Fluid responsiveness

What do I use at the bedside?

Prof. Jean-Louis TEBOUL

Medical ICU

Bicetre hospital

University Paris South

France

Conflicts of interest

- Member of the Medical Advisory Board of **Getinge**
- Lectures for **Edwards LifeSciences**
- Lectures for **Masimo**
- Lectures for **Cheetah**

Fluid responsiveness

is defined

as the capacity of the heart

to significantly **increase** its **SV** (or its **CO**)

in response to a **volume challenge**

Fluid responsiveness: **what** do **I use** at the bedsise ?

1- **What** is **fluid responsiveness**?

2- **Why** is it so **important** to **predict fluid responsiveness**?

3- To predict fluid responsiveness, **I don't use** (unreliable) traditional **markers** of **preload**

4- To predict fluid responsiveness, **I use** (reliable) **dynamic** indices or tests

5- If the patient is **not mechanically ventilated,** I use **PLR**

6- If the patient is **mechanically ventilated**

6a- I can still use **PLR**

6b- I can use **PPV** (or SVV) in some conditions of applicability

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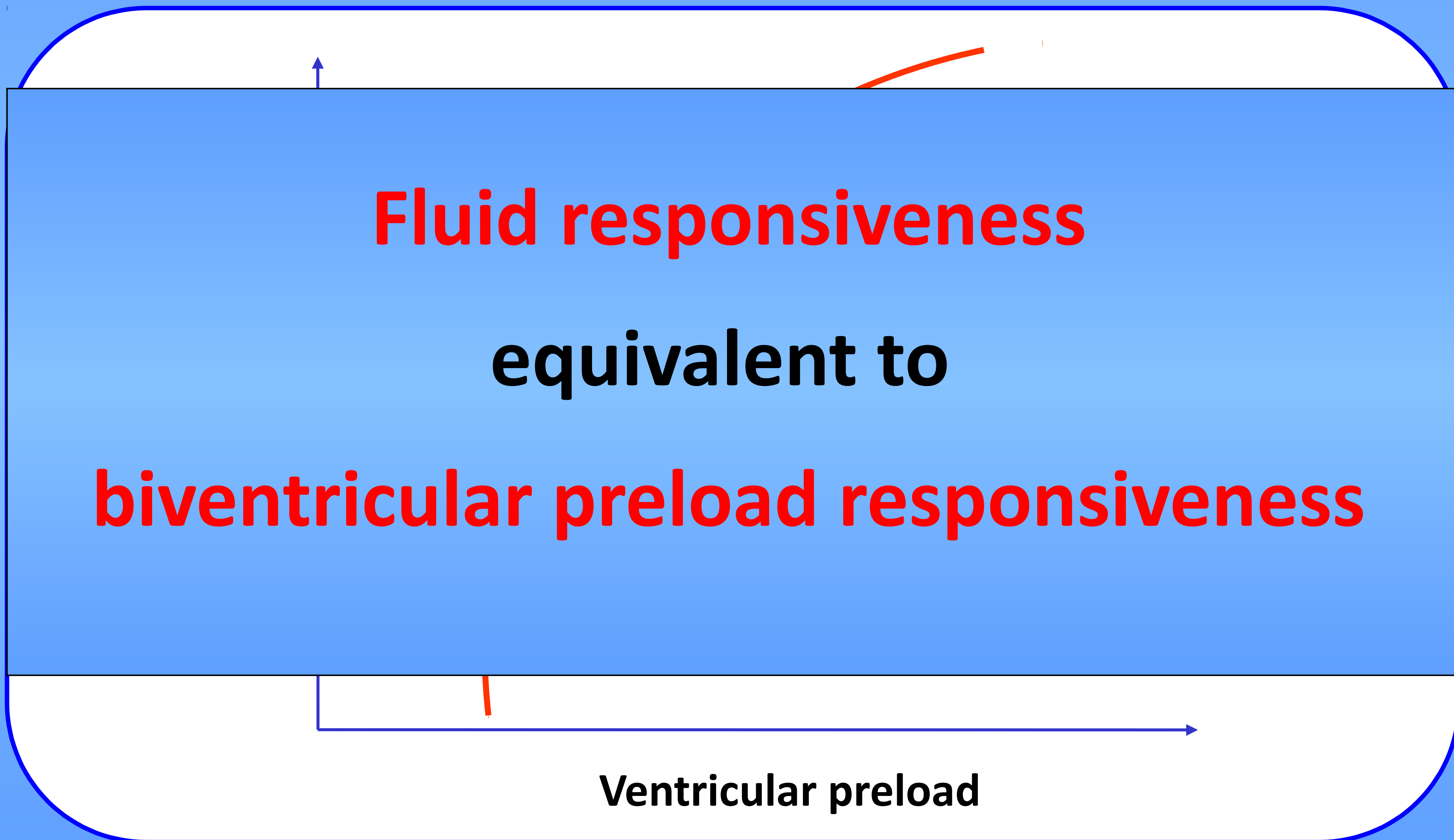
8- Testing **preload responsiveness** is **not advised** for **initiating** IV **fluids** in **shock** states

9- Presence of **preload responsiveness** is **mandatory** to decide to **continue** fluid infusion

10- Presence of **preload unresponsiveness** is **sufficient** to decide to **stop** fluid infusion

Fluid infusion will increase LV stroke volume only if **both ventricles** are **preload responsive**



Fluid responsiveness

equivalent to

biventricular preload responsiveness

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critical care review

Predicting Fluid Responsiveness In ICU Patients*

A Critical Analysis of the Evidence

Frédéric Michard, MD, PhD, and Jean Louis Teboul, MD, PhD

CHEST 2002, 121:2000-8

48% of patients do **not increase** their **cardiac output** in response to **fluid** administration

							Rate of response, %
Calvin							71
Schnei							72
Reuse							63
Magde							52
Diebel							59
Diebel							40
Wagne							56
Leat							
Tavern							60
Magde							45
Tousignan							40
Michard et al[12]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	40
Feissel et al[13]	19	19	HES	8 mL/kg	30	ΔCO > 15%	53
Total	334	406					52

Sepsis in European intensive care units: Results of the SOAP study*

Jean-Louis Vincent, MD, PhD, FCCM; Yasser Sakr, MB, BCh, MSc; Charles L. Sprung, MD; V. Marco Ranieri, MD; Konrad Reinhart, MD, PhD; Herwig Gerlach, MD, PhD; Rui Moreno, MD, PhD; Jean Carlet, MD, PhD; Jean-Roger Le Gall, MD; Didier Payen, MD; on behalf of the Sepsis Occurrence in Acutely Ill Patients Investigators

Crit Care Med 2006; 34:344–353

Table 7. Multivariate, forward stepwise logistic regression analysis in sepsis patients (n = 1177), with intensive care unit mortality as the dependent factor

	OR (95% CI)	*p* Value
SAPS II score[a] (per point increase)	1.0 (1.0–1.1)	<.001
Cumulative fluid balance[b] (per liter increase)	1.1 (1.0–1.1)	.001
Age (per year increase)	1.0 (1.0–1.0)	.001
Initial SOFA score (per point increase)	1.1 (1.0–1.1)	.002
Blo		004
Cir		008
Pse		017
Mec		049
Fen		044

Au cours du **sepsis**, une balance hydrique cumulée **positive** est un **facteur** indépendant de **mortalité**

Extravascular Lung Water is an Independent Prognostic Factor in Patients with Acute Respiratory Distress Syndrome

Mathieu Jozwiak, MD; Serena Silva, MD; Romain Persichini, MD; Nadia Anguel, MD; David Osman, MD; Christian Richard, MD; Jean-Louis Teboul, MD, PhD; Xavier Monnet, MD, PhD

Crit Care Med 2013;41:472–480

200 pts

D_{28} mortality: 54%

	Odds Ratio (CI 95%)		p value
SAPS II	1.03	(1.01 - 1.05)	0.02
$EVLW_{max}$	1.07	(1.02 - 1.12)	0.007
Mean fluid balance	1.0004	(1.0001 – 1.0008)	0.02

In **ARDS**, a **positive** cumulative **fluid balance** is an **independent** factor associated with **mortality**

Stroke volume

LVEDP

In fluid **nonresponders**

there is a high risk of **increase** in LVEDP

and thus in **pulmonary capillary pressure**

Ventricular preload

Lactate and Venoarterial Carbon Dioxide Difference/Arterial-Venous Oxygen Difference Ratio, but Not Central Venous Oxygen Saturation, Predict Increase in Oxygen Consumption in Fluid Responders*

Xavier Monnet, MD, PhD[1,2]; Florence Julien, MD[1,2]; Nora Ait-Hamou, MD[1]; Marie Lequoy, MD[1,2]; Clément Gosset, MD[1,2]; Mathieu Jozwiak, MD[1,2]; Romain Persichini, MD[1,2]; Nadia Anguel, MD[1,2]; Christian Richard, MD[1,2]; Jean-Louis Teboul, MD, PhD[1,2]

Crit Care Med 2013; 41:1412–1420

In fluid **nonresponders**

there is a high risk of **decrease** in **oxygen delivery**

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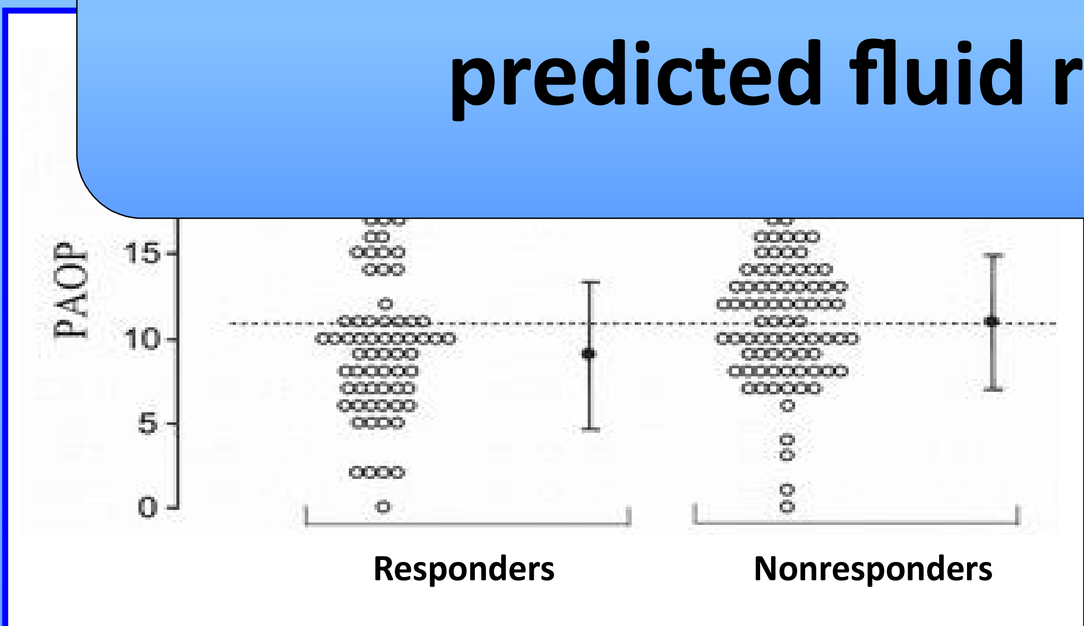
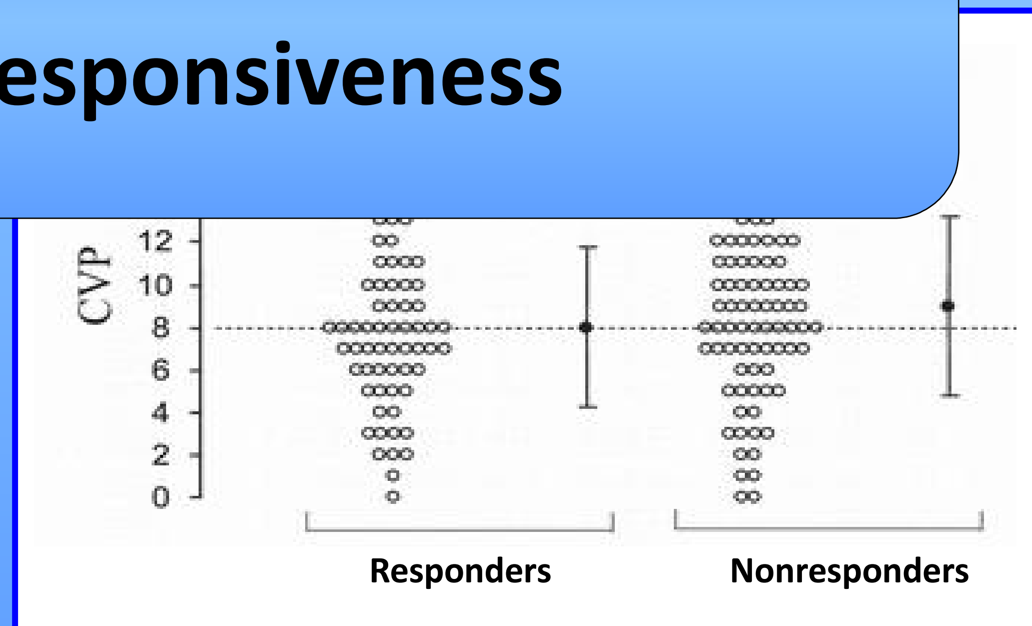
Cardiac filling pressures are not appropriate to predict hemodynamic response to volume challenge*

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

Neither baseline **PAOP nor** baseline **CVP predicted fluid 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

