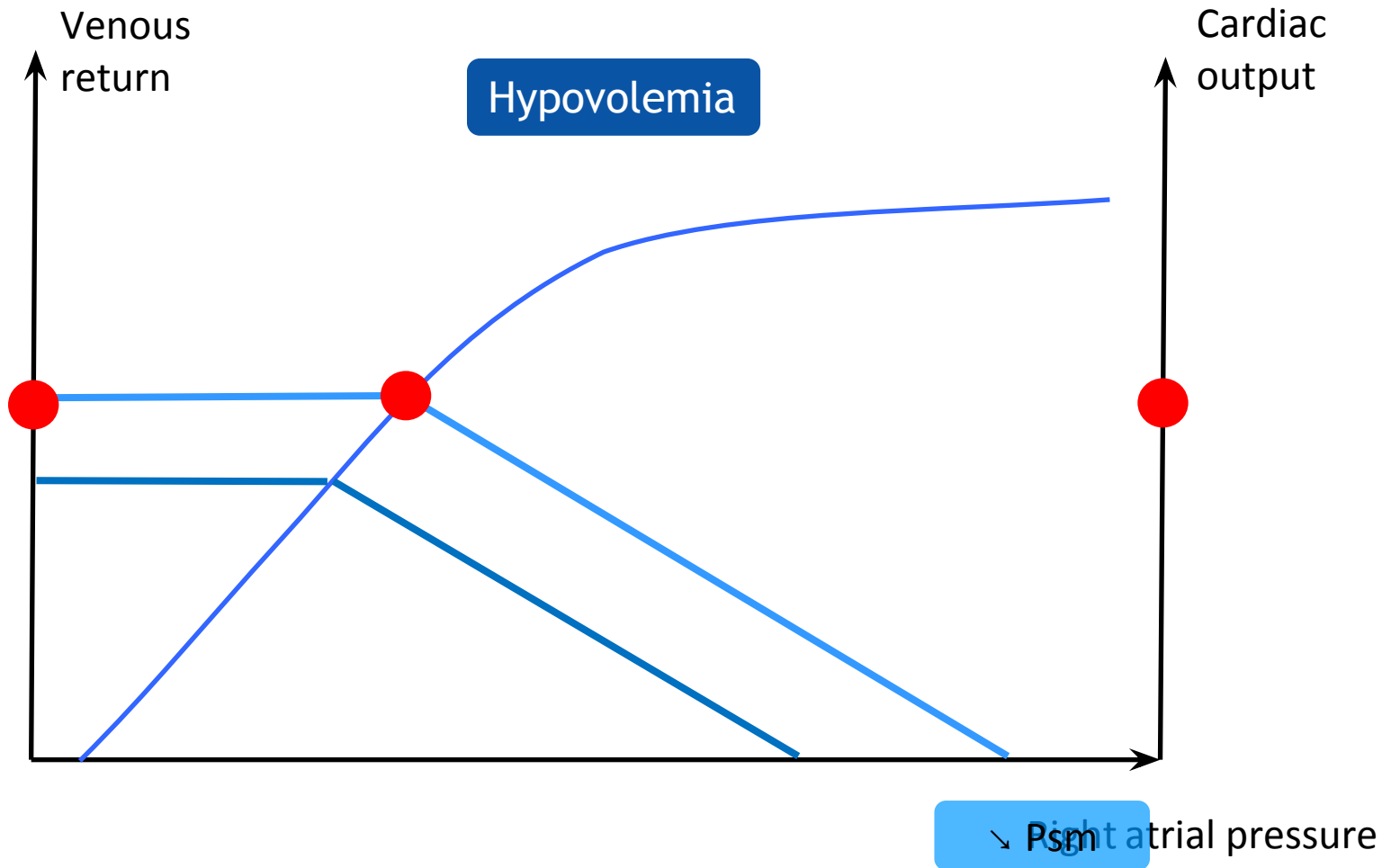


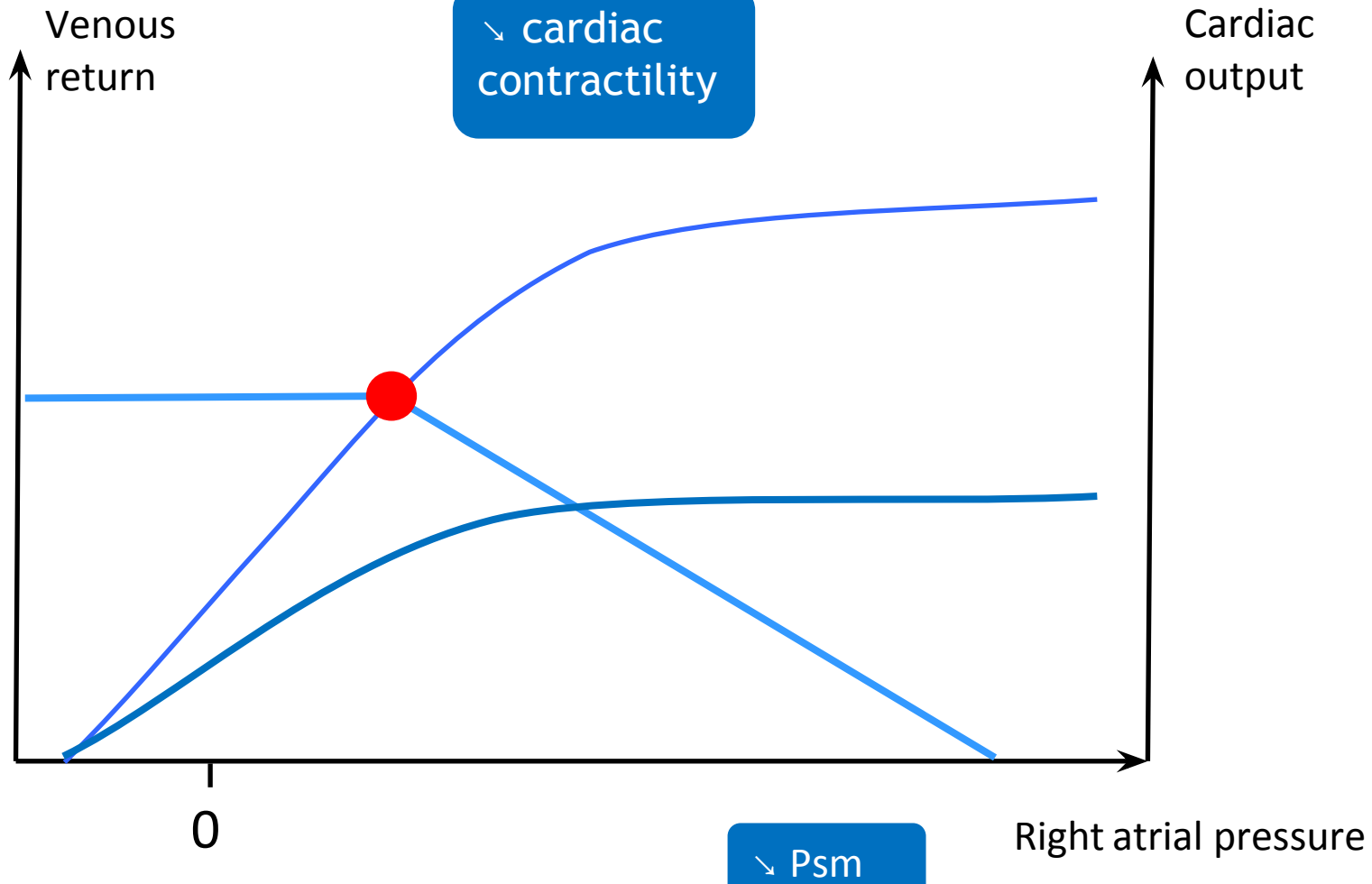
Determination of Cardiac Output By Equating Venous Return Curves With Cardiac Response Curves¹

ARTHUR C. GUYTON

January 1955







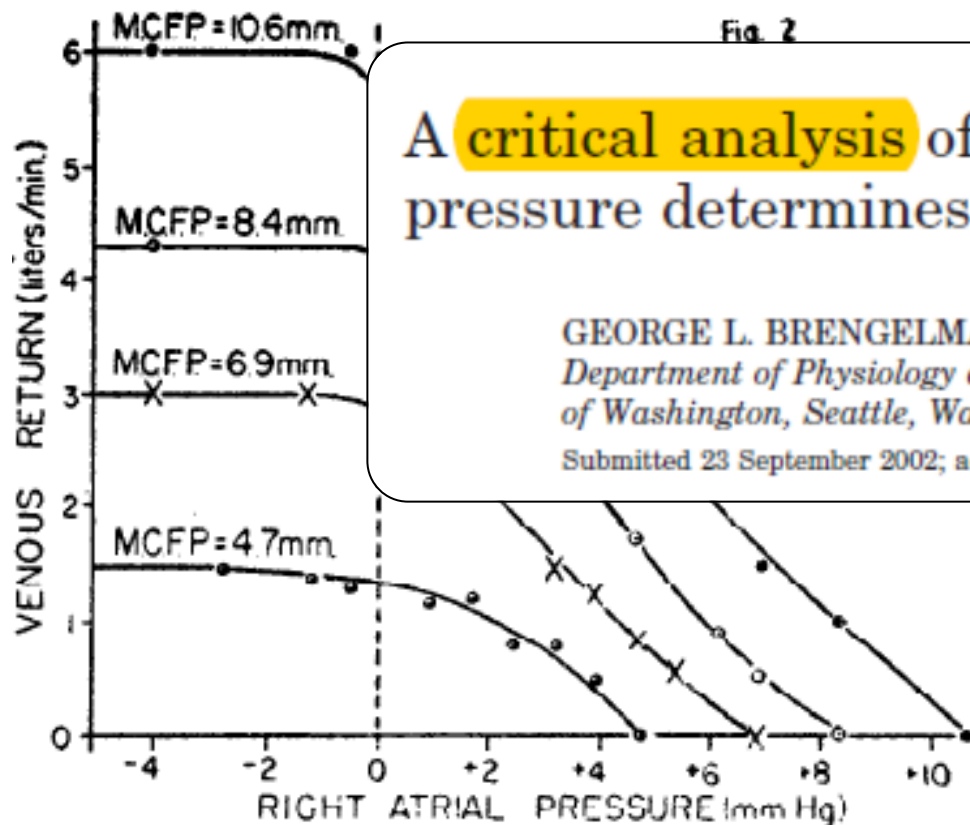
Determination of Cardiac Output By Equating Venous Return Curves With Cardiac Response Curves¹

ARTHUR C. GUYTON

January 1955

105 anesthetized dogs

Measurement of mean circulatory pressure



A critical analysis of the view that right atrial pressure determines venous return

J Appl Physiol 94: 849–859, 2003

GEORGE L. BRENGELMANN

Department of Physiology and Biophysics, University of Washington, Seattle, Washington 98195-7290

Submitted 23 September 2002; accepted in final form 12 October 2002

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How do we assess it at the bedside ?