1802 pts

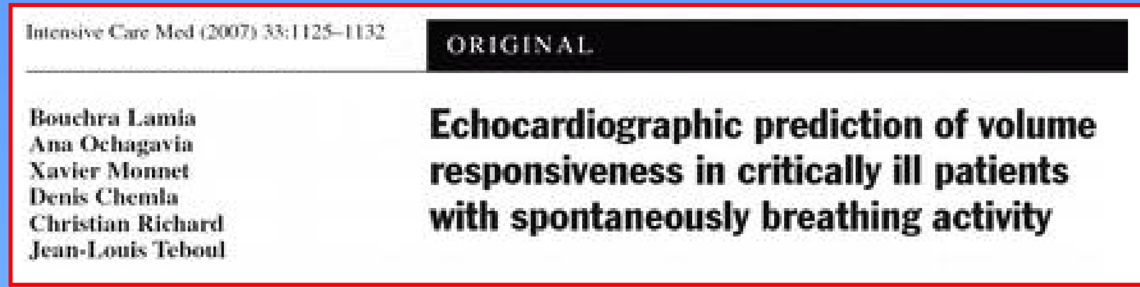
43 Citations

- 22 ICU studies
- 20 operating room studies
- 1 human volunteer study

Summary AUC

0.56

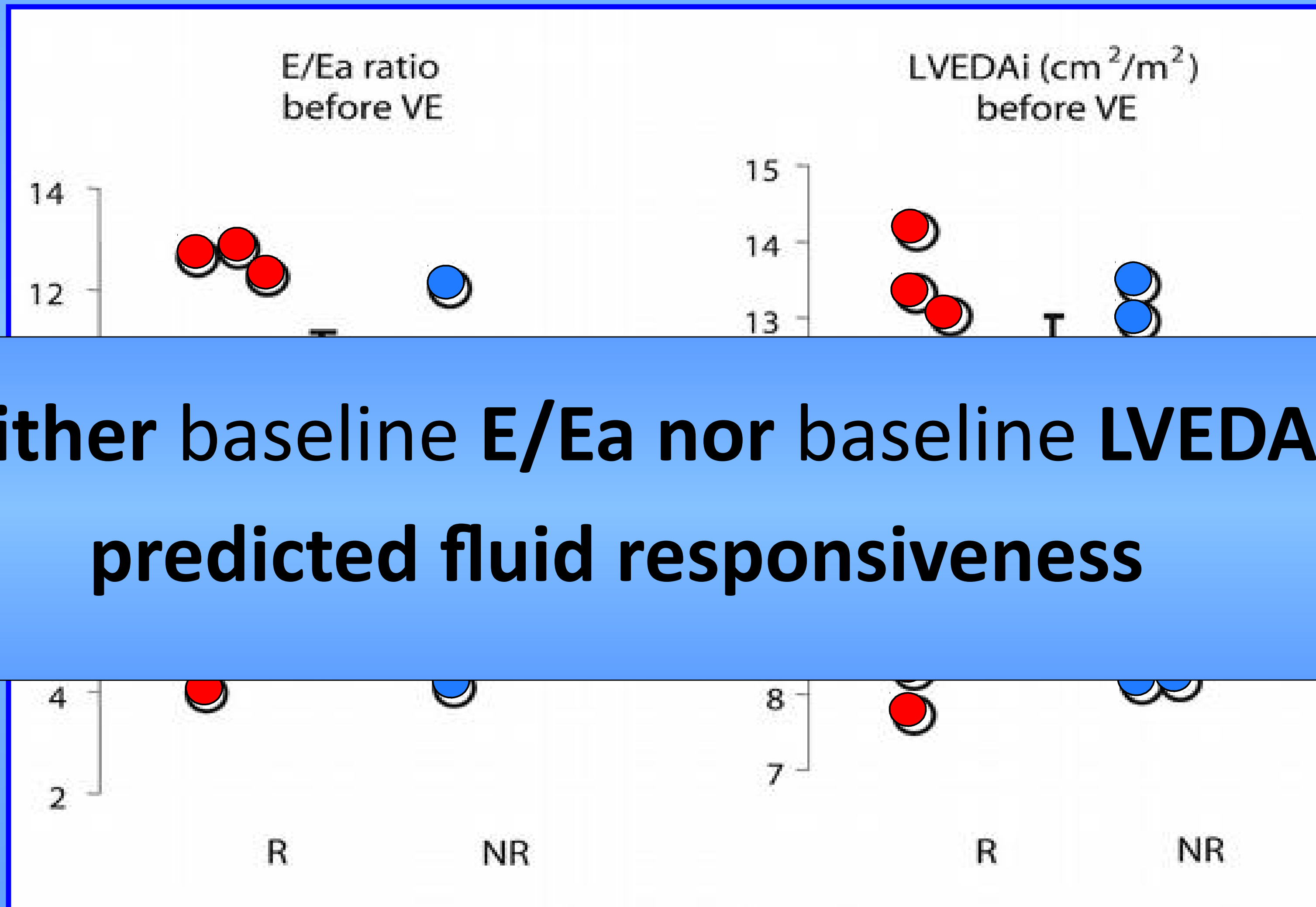
Predicting fluid responsiveness with **CVP** is like


Intensive Care Med (2007) 33:1125–1132

ORIGINAL

Bouchra Lamia
Ana Ochagavia
Xavier Monnet
Denis Chemla
Christian Richard
Jean-Louis Teboul

Echocardiographic prediction of volume responsiveness in critically ill patients with spontaneously breathing activity

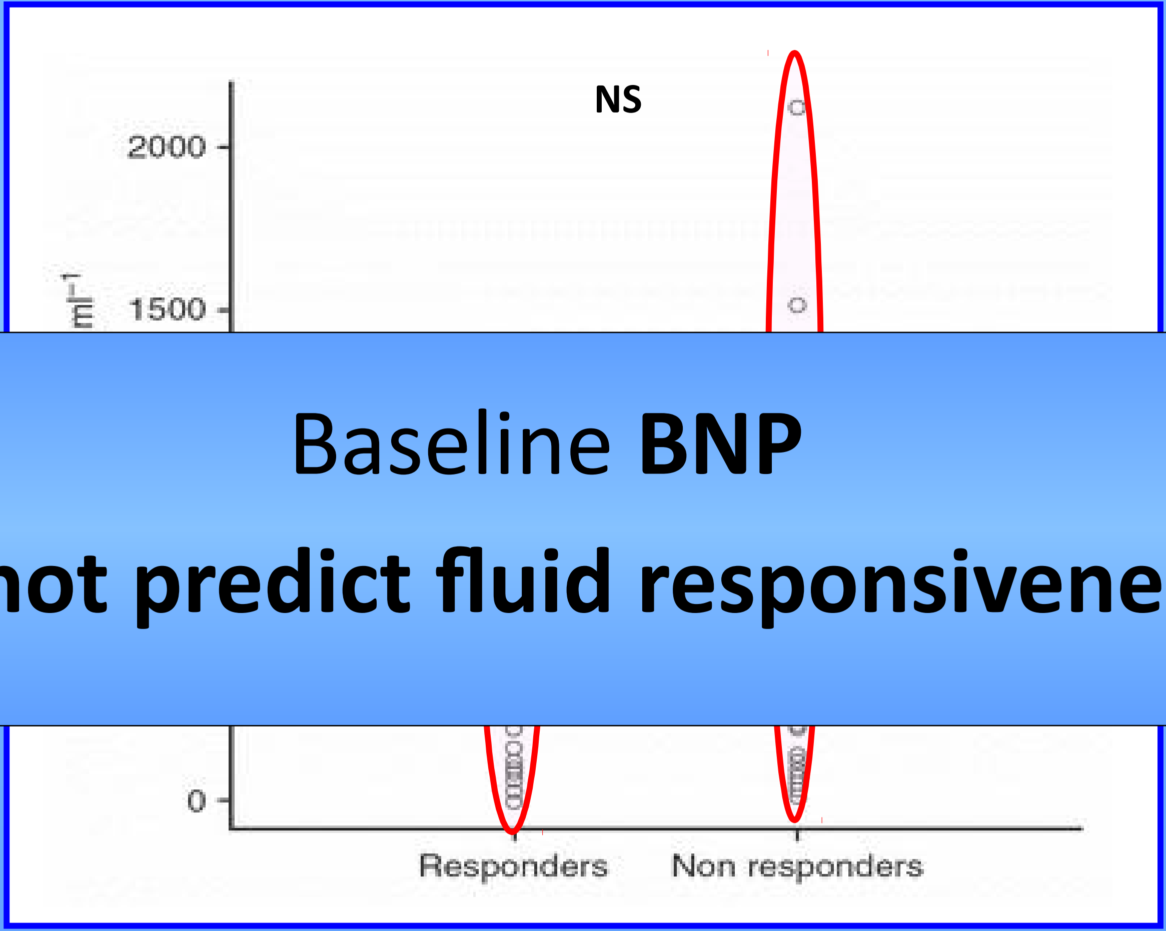


Neither baseline **E/Ea nor** baseline **LVEDAI predicted fluid responsiveness**

B-type natriuretic peptide to assess haemodynamic status after cardiac surgery

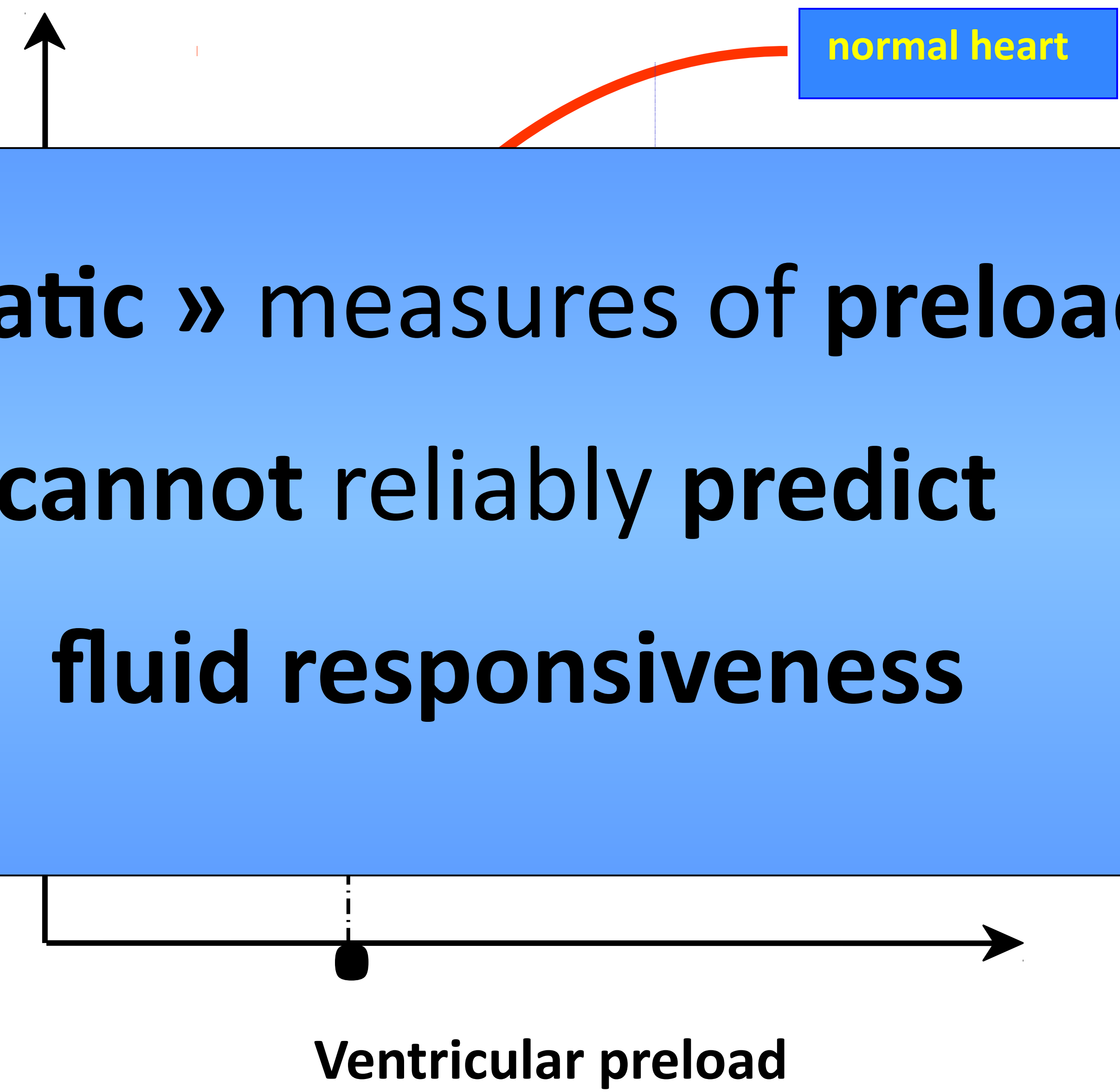
A. Mekontso-Dessap[1]*, L. Tual[2], M. Kirsch[2], G. D'Honneur[2], D. Loisance[2], L. Brochard[1] and J.-L. Teboul[3]

Br J Anaesth 2006; 87:777-782



Baseline **BNP**

did **not predict fluid responsiveness**



« static » measures of **preload**

cannot reliably **predict**

fluid responsiveness

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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

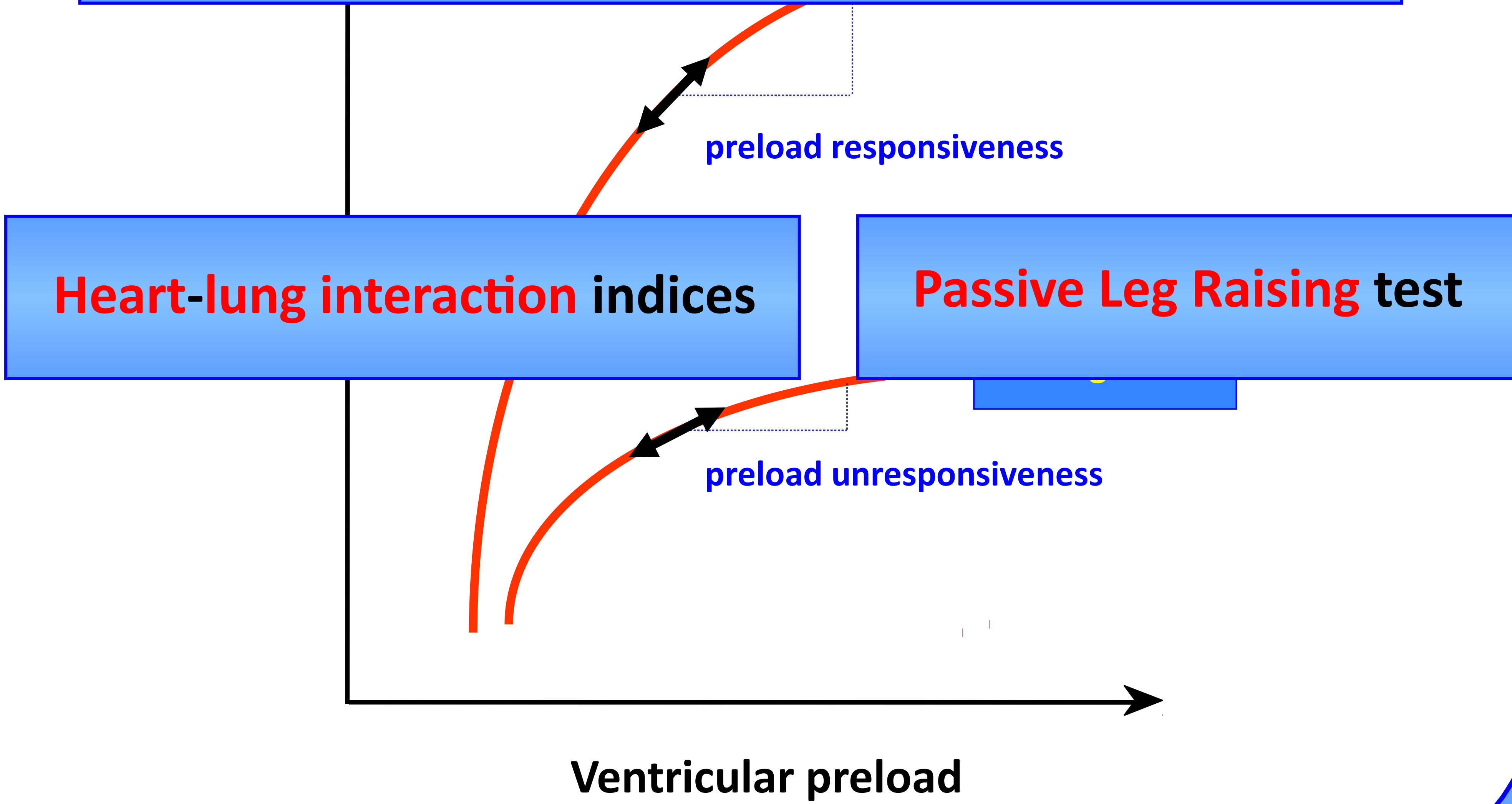
Surviving Sepsis Campaign: International Guidelines for Management of Sepsis and Septic Shock: 2016

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], Gordon R. Bernard[15], Jean-Daniel Chiche[16], Craig Coopersmith[8], Daniel P. De Backer[17], Craig J. French[18], Seitaro Fujishima[19], Herwig Gerlach[20], Jorge Luis Hidalgo[21], Steven M. Hollenberg[22], Alan E. Jones[23], Dilip R. Karnad[24], Ruth M. Kleinpell[25], Younsuk Koh[26], Thiago Costa Lisboa[27], Flavia R. Machado[28], John J. Marini[29], John C. Marshall[30], John E. Mazuski[31], Lauralyn A. McIntyre[32], Anthony S. McLean[33], Sangeeta Mehta[34], Rui P. Moreno[35], John Myburgh[36], Paolo Navalesi[37], Osamu Nishida[38], Tiffany M. Osborn[31], Anders Perner[39], Colleen M. Plunkett[25], Marco Ranieri[40], Christa A. Schorr[22], Maureen A. Seckel[41], Christopher W. Seymour[42], Lisa Shieh[43], Khalid A. Shukri[44], Steven Q. Simpson[45], Mervyn Singer[46], B. Taylor Thompson[47], Sean R. Townsend[48], Thomas Van der Poll[49], Jean-Louis Vincent[50], W. Joost Wiersinga[49], Janice L. Zimmerman[51] and R. Phillip Dellinger[22]

Intensive Care Med (2017) 43:304–377

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

Dynamic indices of preload responsiveness



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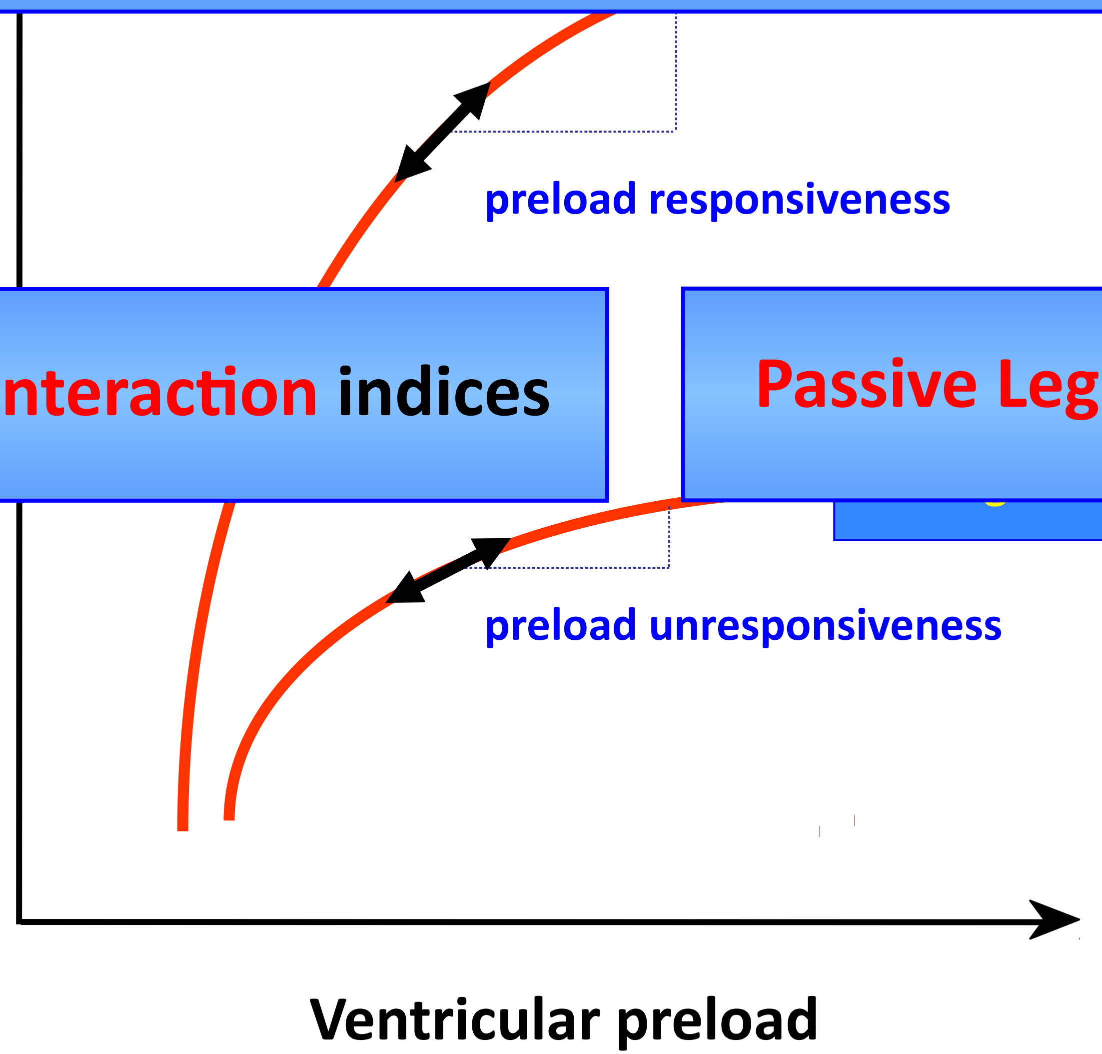
Dynamic indices of preload responsiveness

Heart-lung interaction indices

Passive Leg Raising test



Intensive Care Med (2008) 34:659–663

CLINICAL COMMENTARY

Xavier Monnet
Jean-Louis Teboul

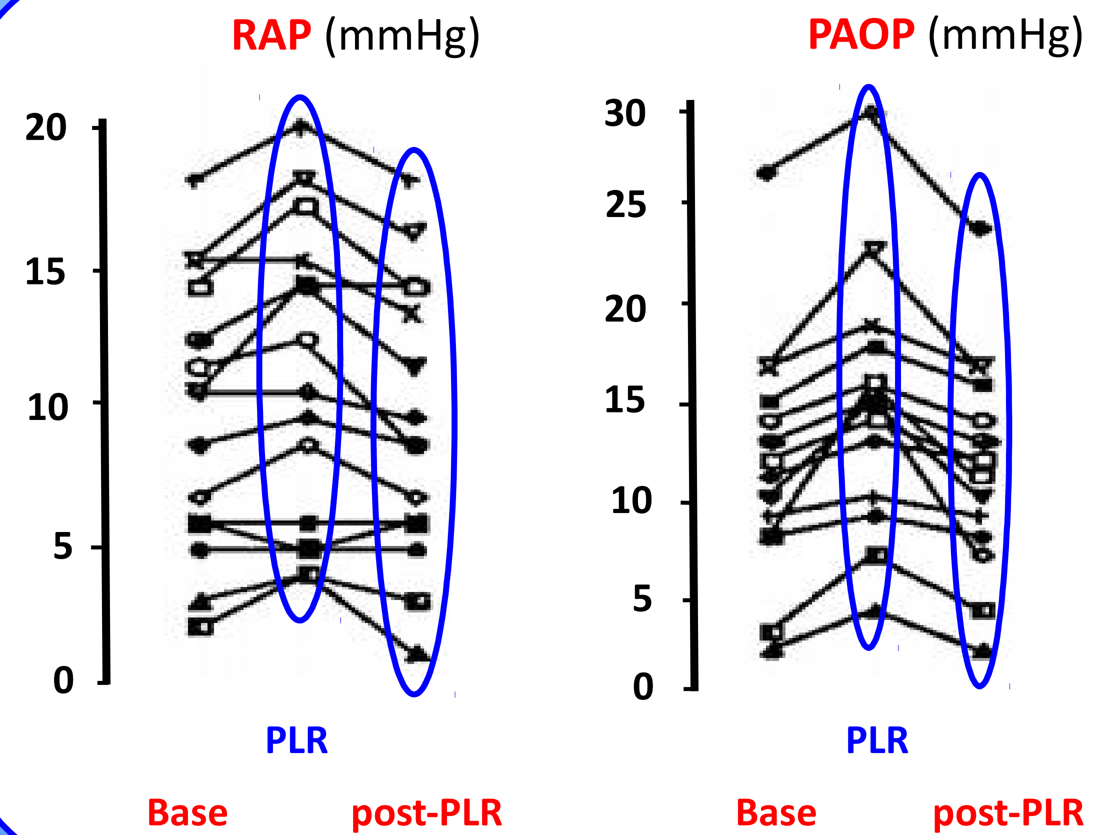
Passive leg raising

transfer of blood
from the legs and abdominal
compartments

Changes in BP Induced by Passive Leg Raising Predict Response to Fluid Loading in Critically Ill Patients*

Thierry Boulain, MD; Jean-Michel Achard, MD; Jean-Louis Teboul, MD; Christian Richard, MD; Dominique Perrotin, MD; and Guy Gimes, MD

CHEST 2002; 121:1245–1252



Intensive Care Med (2008) 34:659–663

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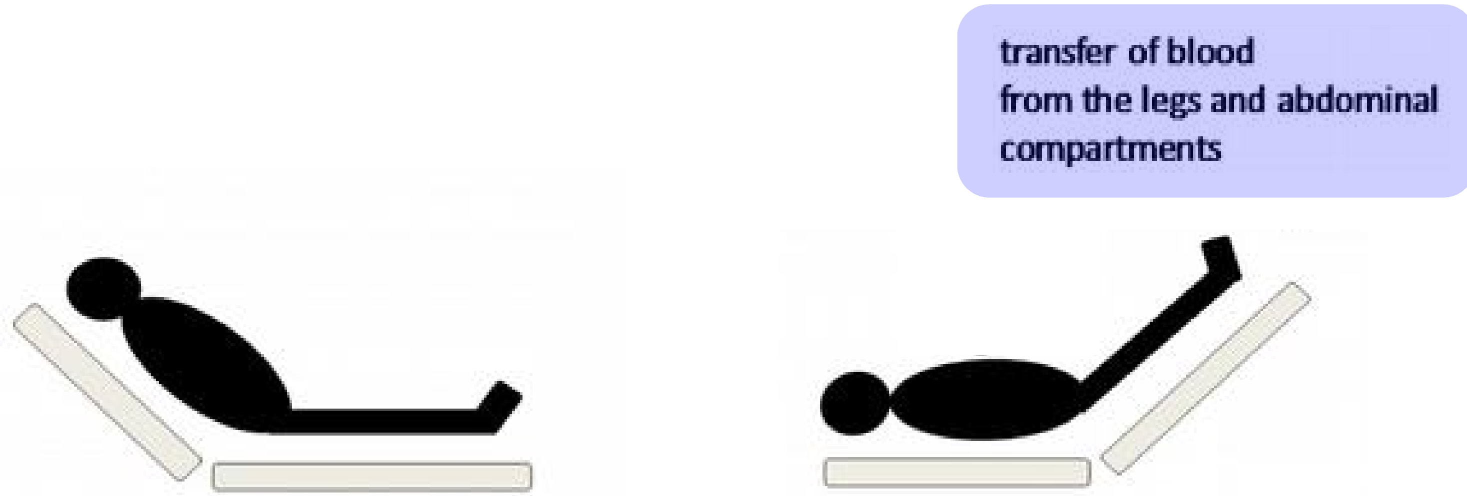
Passive leg raising



PLR mimics fluid challenge

The hemodynamic response to PLR

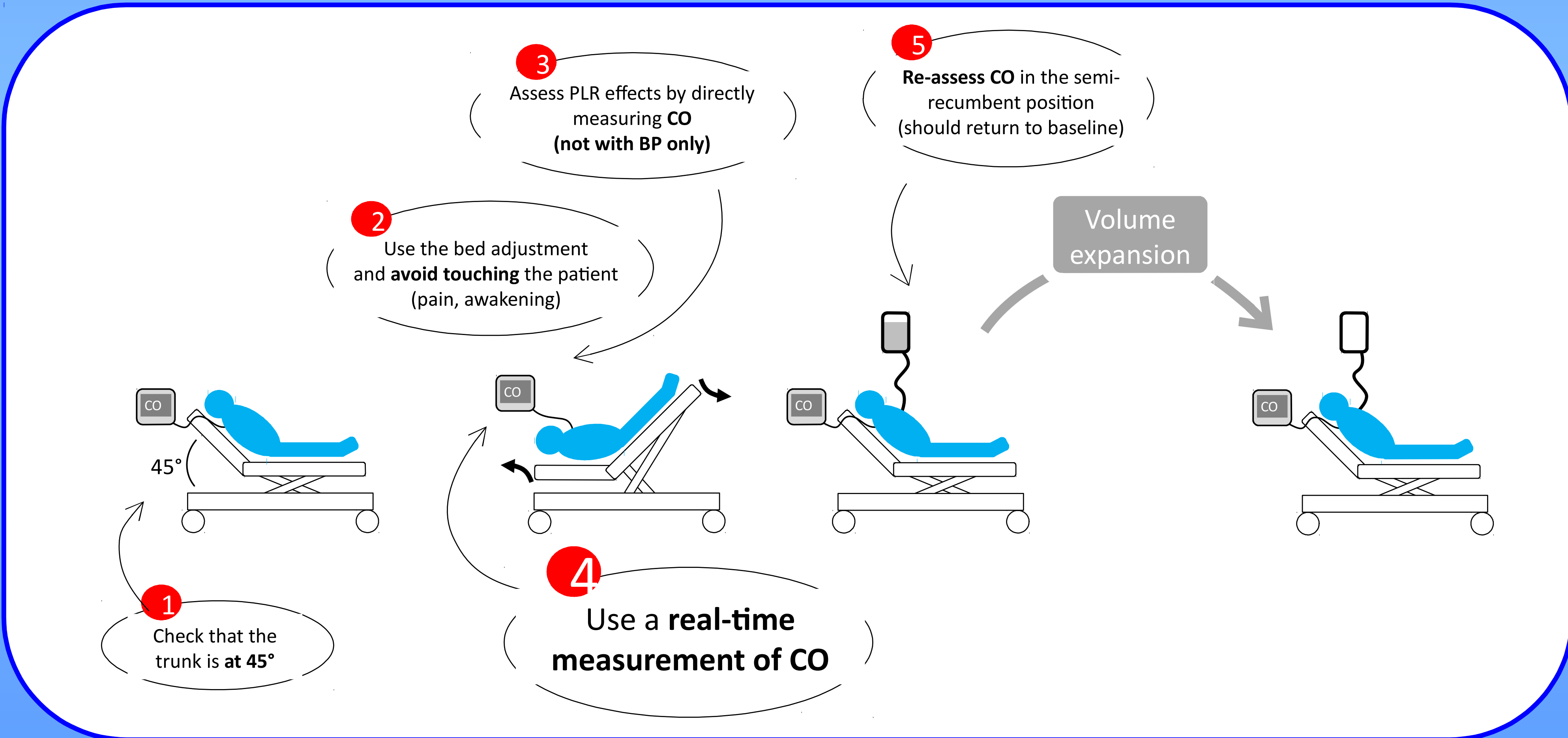
can predict the hemodynamic response to volume infusion

EDITORIAL

Passive leg raising: five rules, not a drop of fluid!