How is it useful in practice ?

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How do we assess venous return at the bedside

4 methods

Cardiac arrest

Not for the ICU patients

Navigator®

Not commercialised anymore

Arterial occlusion

Can be used in the ICU

Heart-lung interactions



?

How do we assess venous return at the bedside

Heart-lung interactions

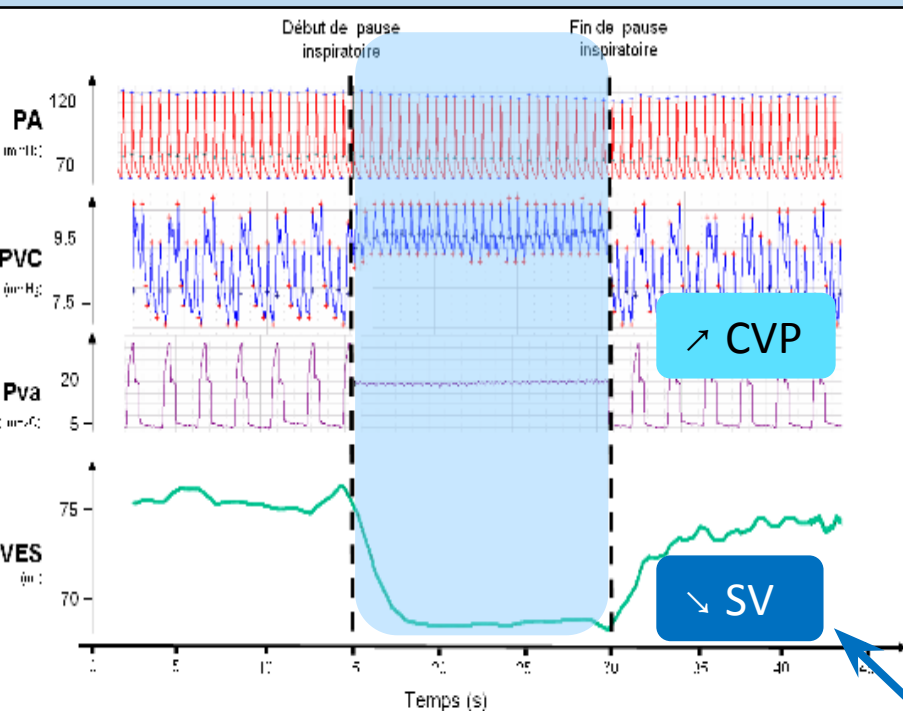
Assessment of venous return curve and mean systemic filling pressure in postoperative cardiac surgery patients*

Jacinta J. Maas, MD; Bart F. Geerts, MD; Paul C. M. van den Berg, MD, PhD; Michael R. Pinsky, MD; Jos R. C. Jansen, PhD

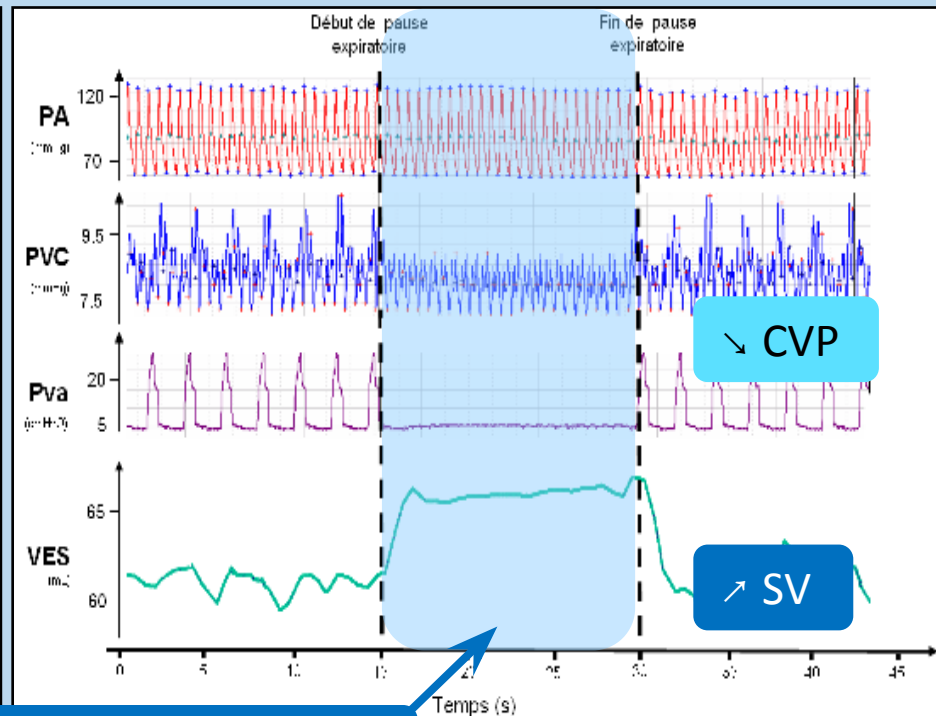
Crit Care Med 2009

12 cardiac surgery post-op patients
Psm estimated through heart-lung interactions

End inspiratory hold



End expiratory hold



4 pairs of CVP:SV

Effects of norepinephrine on mean systemic pressure and venous return in human septic shock

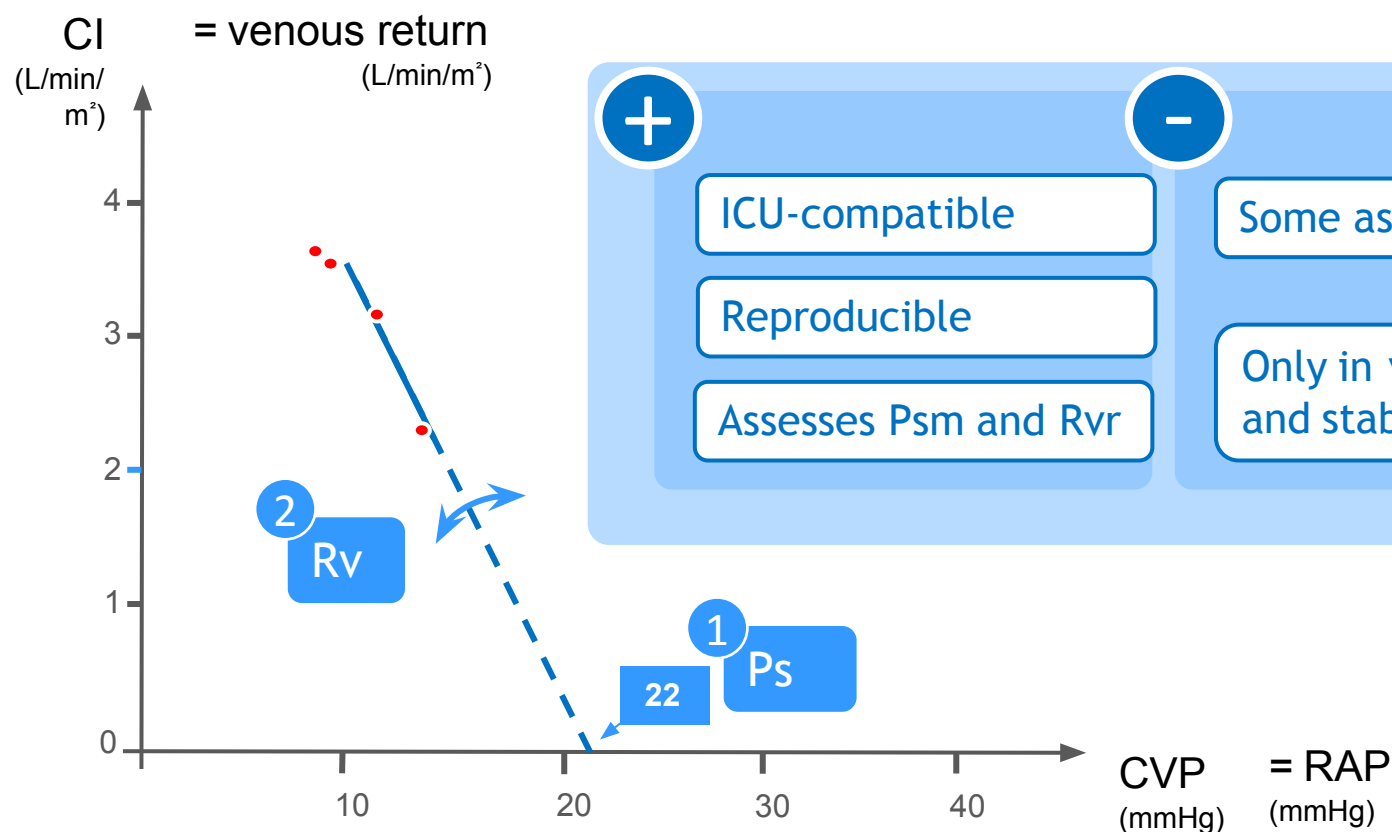
Romain Persichini, MD; Serena Silva, MD; Jean-Louis Teboul, MD, PhD; Mathieu Jozwiak, MD; Denis Chemla, MD, PhD; Christian Richard, MD; Xavier Monnet, MD, PhD