Xavier Monnet[1,2*] and Jean-Louis Teboul[1,2]

Crit Care 2015, 19:18



Intensive Care Med (2016) 42:1935–1947

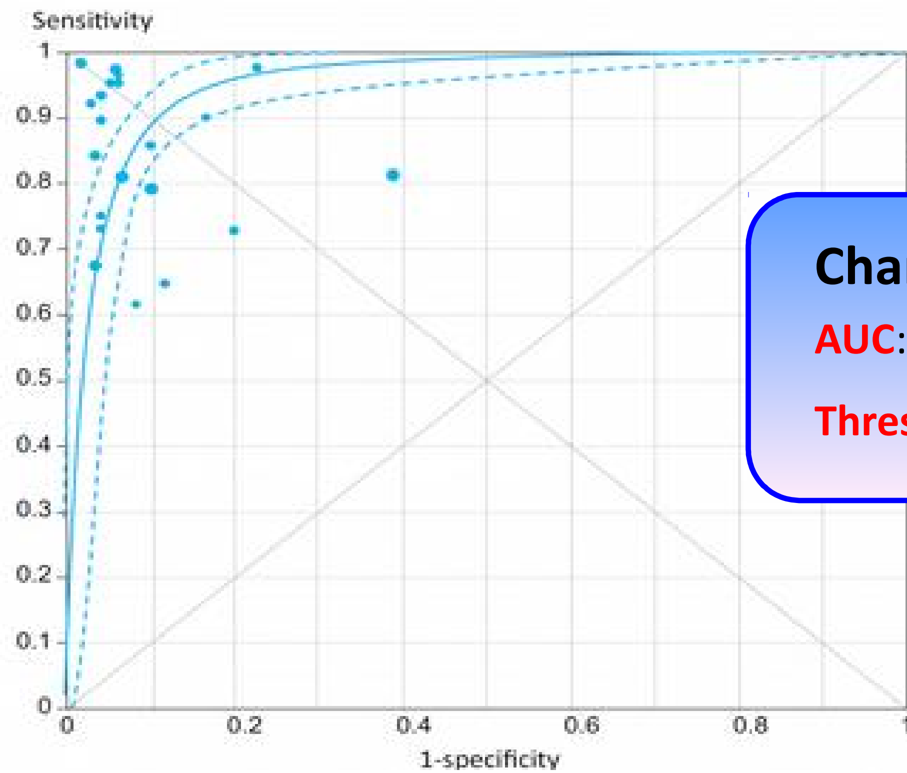
ORIGINAL

Xavier Monnet
Paul Marik
Jean-Louis Teboul

Passive leg raising for predicting fluid responsiveness: a systematic review and meta-analysis

***21* clinical studies**

***995* pts**



Changes in CO

AUC: 0.95 ± 0.01

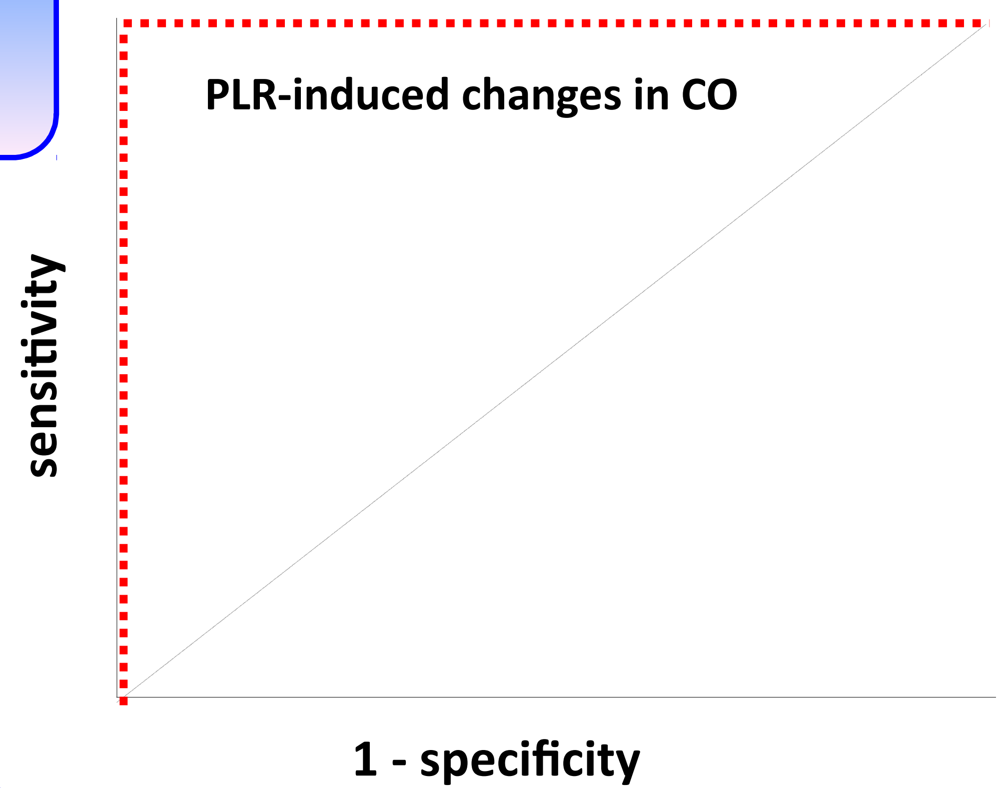
Threshold: 10%

Passive leg raising predicts fluid responsiveness in the critically ill*

Xavier Monnet, MD, PhD; Mario Rienzo, MD; David Osman, MD; Nadia Anguel, MD; Christian Richard, MD; Michael R. Pinsky, MD, Dr hc; Jean-Louis Teboul, MD, PhD

Crit Care Med 2006; 34:1402–1407

Pts with **spontaneous breathing**



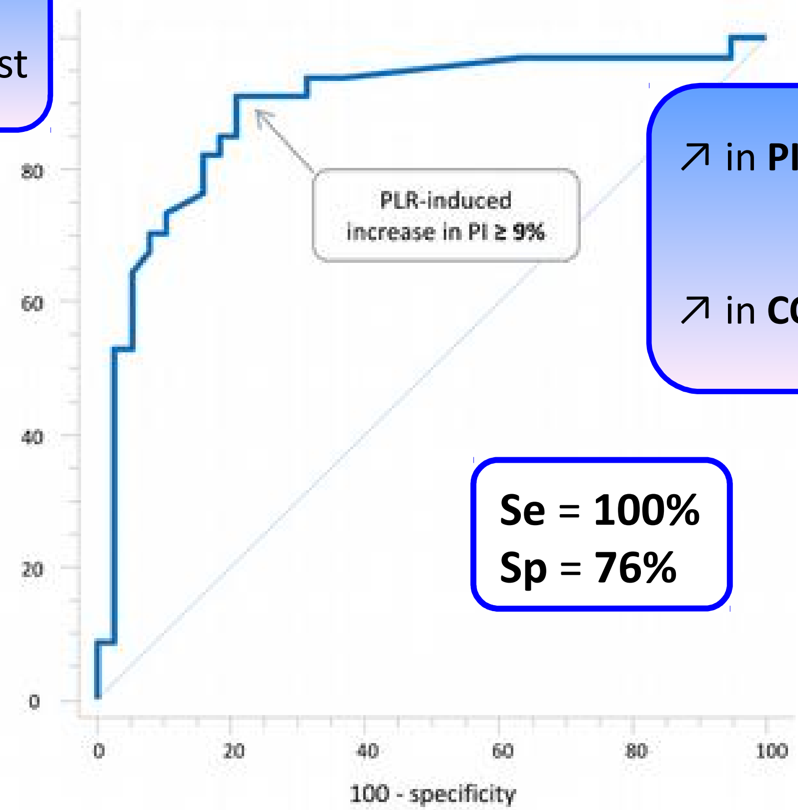
The effects of passive leg raising may be detected by the plethysmographic oxygen saturation signal in critically ill patients

Alexandra Beurton[1,2*], Jean-Louis Teboul[1,2], Francesco Gavelli[1], Filipe Andre Gonzalez[1], Valentina Girotto[1], Laura Galarza[1], Nadia Anguel[1], Christian Richard[1] and Xavier Monnet[1,2]

Critical Care (2019) 23:19

34 cases with **positive PLR** test

38 cases with **negative PLR** test



↗ in **PI** during PLR **≥ 9%**

predicts

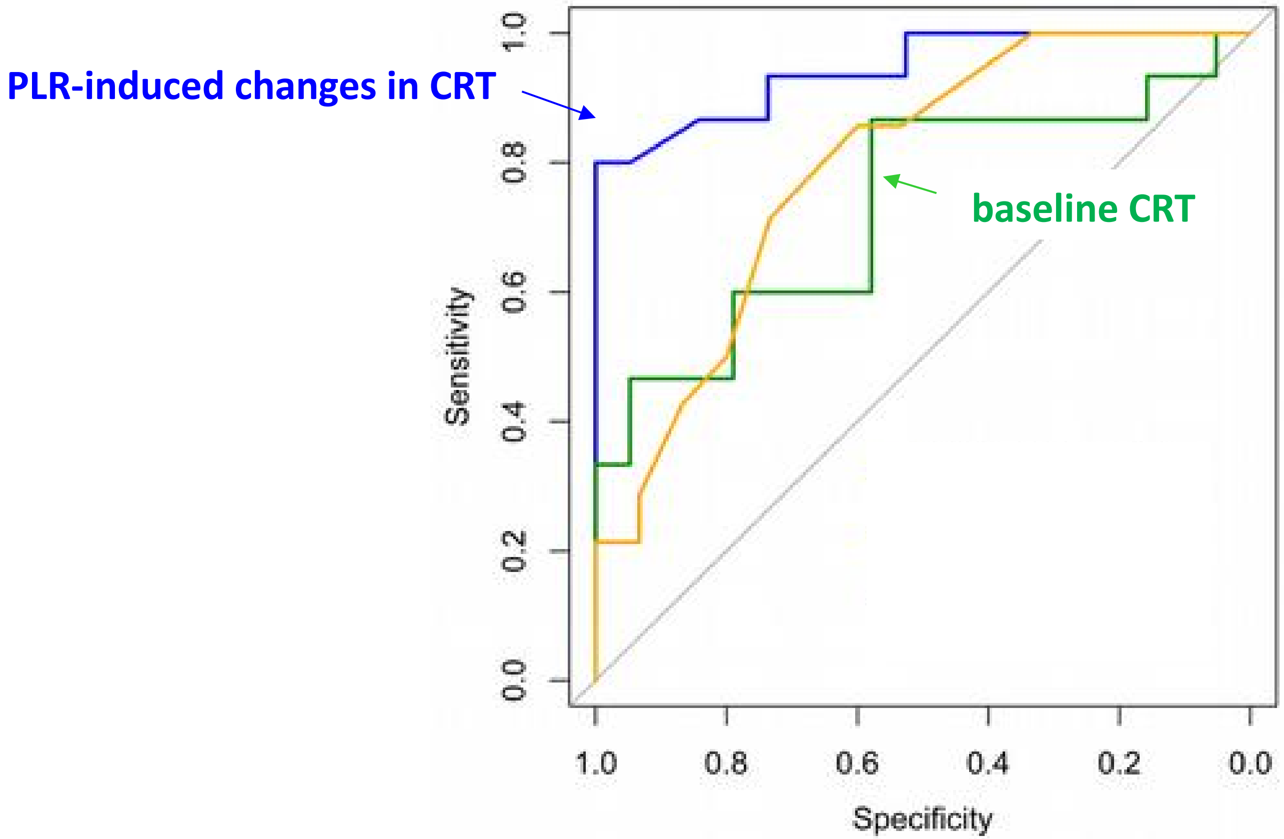
↗ in **CO** during PLR ≥ **10%**

Se = 100%
Sp = 76%

Capillary refill time variation induced by passive leg raising predicts capillary refill time response to volume expansion

Matthias Jacquet-Lagrèze[1,2*], Nourredine Bouhamri[1], Philippe Portran[1,2], Rémi Schweizer[1,2], Florent Baudin[3,2], Marc Lilot[4,5,6,7], William Fornier[1,2] and Jean-Luc Fellahi[1,2]

Critical Care (2019) 23:281



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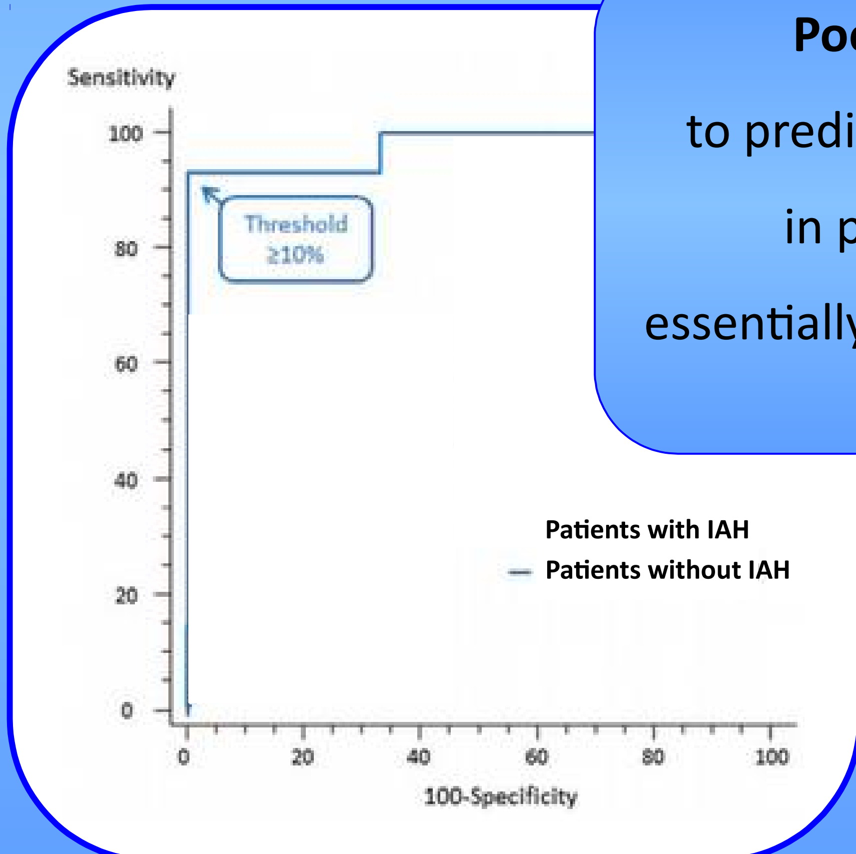
Intensive Care Med (2017) 43:304–377