Crit Care Med 2012

16 septic shock patients

Norepinephrine administration

Psm through respiratory holds



How do we assess venous return at the bedside

4 methods

Cardiac arrest

Not for the ICU patients

Navigator®

Not commercialised anymore

Arterial occlusion

Can be used in the ICU

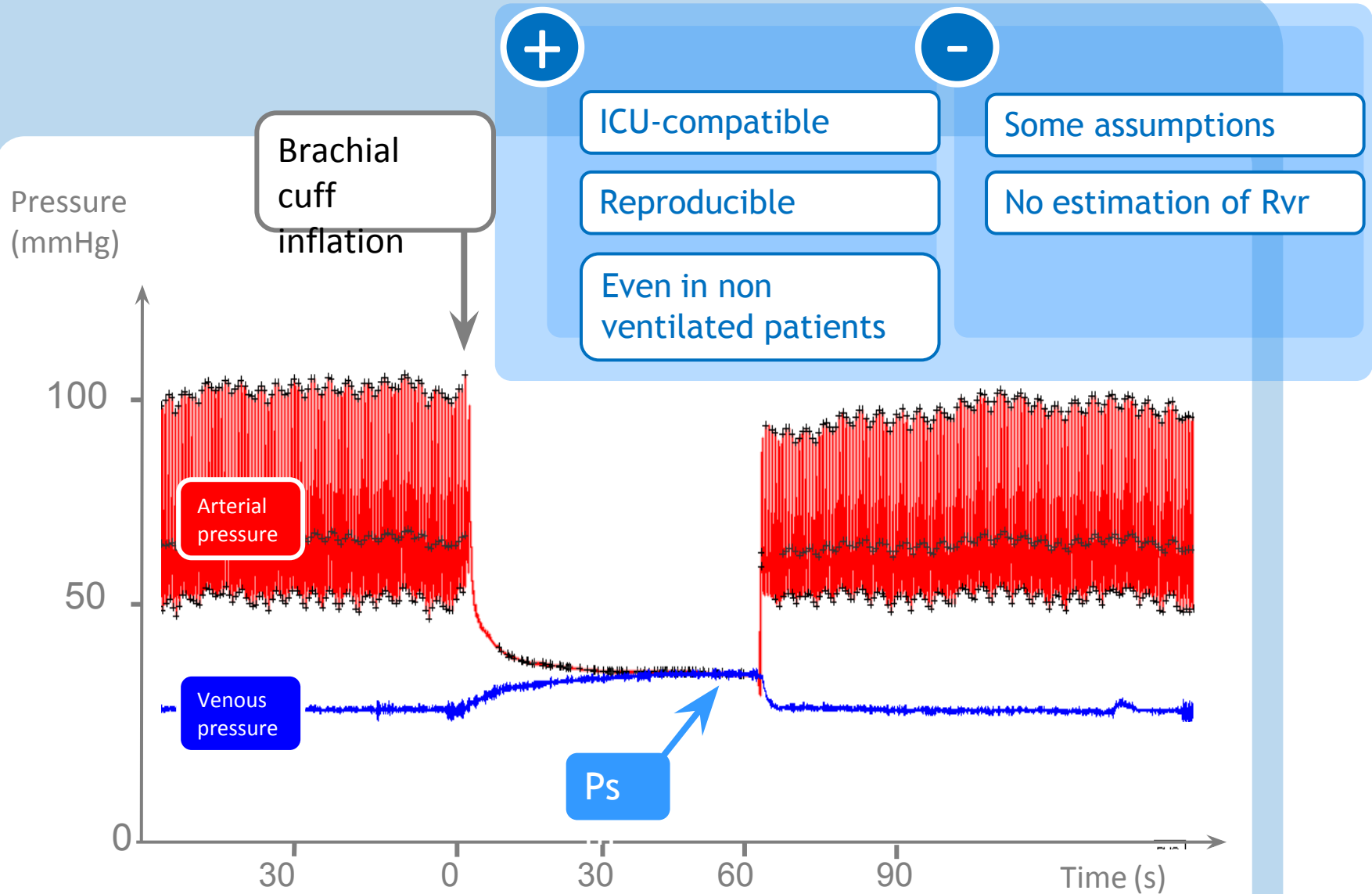
Heart-lung interactions



?

How do we assess venous return at the bedside

Arterial occlusion



Intensive Care Med (2012) 38:1452–1460
DOI 10.1007/s00134-012-2586-0

ORIGINAL

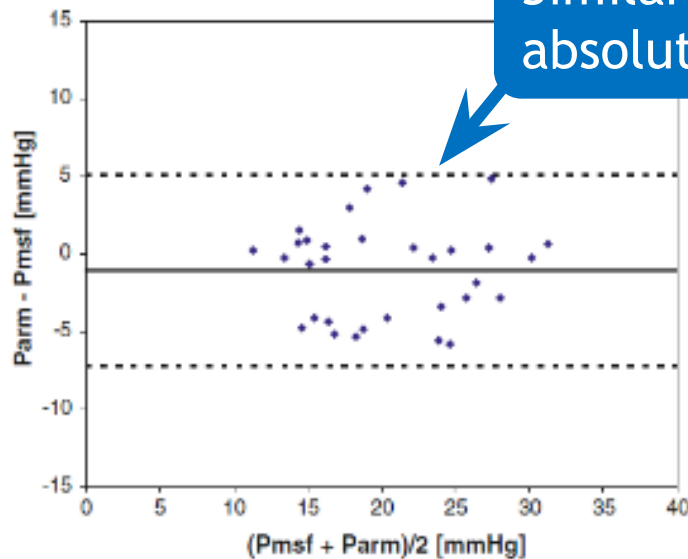
Jacinta J. Maas
Michael R. Pinsky
Bart F. Geerts
Rob B. de Wilde
Jos R. Jansen

Estimation of mean systemic filling pressure in postoperative cardiac surgery patients with three methods

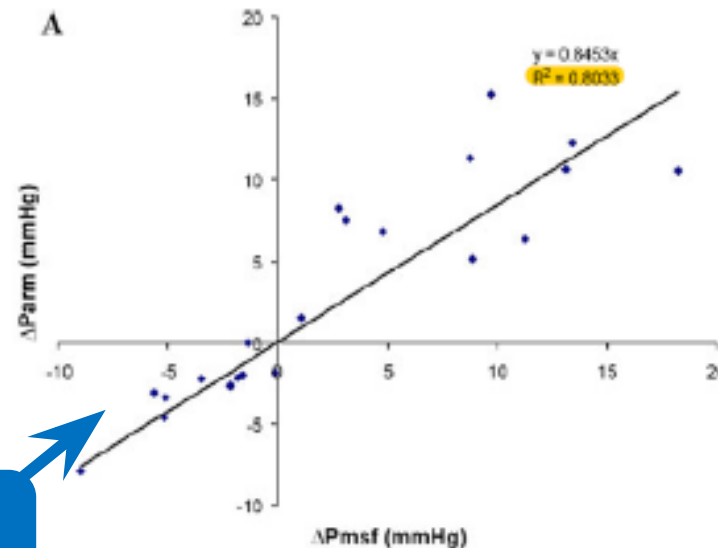
11 post-op patients

Respiratory holds vs. Navigator vs. Stop-flow
during various interventions

Similar
absolute values



... and
relative
changes

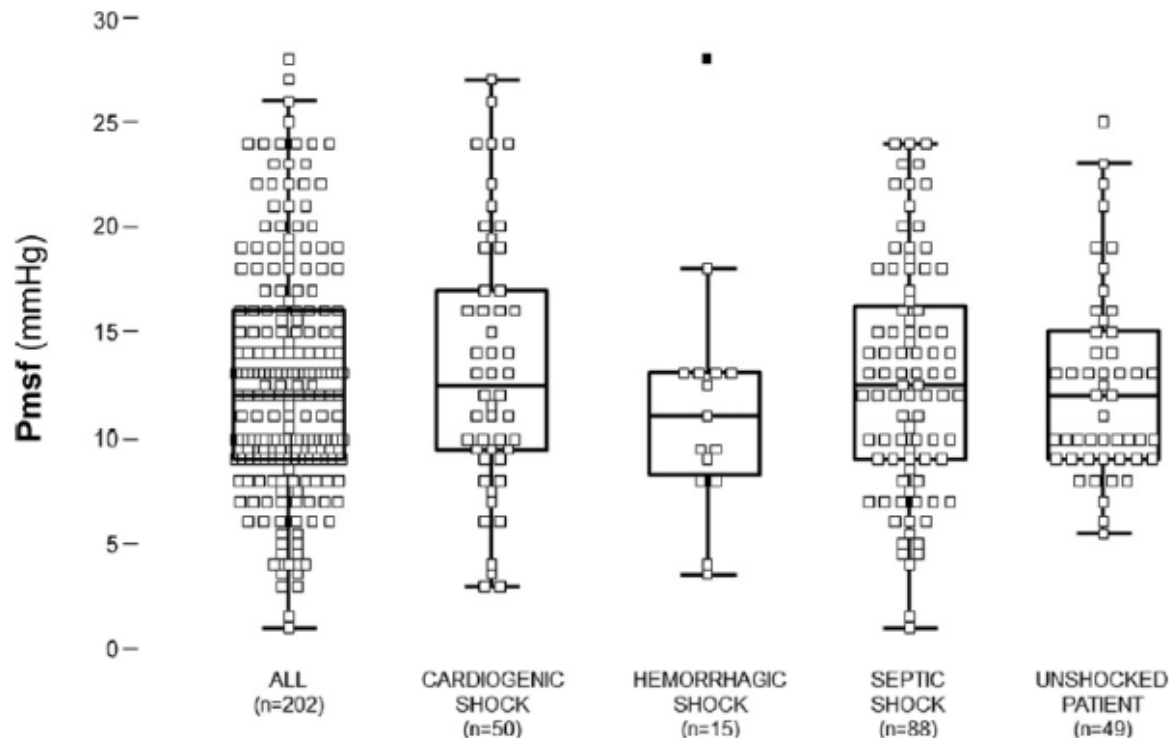


Am J Physiol Heart Circ Physiol 309: H1003–H1007, 2015.
First published July 25, 2015; doi:10.1152/ajpheart.00413.2015.