Dynamic measures of assessing whether a patient requires additional fluid have been proposed in an effort to improve fluid management and have demonstrated better diagnostic accuracy at predicting those patients who are likely to respond to a fluid challenge by increasing stroke volume. These techniques encompass passive leg raises, fluid challenges against stroke volume measurements, or the variations in systolic pressure, pulse pressure, or stroke volume to changes in intrathoracic pressure induced by mechanical ventilation

Intra-Abdominal Hypertension Is Responsible for False Negatives to the Passive Leg Raising Test

Alexandra Beurton, MD[1,2]; Jean-Louis Teboul, MD, PhD[1,2]; Valentina Girotto, MD[1]; Laura Galarza, MD[1]; Nadia Anguel, MD[1]; Christian Richard, MD[1]; Xavier Monnet, MD, PhD[1,2]

Crit Care Med **2019; 47:e639-e647**



Poor ability of **PLR**

to predict fluid responsiveness

in patients with **IAH**

essentially due to false negatives

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Intensive Care Med (2016) 42:1935–1947

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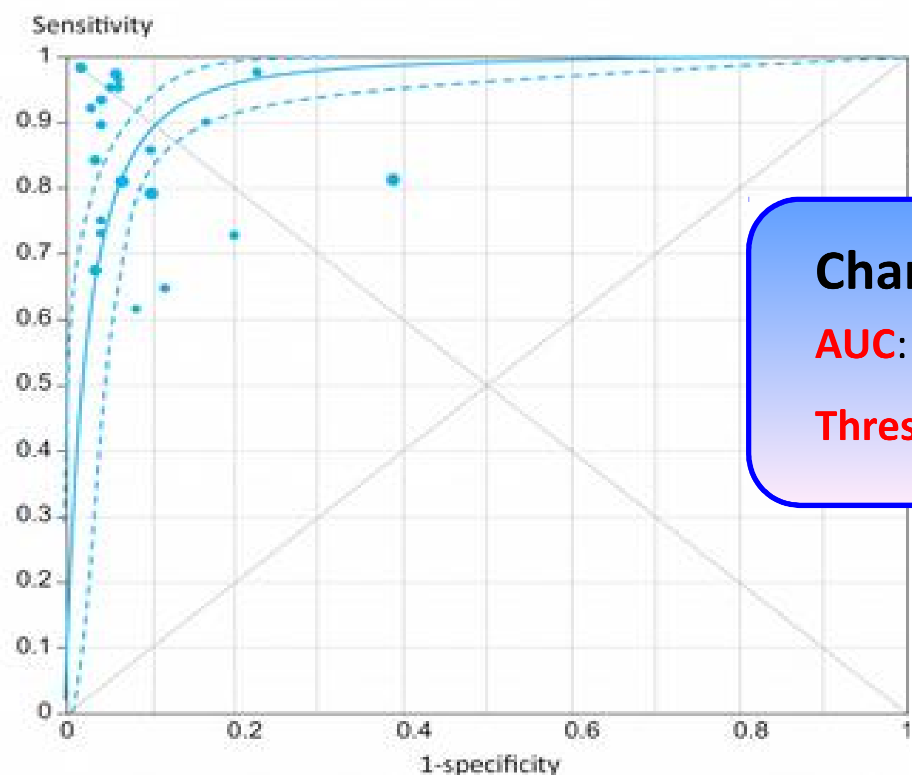

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Dynamic indices of preload responsiveness

The idea behind is that

the **more** the **cardiac output** (or stroke volume)

changes with **MV**,

the **more likely** the patient is **preload responsive**

He ... test

preload unresponsiveness

Respiratory variation of SV

(PPV, SVV)

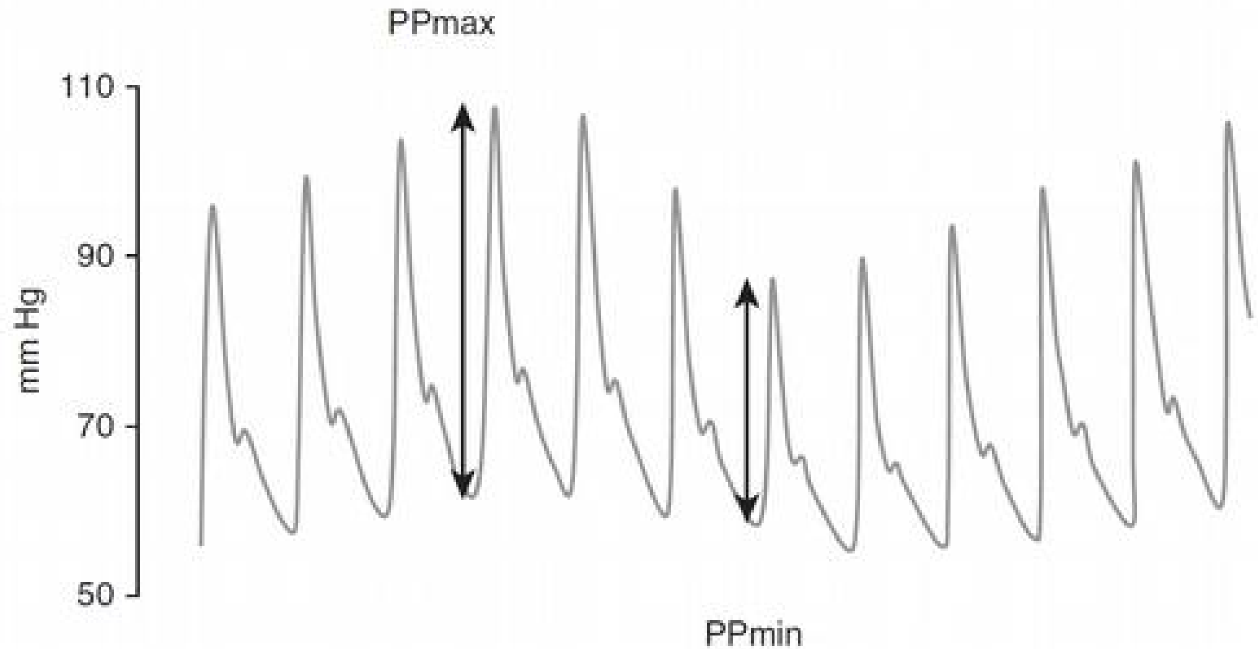
Ventricular preload

Arterial Pulse Pressure Variation with Mechanical Ventilation

Jean-Louis Teboul[1], Xavier Monnet[1], Denis Chemla[2], and Frédéric Michard[3]

Am J Respir Crit Care Med Vol 199, Iss 1, pp 22–31, Jan 1, 2019

$$PPV = \frac{PPmax - PPmin}{(PPmax + PPmin) / 2}$$



Arterial Pulse Pressure Variation with Mechanical Ventilation

Jean-Louis Teboul[1], Xavier Monnet[1], Denis Chemla[2], and Frédéric Michard[3]

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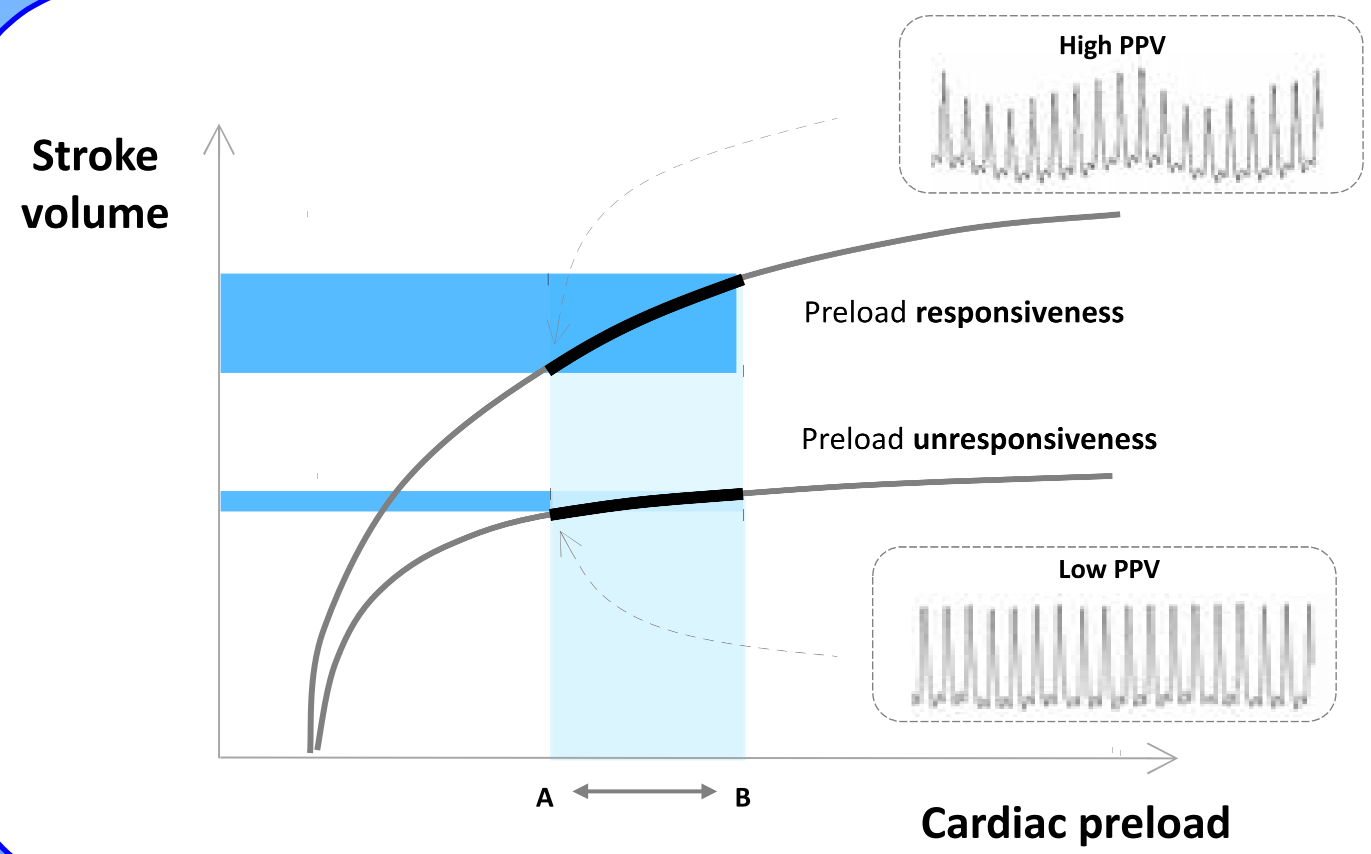
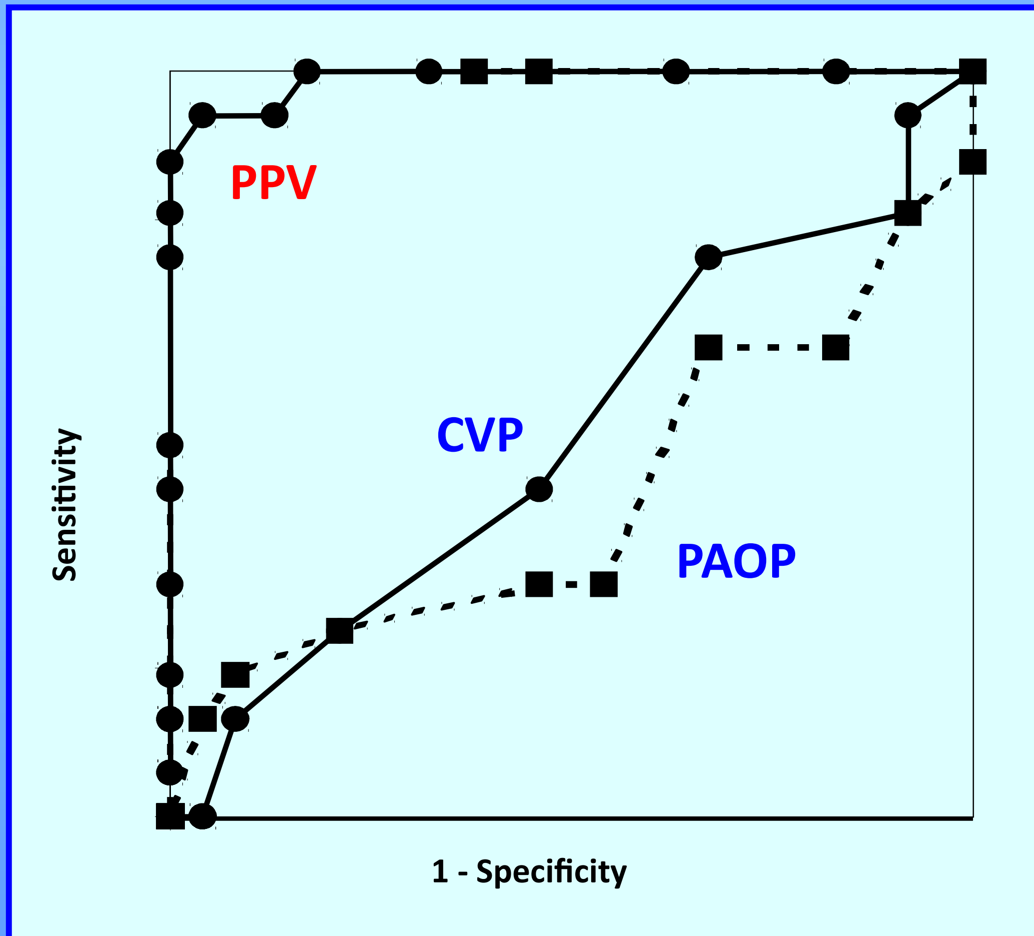


Relation between Respiratory Changes in Arterial Pulse Pressure and Fluid Responsiveness in Septic Patients with Acute Circulatory Failure

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

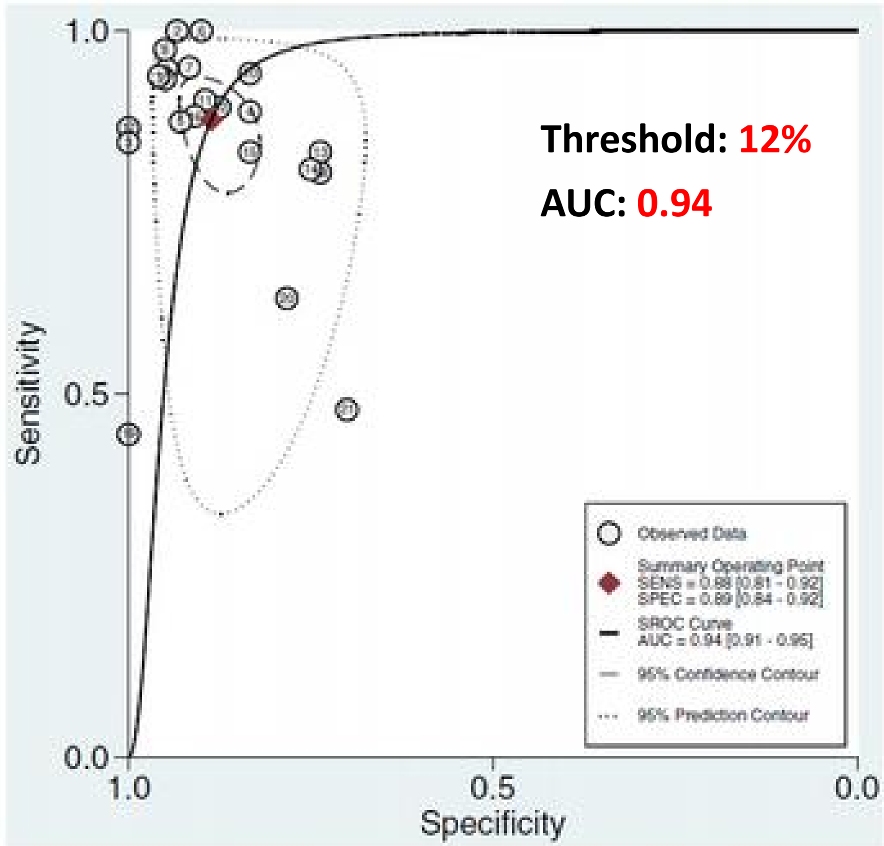


Does pulse pressure variation predict fluid responsiveness in critically ill patients? A systematic review and meta-analysis

Xiaobo Yang and Bin Du*

Critical Care 2014, **18**:650

22 studies



807 pts

Pulse Pressure Variation

Calculated automatically and displayed in real-time

by functional hemodynamic monitors

Arterial pressure waveform analysis → **Stroke volume**

Stroke Volume Variation

Calculated automatically and **displayed** in **real-time**

by functional hemodynamic monitors

Intensive Care Med (2012) 38:1429–1437

REVIEW

Claudio Sandroni
Fabio Cavallaro
Cristina Marano
Chiara Falcone
Paolo De Santis
Massimo Antonelli

Accuracy of plethysmographic indices as predictors of fluid responsiveness in mechanically ventilated adults: a systematic review and meta-analysis

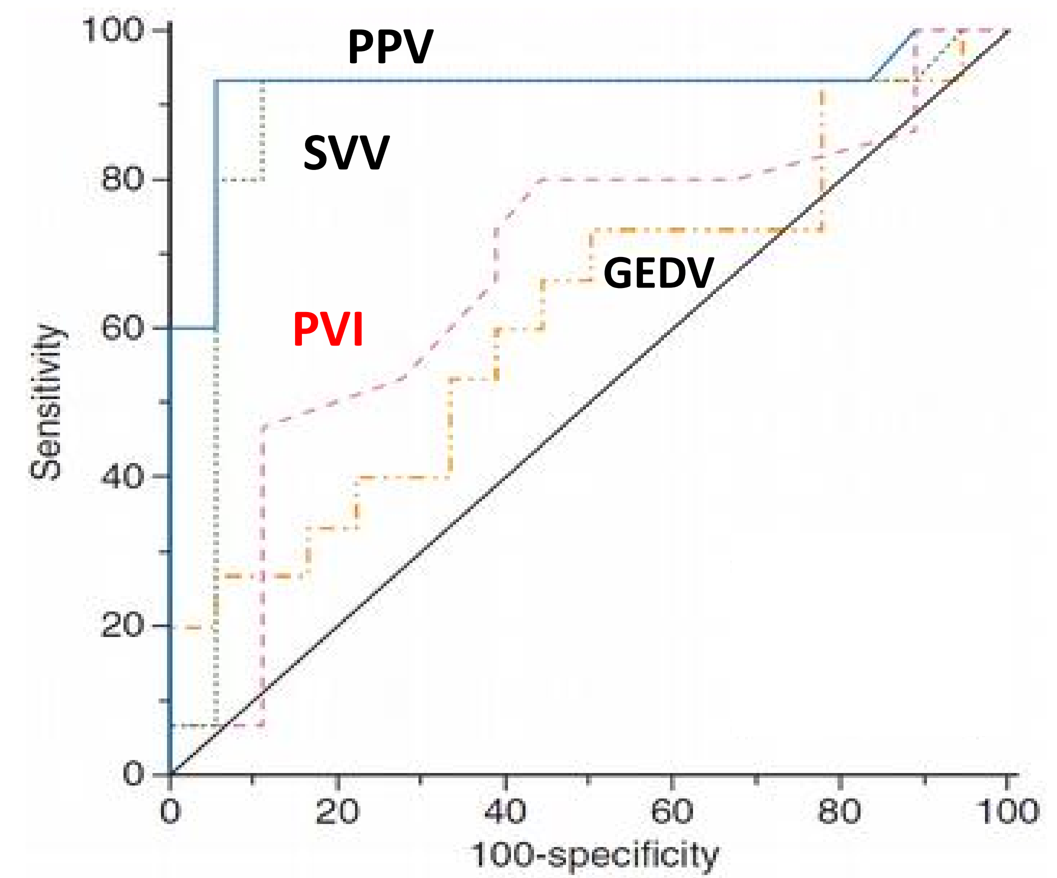
References (first author)	Index	Number of patients/boluses	% Responders	Best threshold	AUC (SE)	Sensitivity	Specificity
Natalini	ΔPOP	22/31	61.0	15.0	0.70 (0.094)	0.63	0.83
Solus-Biguenet	ΔPOP	8/54	42.0	9.5	0.68 (0.071)	0.64	0.68
Cannesson	ΔPOP	25/25	60.0	13.0	0.85 (0.081)	0.93	0.90
Feissel	ΔPOP	23/28	64.0	14.0	0.94 (0.050)	0.94	0.80
Wyffels	ΔPOP	32/32	62.5	11.8	0.89 (0.061)	0.90	0.83
Hoiseth	ΔPOP	25/34	64.7	11.4	0.72 (0.082)	0.86	0.67
Cannesson	ΔPOP[b]	25/25	64.0	12.0	0.94 (0.043)	0.87	0.89
	PVI	25/25	64.0	14.0	0.93 (0.051)	0.81	1.00
Zimmermann	PVI	20/20	75.0	9.5	0.97 (0.033)	0.93	1.00
Desgranges	PVI	28/28	68.0	12.0	0.84 (0.077)	0.74	0.67
Hood (large bolus)	PVI	25/25	88.0	10.0	0.96 (0.031)	0.86	1.00
Hood (small bolus)	PVI	25/63	36.5	10.0	0.71 (0.071)	0.65	0.67
Overall[a]		233/365	62.3 ± 14.0	9.5–15.0	0.85 [0.79–0.92]	0.80 [0.74–0.85]	0.76 [0.68–0.82]

British Journal of Anaesthesia 110 (2): 207–13 (2013)

BJA

Pleth variability index is a weak predictor of fluid responsiveness in patients receiving norepinephrine

X. Monnet[1,2*], L. Guérin[1,2], M. Jozwiak[1,2], A. Bataille[1,2], F. Julien[1,2], C. Richard[1,2] and J.-L. Teboul[1,2]

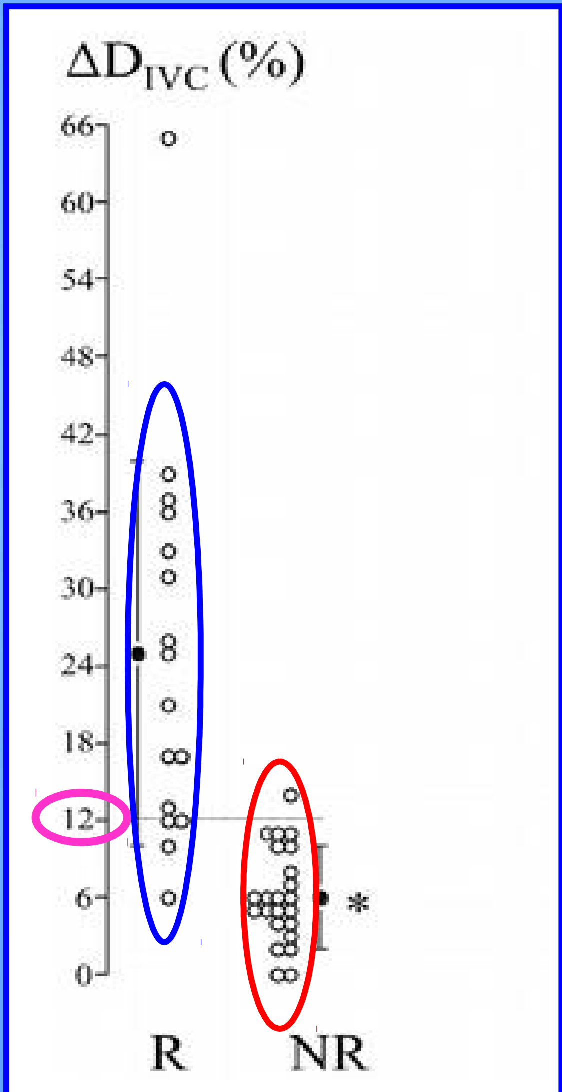


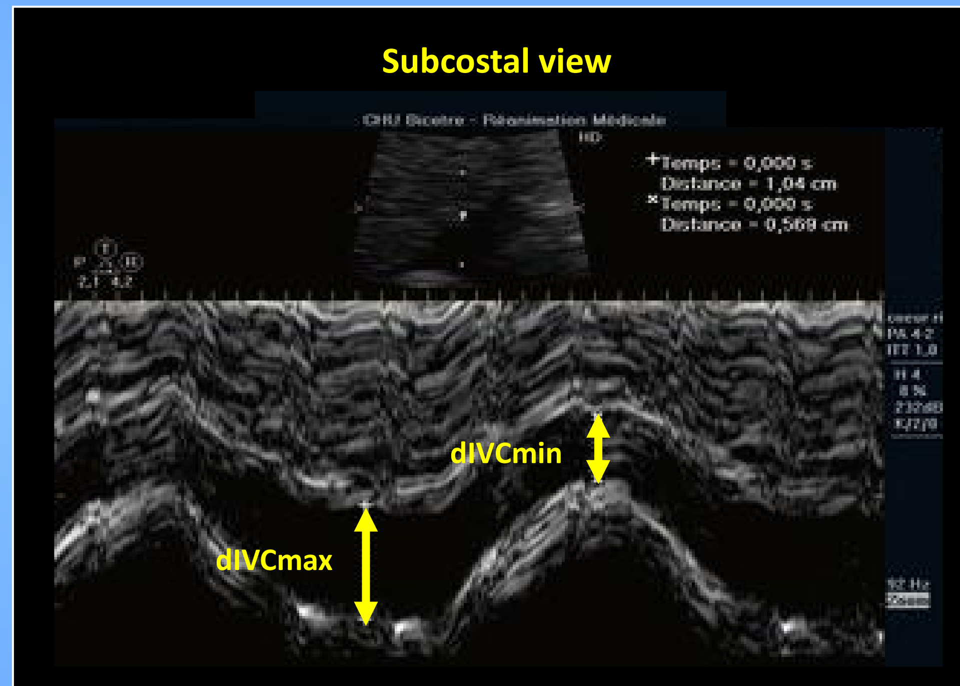
Intensive Care Med (2004) 30:1834–1837

BRIEF REPORT

Marc Feissel
Frédéric Michard
Jean-Pierre Faller
Jean-Louis Teboul

The respiratory variation in inferior vena cava diameter as a guide to fluid therapy





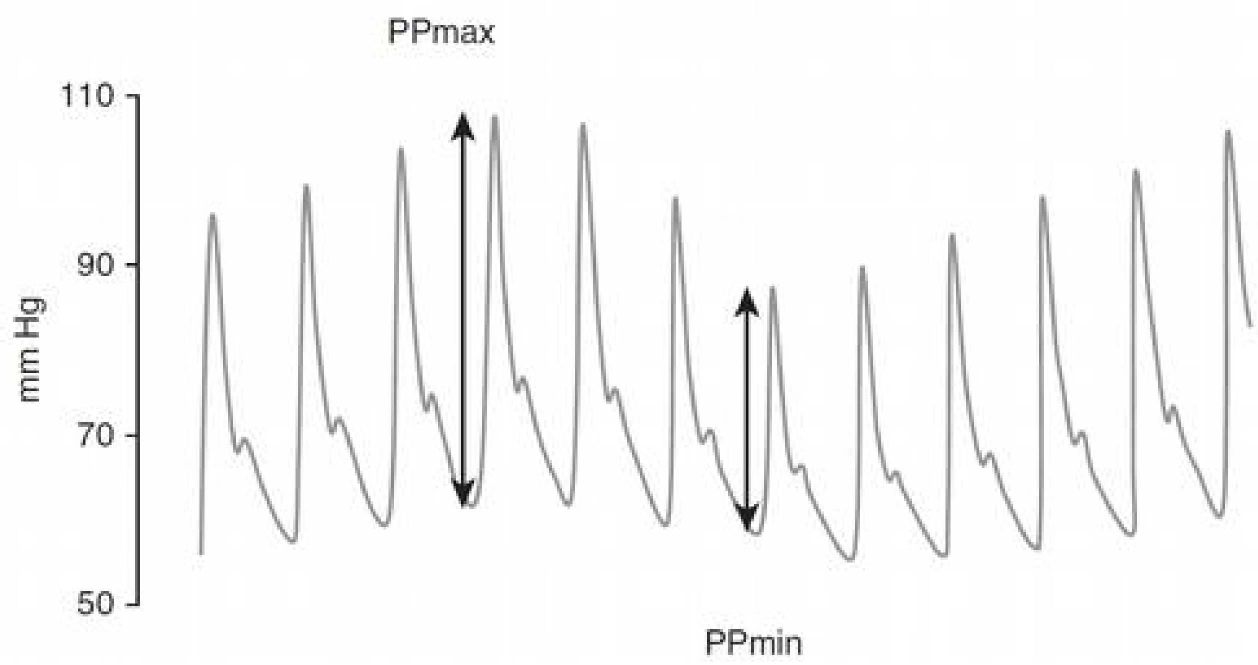
$$\Delta\ dIVC\ \% = \frac{dIVCmax - dIVCmin}{(dIVCmax + dIVCmin)/2}$$

Arterial Pulse Pressure Variation with Mechanical Ventilation

Jean-Louis Teboul[1], Xavier Monnet[1], Denis Chemla[2], and Frédéric Michard[3]

Am J Respir Crit Care Med Vol 199, Iss 1, pp 22–31, Jan 1, 2019

$$PPV = \frac{PPmax - PPmin}{(PPmax + PPmin) / 2}$$



Applicability of pulse pressure variation: how many shades of grey?