Value and determinants of the mean systemic filling pressure in critically ill patients

Xavier Repessé,¹ Cyril Charron,¹ Julia Fink,¹ Alain Beauchet,⁴ Florian Deleu,¹ Michel Slama,⁵
Guillaume Belliard,¹ and Antoine Vieillard-Baron^{1,2,3}

202 dying ICU patients



How do we assess venous return at the bedside

Equivalent methods ?

Am J Physiol Heart Circ Physiol 311: H794-H806, 2016.
First published July 15, 2016; doi:10.1152/ajpheart.00931.2015.

Effect of PEEP, blood volume, and inspiratory hold maneuvers on venous return

David Berger,¹ Per W. Møller,^{1,2} Alberto Weber,³ Andreas Bloch,¹ Stefan Bloechlinger,¹ Matthias Haenggeli,¹ Søren Søndergaard,² Stephan M. Jakob,¹ Sheldon Magder,⁵ and

Pigs

Ventilatory holds vs. Inflation of a RA balloon

	Euvoemia PEEP 5 cmH ₂ O, n = 8	cmH ₂ O, n = 6	cmH ₂ O, n = 8
MSFP _{RAO} ; mmHg	13.0 (2.8)	10.9 (2.0)	10.9 (2.0)
MSFP _{insp_hold} ; mmHg	15.9 (3.7)	11.9 (2.0)	19.7 (9.8)

The respiratory holds method might overestimate P_{sm}

... but not its changes

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Bedside applications of venous return

To better understand the complex haemodynamic problems and the effects of treatments

Haemodynamic
effects of MV

Hypovolaemia and
fluid loading

Effects of
norepinephrine

Effects of
fluid loading

Effects of other
vasoactive drugs

Bedside

Effects of fluid

applications

loading

Effects of passive leg raising and volume expansion on mean systemic pressure and venous return in shock in humans

Laurent Guérin^{1,2}, Jean-Louis Teboul^{1,2}, Romain Persichini^{1,2}, Martin Dres^{1,2}, Christian Richard^{1,2} and Xavier Monnet^{1,2*}

Critical Care (2015)



30 patients

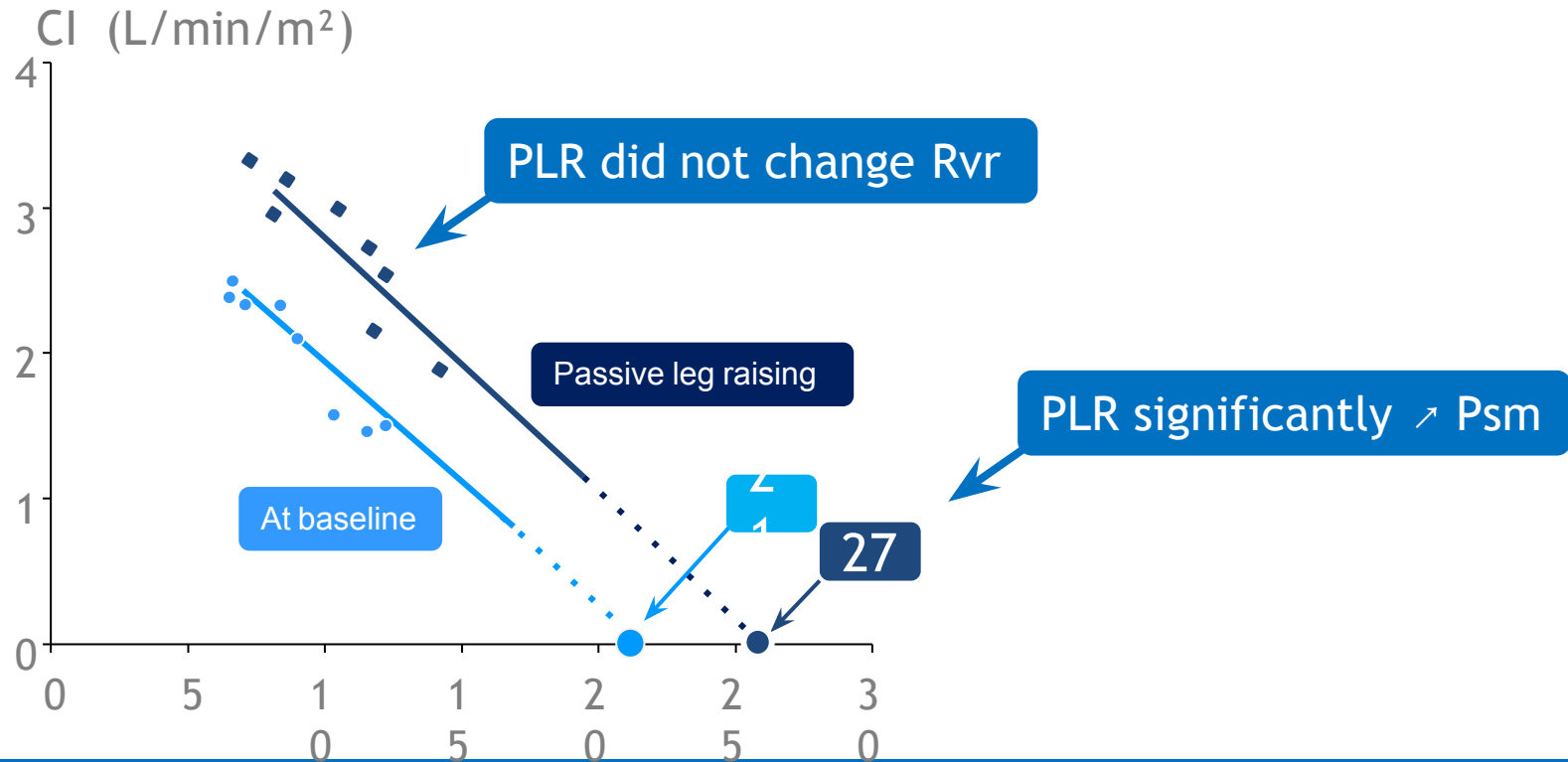
PLR and volume expansion

Psm through respiratory holds

Message #1



PLR is actually a preload challenge
It does not increase Rvr

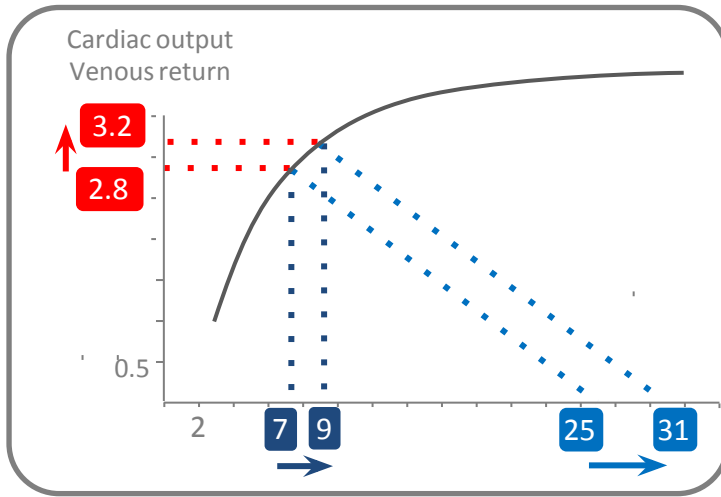


Bedside

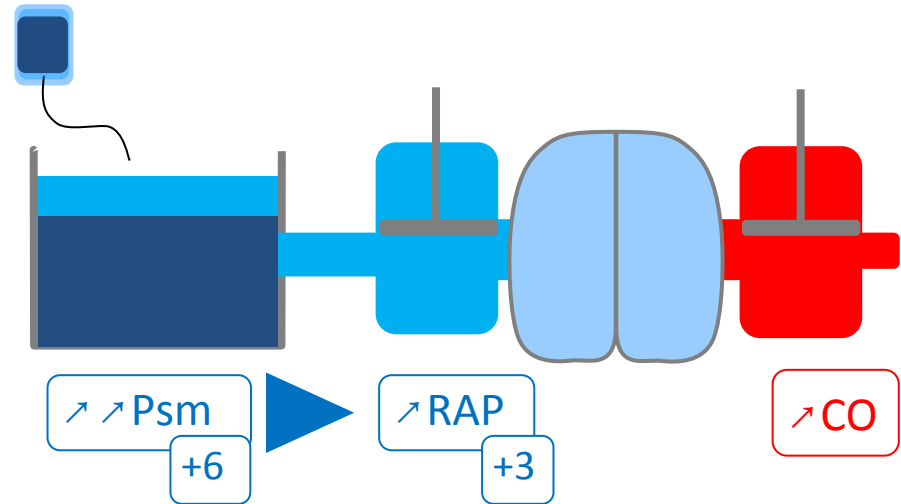
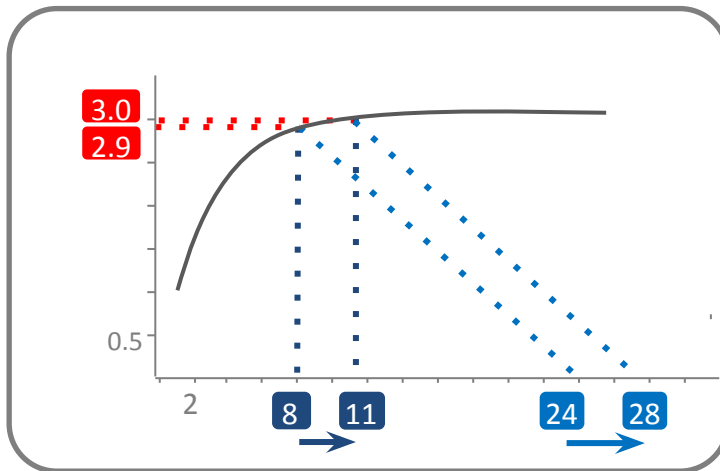
applications