Frederic Michard[1*], Denis Chemla[2] and Jean-Louis Teboul[3]

Critical Care (2015) 19:144

		False positive	False negative
L	Low HR/RR ratio (Extreme bradycardia or high frequency ventilation)		✔
I	Irregular heart beats	✔	
M	Mechanical ventilation with low tidal volume		✔
I	Increased abdominal Pressure (Pneumoperitoneum)	✔	
T	Thorax open		✔
S	Spontaneous breathing	✔	✔

Fluid responsiveness: **what** do **I use** at the bedsise ?

1- **What** is **fluid responsiveness**?

2- **Why** is it so **important** to **predict fluid responsiveness**?

3- To predict fluid responsiveness, **I don't use** (unreliable) traditional **markers** of **preload**

4- To predict fluid responsiveness, **I use** (reliable) **dynamic** indices or tests

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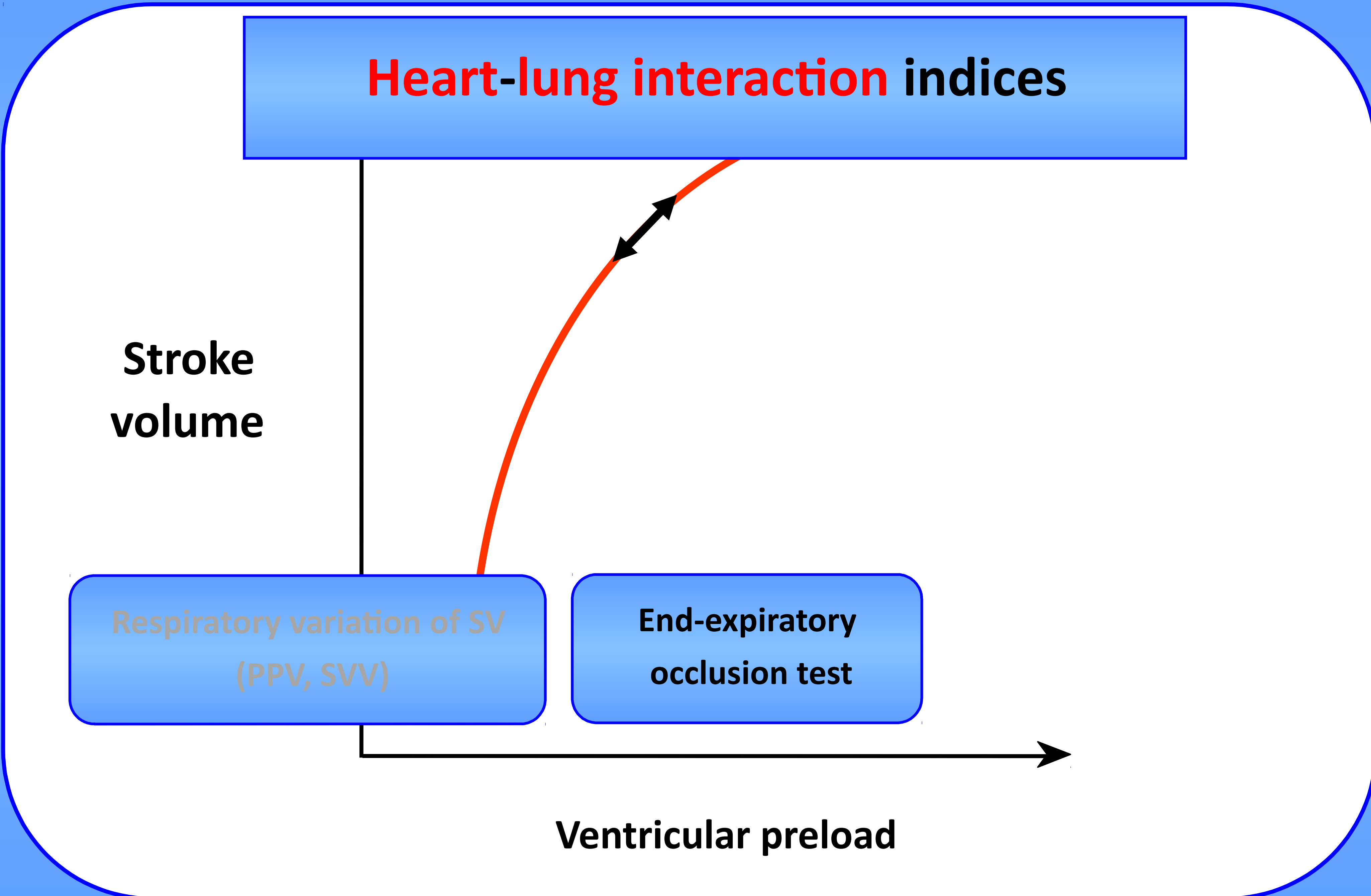
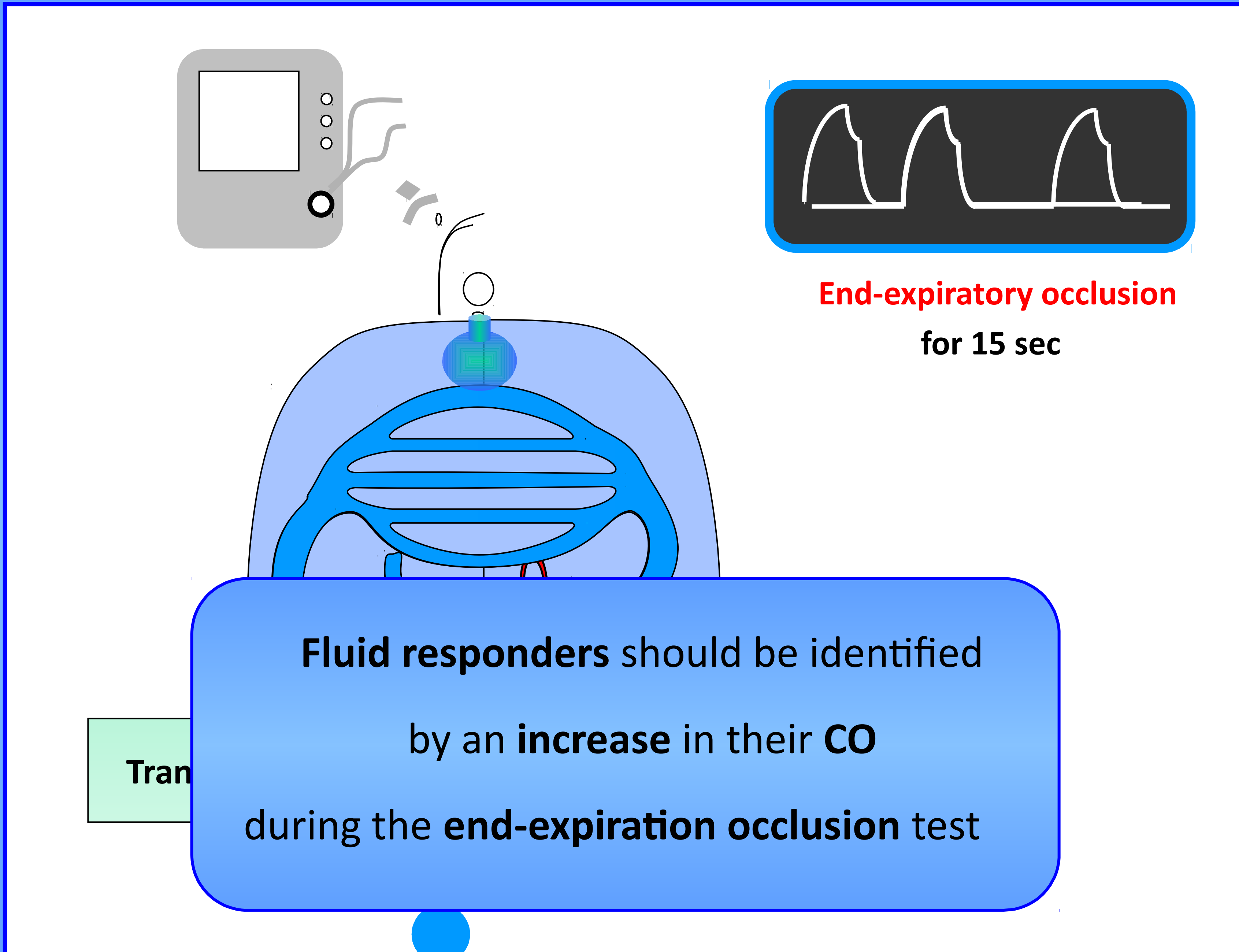


Heart-lung interaction indices
Stroke volume
Respiratory variation of SV (PPV, SVV)
End-expiratory occlusion test
Ventricular preload

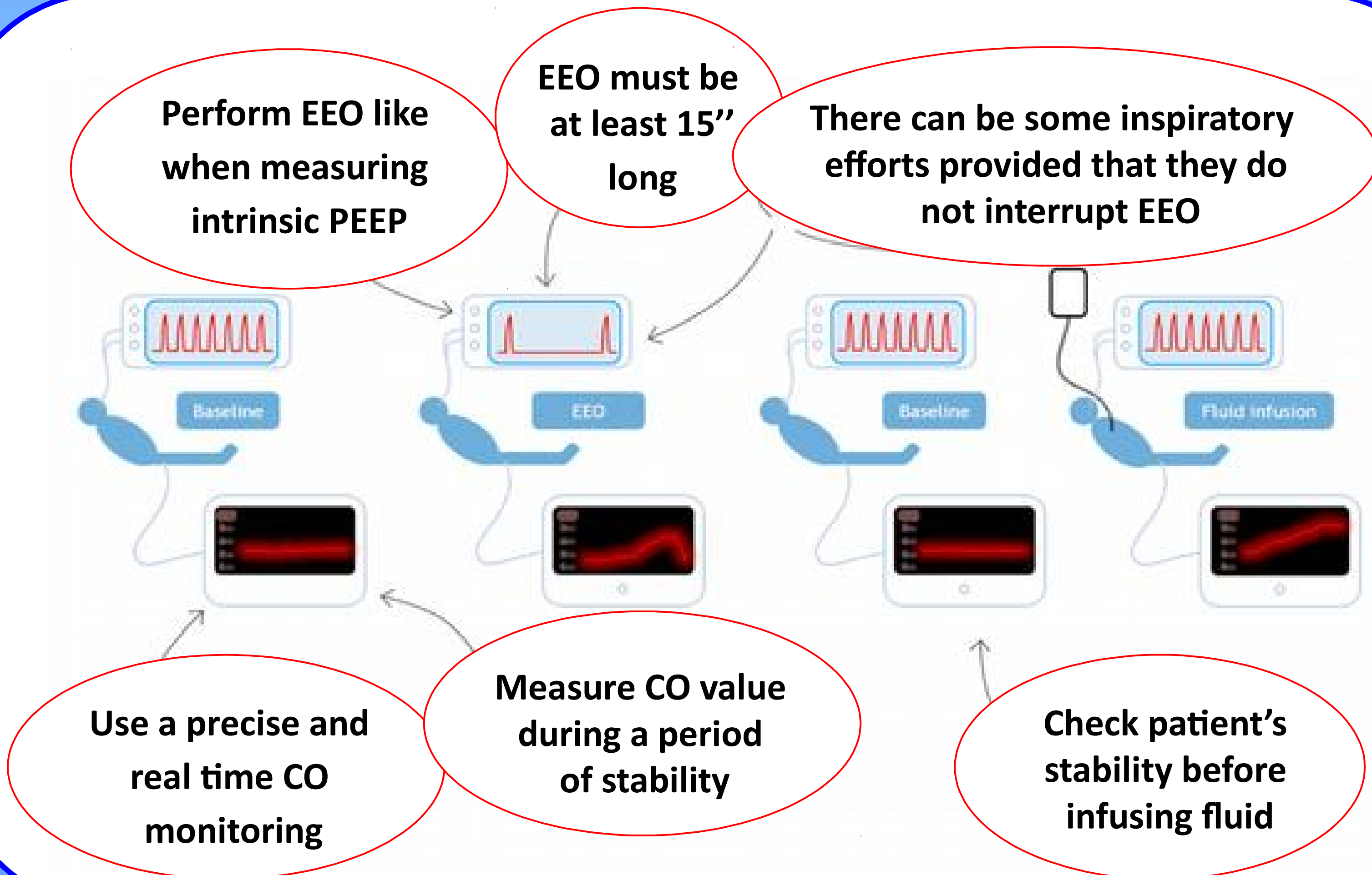

End-expiratory occlusion
for 15 sec
Fluid responders should be identified
by an **increase** in their **CO**
during the **end-expiration occlusion** test

The end-expiratory occlusion test: please, let me hold your breath!

Francesco Gavelli[1,2,3]*, Jean-Louis Teboul[1,2] and Xavier Monnet[1,2]

Critical Care (2019) 23:274

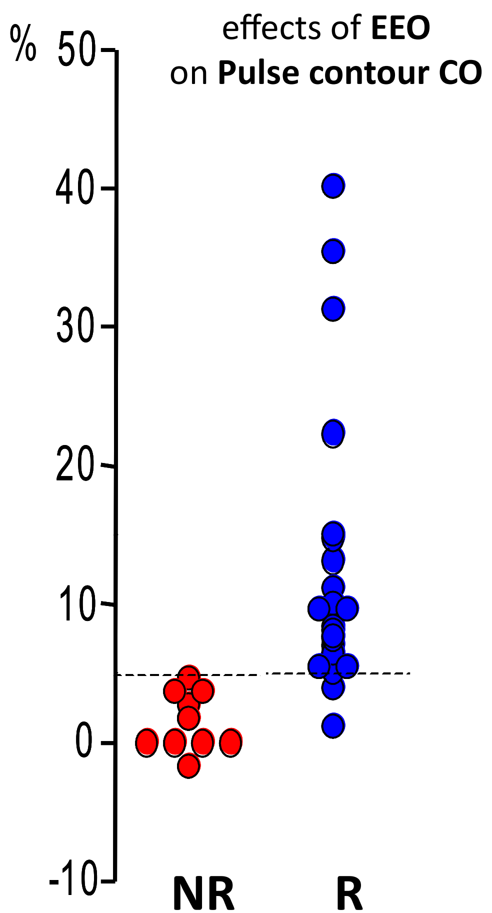
NEW!