Preload responsive

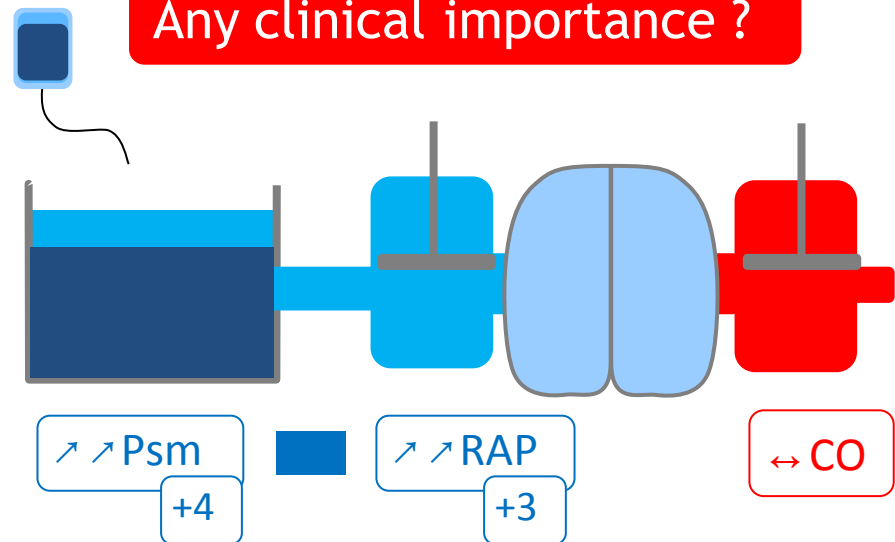
Effects of fluid



Preload unresponsive



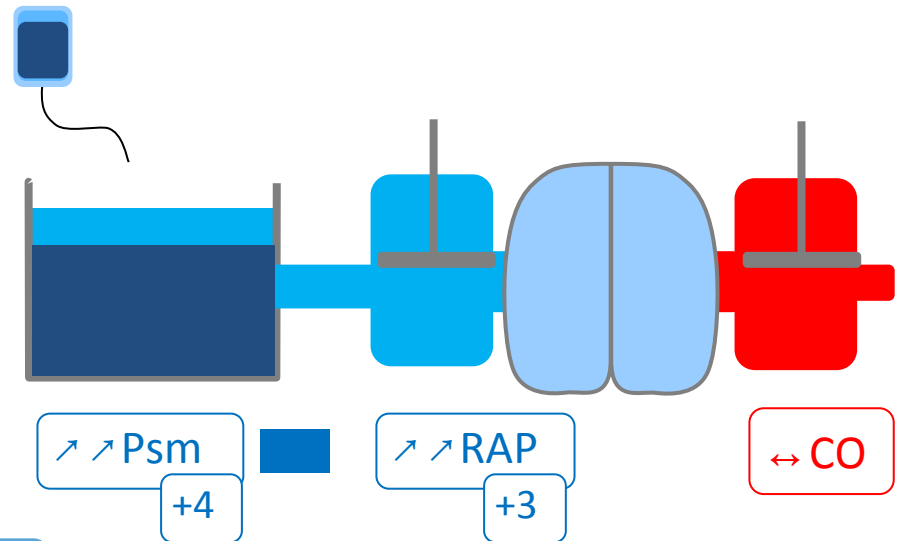
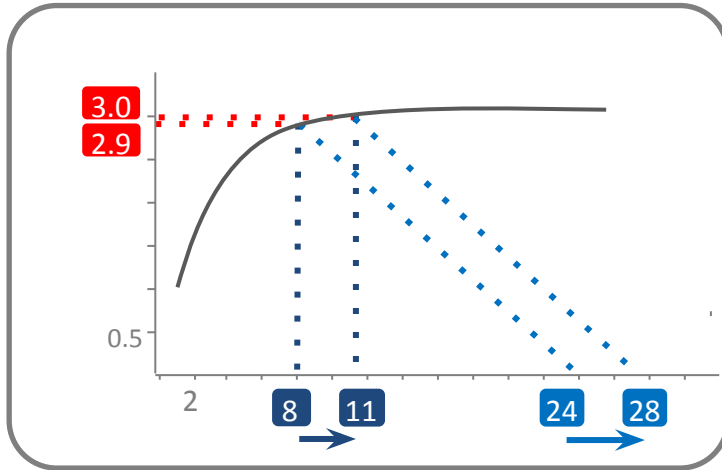
Any clinical importance ?



Bedside

Effects of fluid

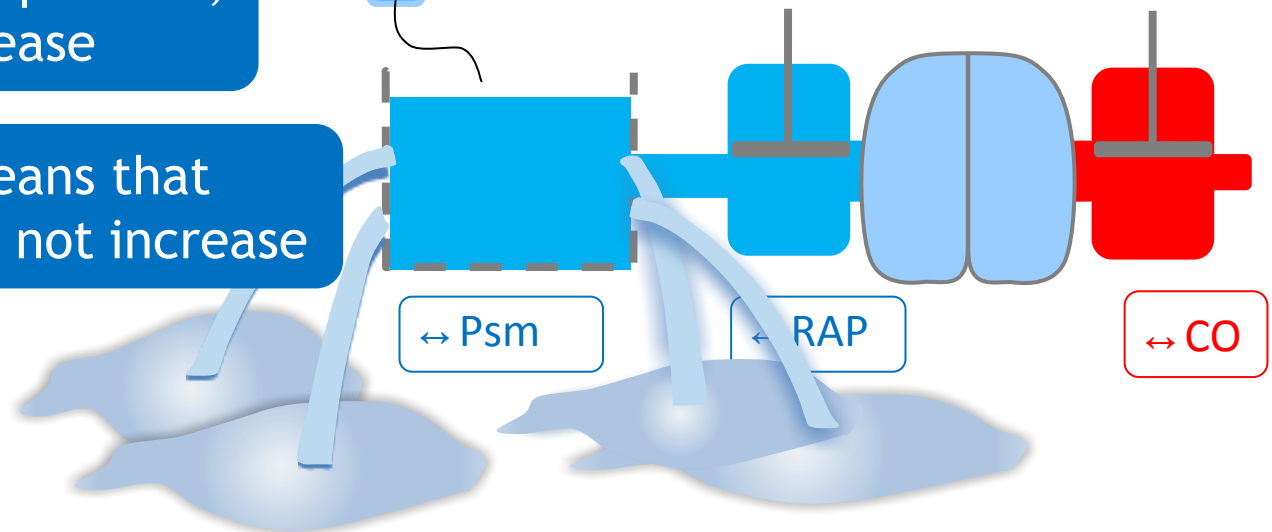
Preload unresponsive



Message #2

In fluid non-responders,
CVP must increase

If not, it means that
preload did not increase



Bedside applications of venous return

To better understand the complex haemodynamic problems and the effects of treatments

Haemodynamic
effects of MV

Effects of
norepinephrine

Passive leg raising
and fluid loading

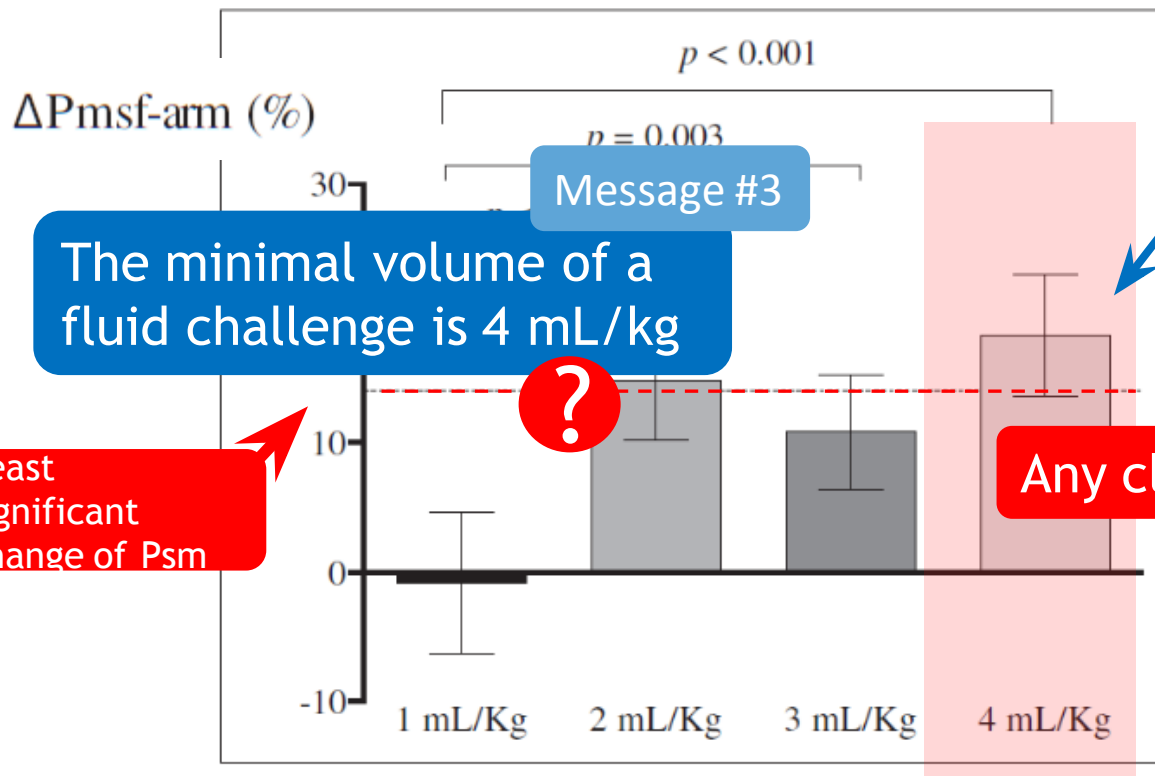
Fluid challenge

Effects of other
vasoactive drugs

Hemodynamic Effect of Different Doses of Fluids for a Fluid Challenge: A Quasi-Randomized Controlled Study

Hollmann D. Aya, MD¹; Andrew Rhodes, MD(Res)²; Irina Chis Ster, PhD²; Nick Fletcher, MD¹; R. Michael Grounds, MD(Res)¹; Maurizio Cecconi, MD(Res)¹

80 patients after cardiac surgery
IV infusion of 1, 2, 3, or 4 mL/Kg
Psm estimated by brachial occlusion



Psm significantly increases if ≥ 4 mL/kg

The minimal volume of a fluid challenge is 4 mL/kg

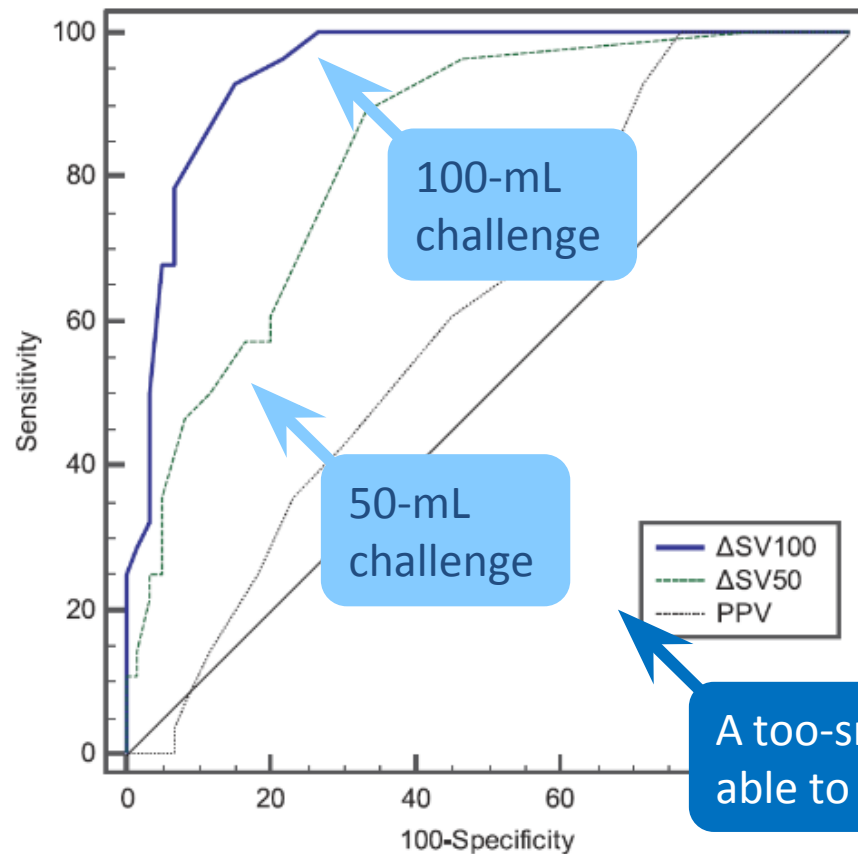
Least significant change of Psm

Any clinical importance ?

Mini-fluid Challenge of 100ml of Crystalloid Predicts Fluid Responsiveness in the Operating Room

Matthieu Blais, M.D., Ph.D., Hugues de Courson, M.D., Romain Lanchon, M.D., Bruno Pereira, Ph.D., Guillaume Bardonneau, M.D., Marion Griton, M.D., Musa Sesay, M.D., Karine Nouette-Gaulain, M.D., Ph.D.

ANESTHESIOLOGY 2017



44 patients before neurosurgery

Minifluid challenge with 100 mL

Pulse contour analysis (ProQT/Pulsioflex)

A too-small fluid challenge is not able to test fluid responsiveness

Bedside applications of venous return

To better understand the complex haemodynamic problems and the effects of treatments

Haemodynamic effects of MV

Effects of norepinephrine

Passive leg raising and fluid loading

Fluid challenge

Effects of other vasoactive drugs

Norepinephrine increases cardiac preload and reduces preload dependency assessed by passive leg raising in septic shock patients*

Xavier Monnet, MD, PhD; Julien Jabot, MD; Julien Maizel, MD; Christian Richard, MD; Jean-Louis Teboul, MD, PhD

Crit Care Med 2011

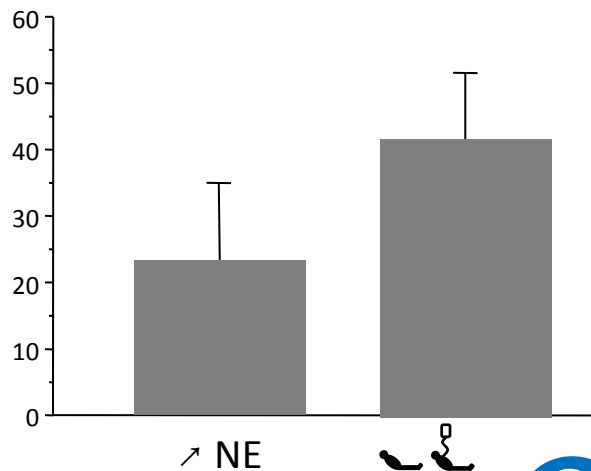
25 septic shock pts

PLR before and after increasing NE

Norepinephrine ↗
pressure marker of preload

Norepinephrine ↗
volume marker of preload

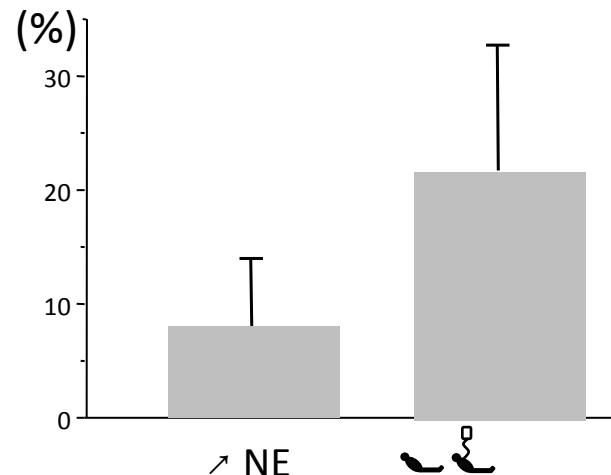
Changes in **CVP** (%)



Volume expansion

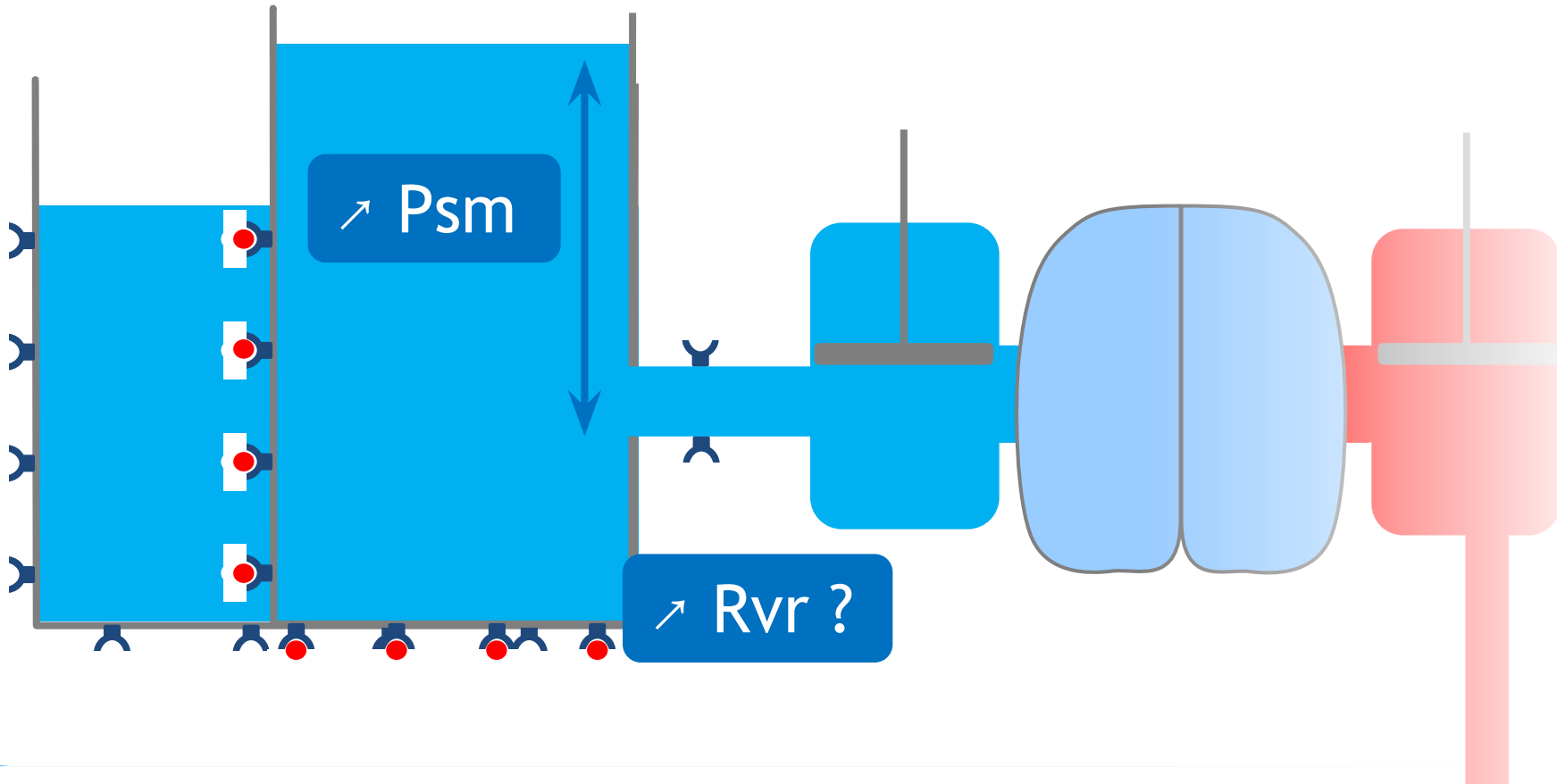
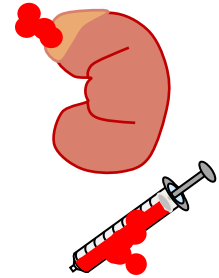
?

Changes in **LV end-diastolic area** (%)



How does norepinephrine increase cardiac preload ?

Applications



Effects of norepinephrine on mean systemic pressure and venous return in human septic shock

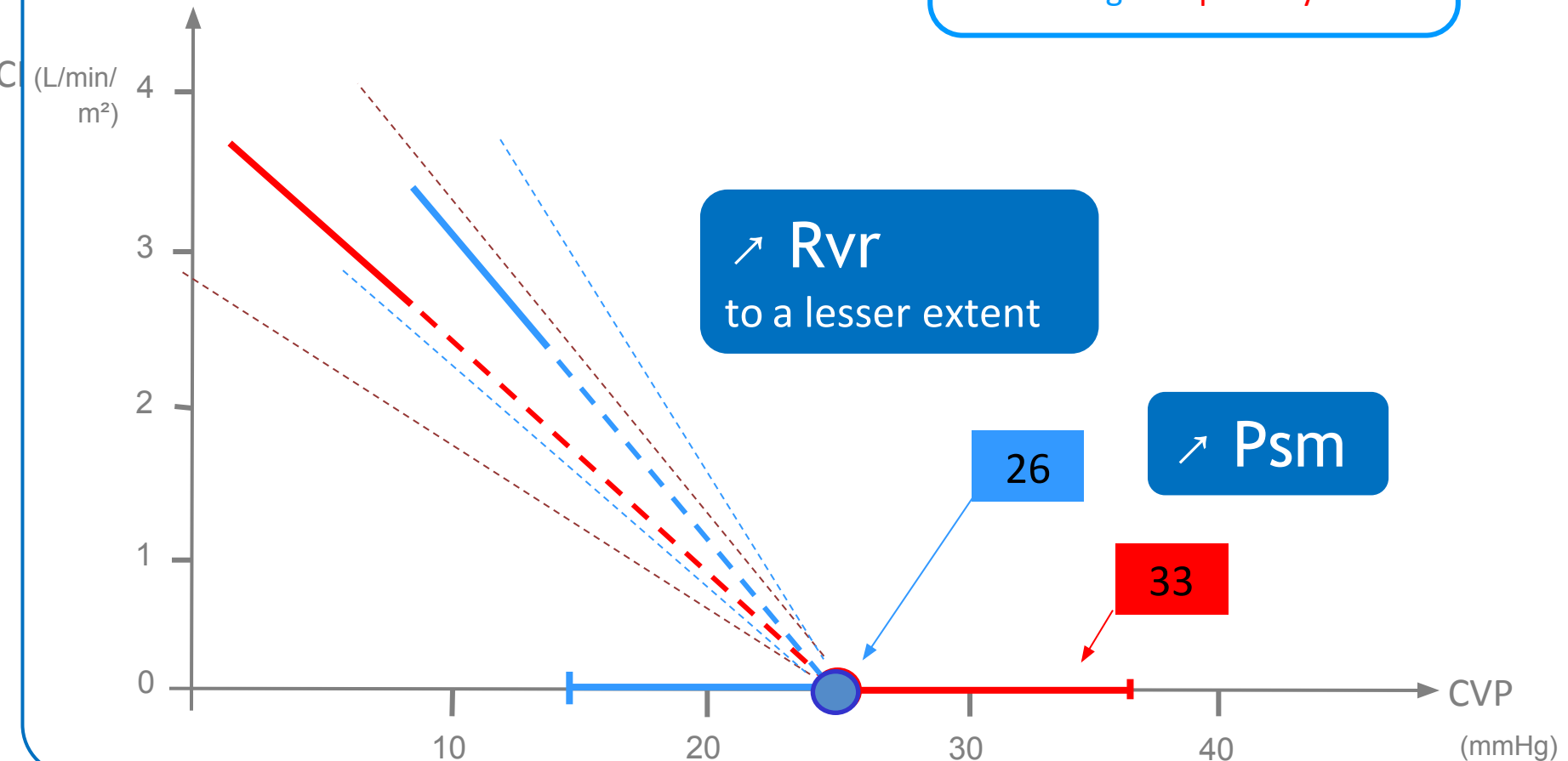
Romain Persichini, MD; Serena Silva, MD; Jean-Louis Teboul, MD, PhD; Mathieu Jozwiak, MD; Denis Chelma, MD, PhD; Christian Richard, MD; Xavier Monnet, MD, PhD

Crit Care Med 2012

16 septic shock patients

Norepinephrine administration

Psm through respiratory holds



Cardiac Output Response to Norepinephrine in Postoperative Cardiac Surgery Patients: Interpretation With Venous Return and Cardiac Function Curves*

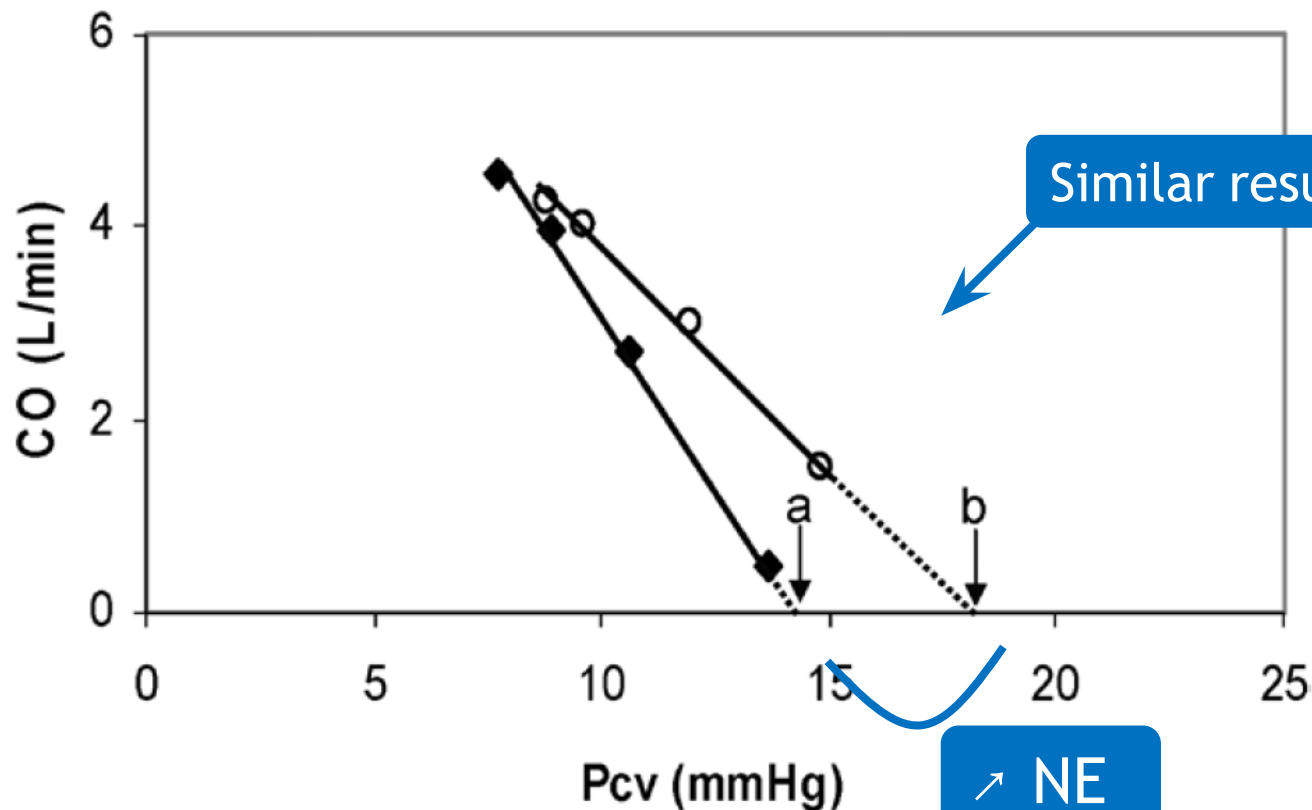
[*Crit Care Med* 2013]

Jacinta J. Maas, MD¹; Michael R. Pinsky, MD, MCCM²; Rob B. de Wilde, PhD¹;
Evert de Jonge, MD, PhD¹; Jos R. Jansen, MS, PhD¹

16 patients after cardiac surg.

↗ norepinephrine

Psm through respiratory holds



?

Any clinical importance ?

Venous
return

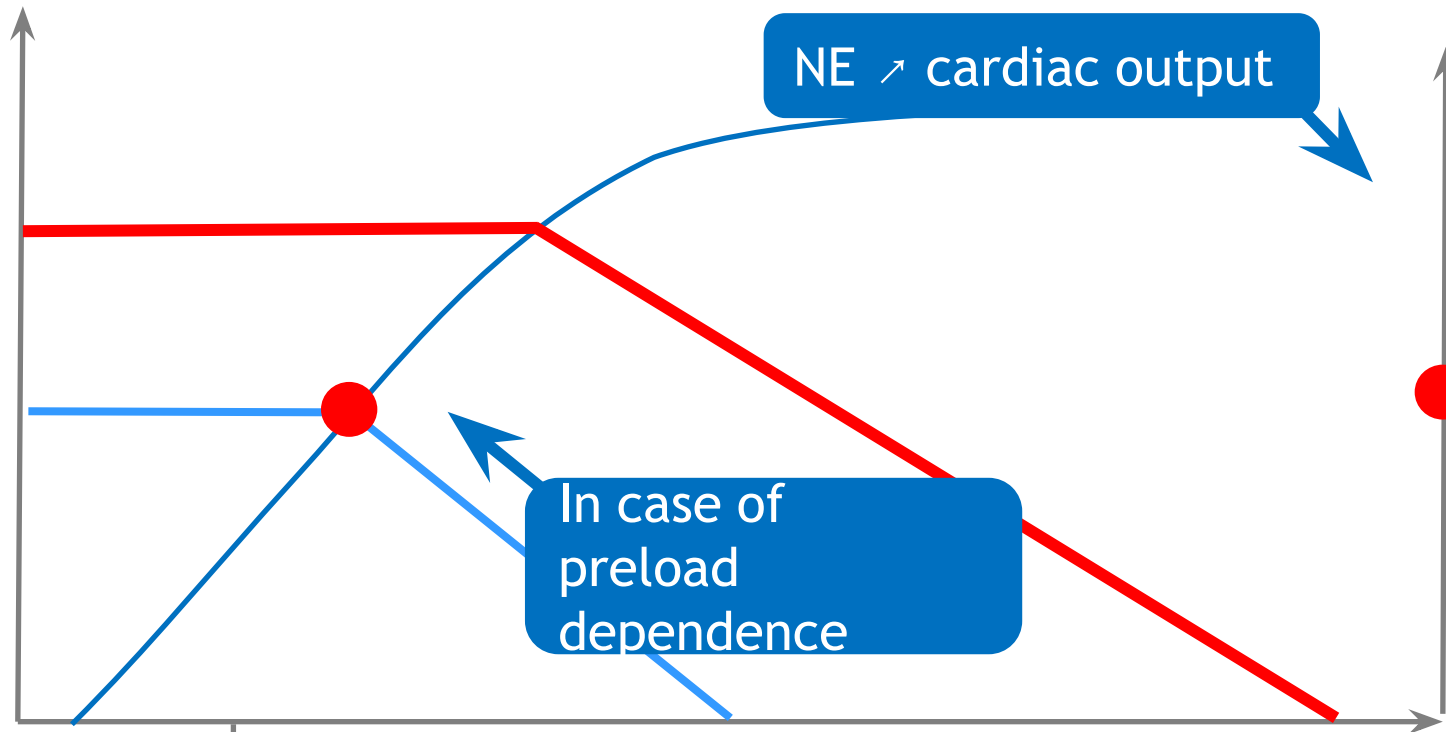
Cardiac
output

NE ↗ cardiac output

In case of
preload
dependence

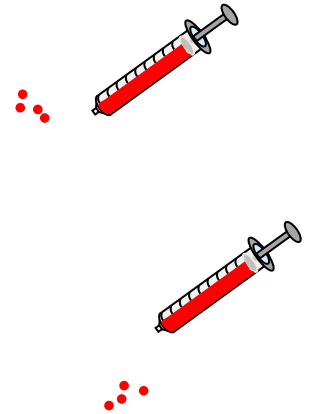
↗ ↗ Psm

Right atrial
pressure



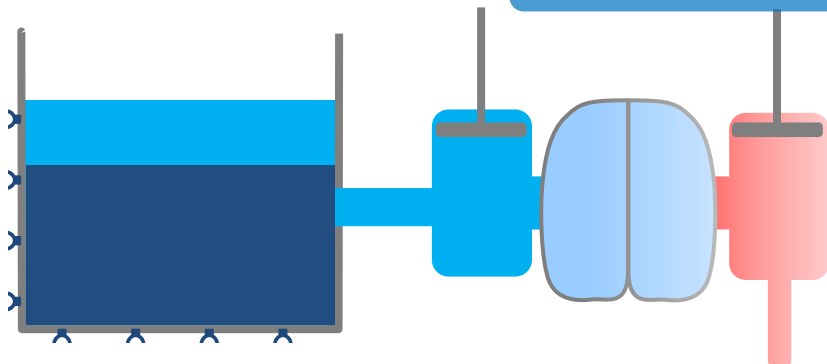
Message #4

NE exerts additive and synergic effects with fluids



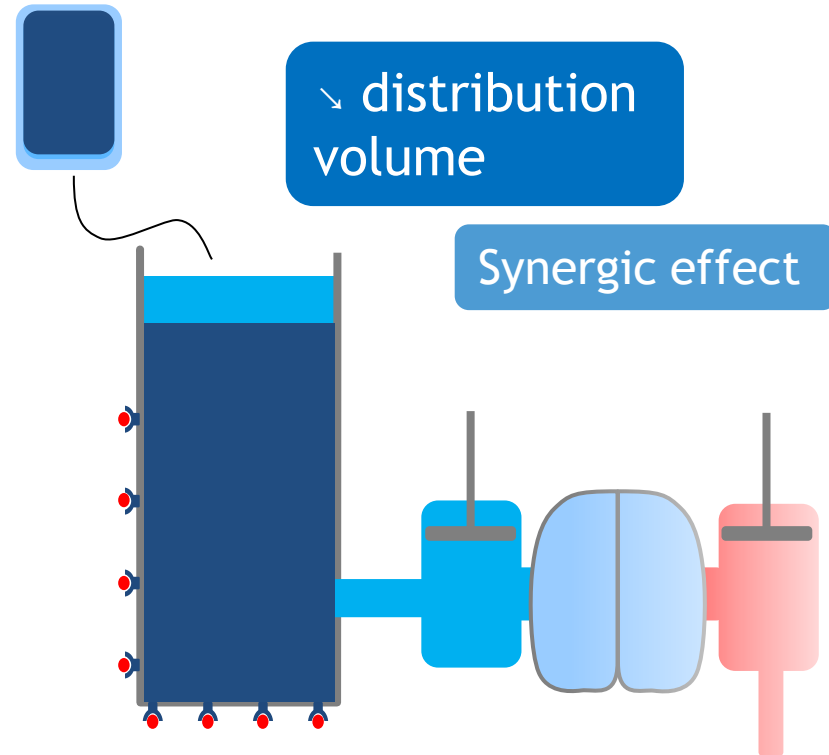
Contributes to \nearrow preload

Additive effect



\searrow distribution volume

Synergic effect

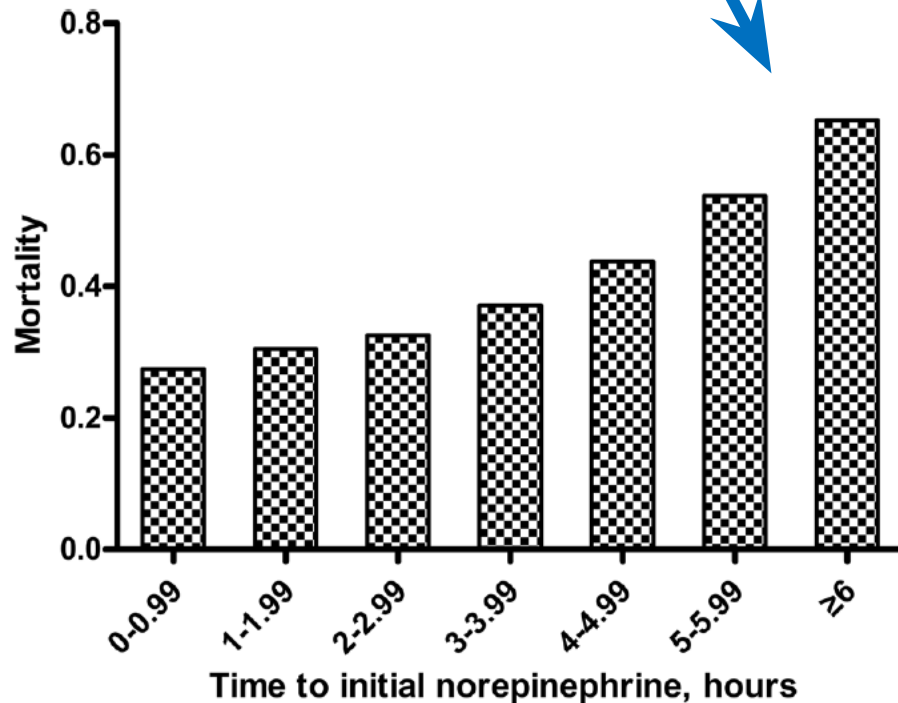


Early versus delayed administration of norepinephrine in patients with septic shock

Xiaowu Bai, Wenkui Yu*, Wu Ji, Zhiliang Lin, Shanjun Tan, Kaipeng Duan, Yi Dong, Lin Xu and Ning Li*

Mortality ↗ along with the delay of NE administration

Retrospective analysis
213 septic shock patients



Early versus delayed administration of norepinephrine in patients with septic shock

Xiaowu Bai, Wenkui Yu^{*}, Wu Ji, Zhiliang Lin, Shanjun Tan, Kaipeng Duan, Yi Dong, Lin Xu and Ning Li^{*}

Retrospective analysis
213 septic shock patients

Characteristic	<2 hours (number = 86)	≥2 hours (number = 127)	P value
24-hour norepinephrine administration (mg)	29.4 ± 9.7	32.8 ± 10.0	0.013
Time to initial antimicrobial treatment (h)	1.6 ± 1.4	1.7 ± 1.5	0.126
Volume of intravenous fluids within 24 h (L)	6.2 ± 0.6	6.9 ± 0.7	<0.001

Early administration of
NE may ↘ fluid balance

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How do we assess it at the bedside ?

How is it useful in practice ?

Venous return

1

What is the basic physiology ?

In the Guyton's theory, the heart's role is to lower RAP and to generate the pressure gradient of venous return

2

How do we assess it at the bedside ?

Although imperfect, there are methods that can be used at the bedside to estimate Psm and Rvr

3

How is it useful in practice ?

Dedicated to the reasearch area, these methods help better understand complex diseases and treatments