Predicting volume responsiveness by using the end-expiratory occlusion in mechanically ventilated intensive care unit patients

Xavier Monnet, MD, PhD; David Osman, MD; Christophe Ridel, MD; Bouchra Lamia, MD; Christian Richard, MD; Jean-Louis Teboul, MD, PhD

Crit Care Med 2009; 37:951–956

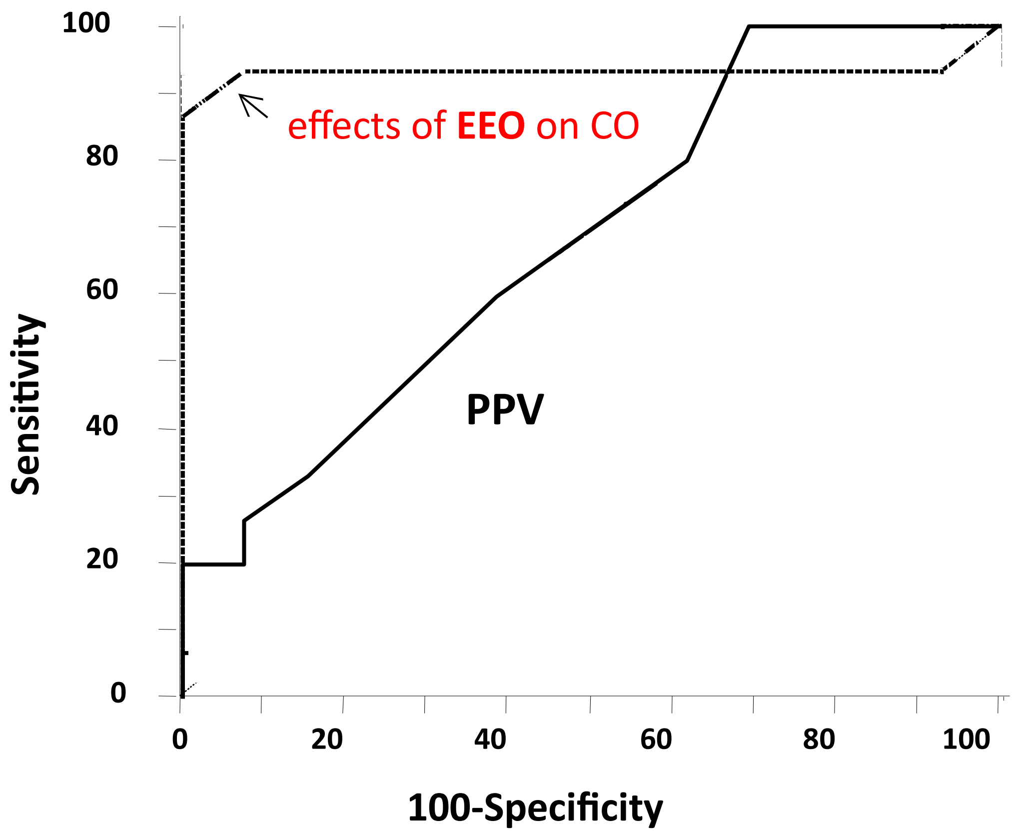


Passive leg-raising and end-expiratory occlusion tests perform better than pulse pressure variation in patients with low respiratory system compliance

Xavier Monnet, MD, PhD; Alexandre Bleibtreu, MD; Alexis Ferre, MD; Martin Dres, MD; Rim Gharbi, MD; Christian Richard, MD; Jean-Louis Teboul, MD, PhD

Crit Care Med 2012; 40:152–157

Compliance of the respiratory system < 30 mL/cmH_2O



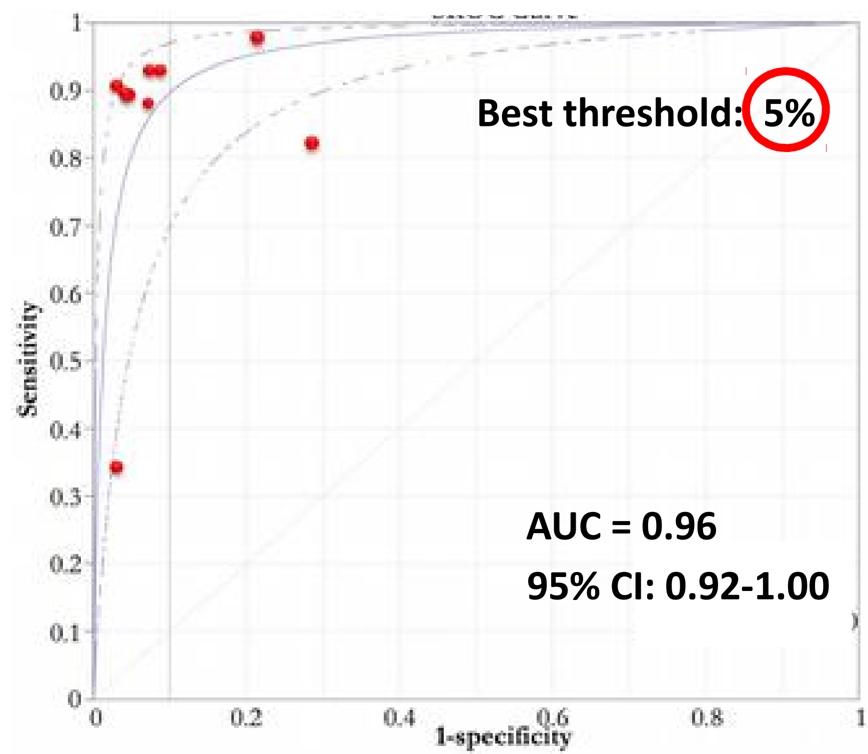
Functional hemodynamic tests: a systematic review and a metanalysis on the reliability of the end-expiratory occlusion test and of the mini-fluid challenge in predicting fluid responsiveness

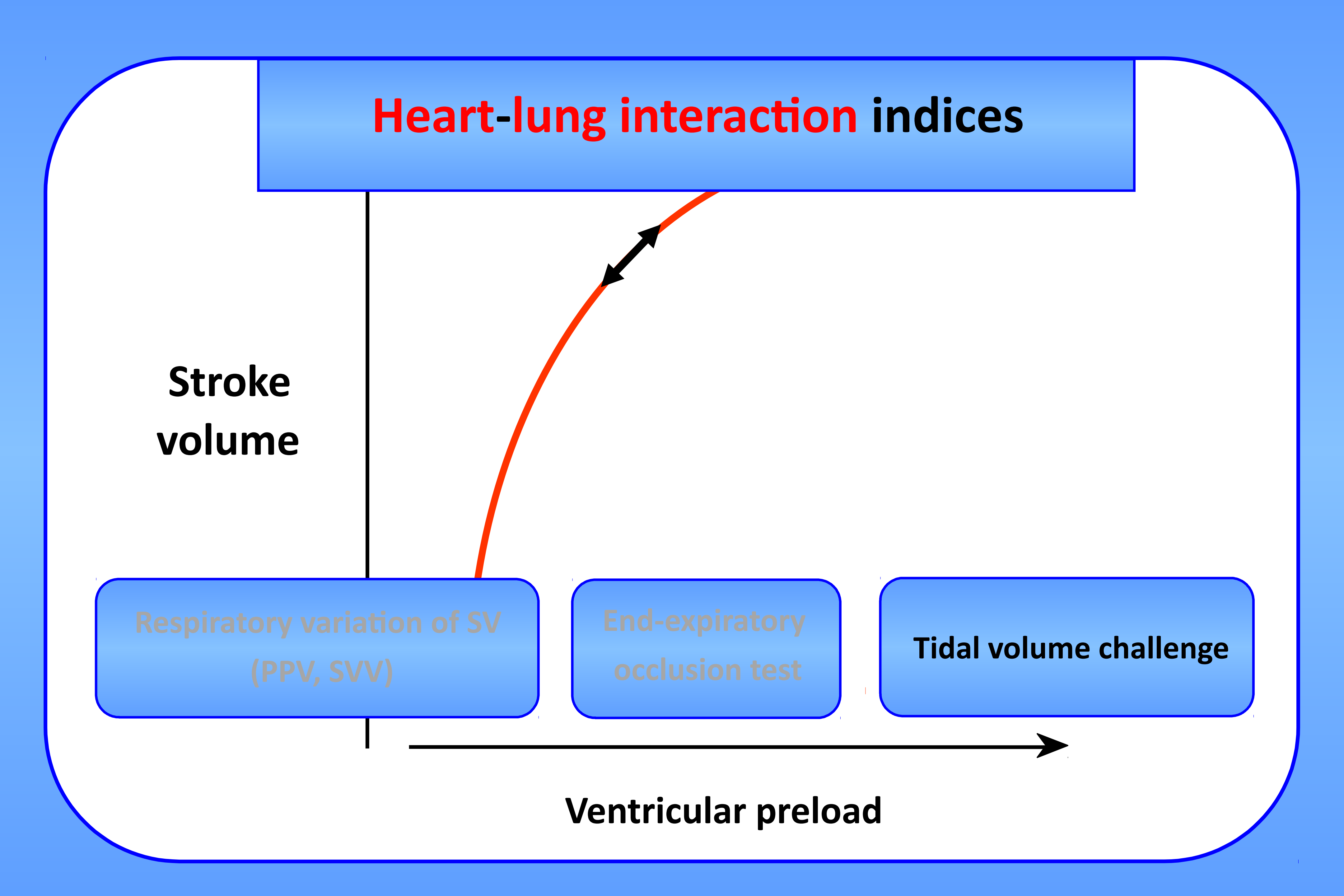
Antonio Messina[1*], Antonio Dell'Anna[2,3], Marta Baggiani[4], Flavia Torrini[2,3], Gian Marco Maresca[2,3], Victoria Bennett[5], Laura Saderi[6], Giovanni Sotgiu[6], Massimo Antonelli[2,3] and Maurizio Cecconi[1,7]

Critical Care (2019) 23:264

9 studies

EEOT

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Stroke volume
Respiratory variation of SV (PPV, SVV)
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Tidal volume challenge
Ventricular preload

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

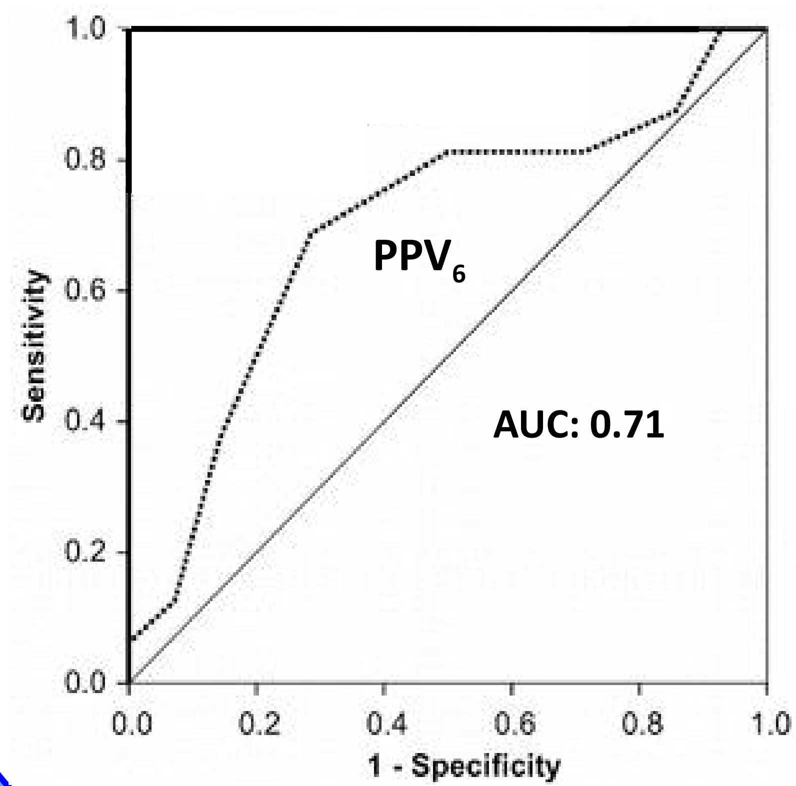
Sheila Nainan Myatra, MD, FCCM[1]; Natesh R. Prabu, MD[1]; Jigeeshu Vasishtha Divatia, MD, FCCM[1]; Xavier Monnet, MD, PhD[2]; Atul Prabhakar Kulkarni, MD, FICCM[1]; Jean-Louis Teboul, MD, PhD[2]

Crit Care Med 2017; 45:415–421

PPV at **6 mL/kg**

cannot predict

fluid responsiveness



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

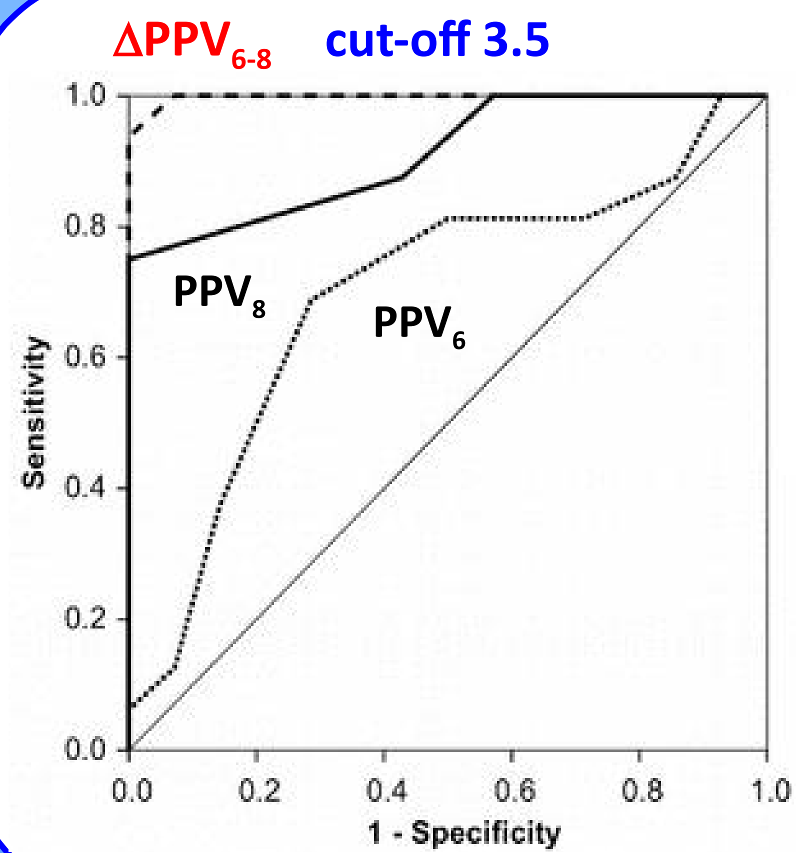
Crit Care Med 2017; 45:415–421

Tidal volume challenge

Transient (1 min) **increase**

in **tidal volume**

from **6** to **8 mL/kg**

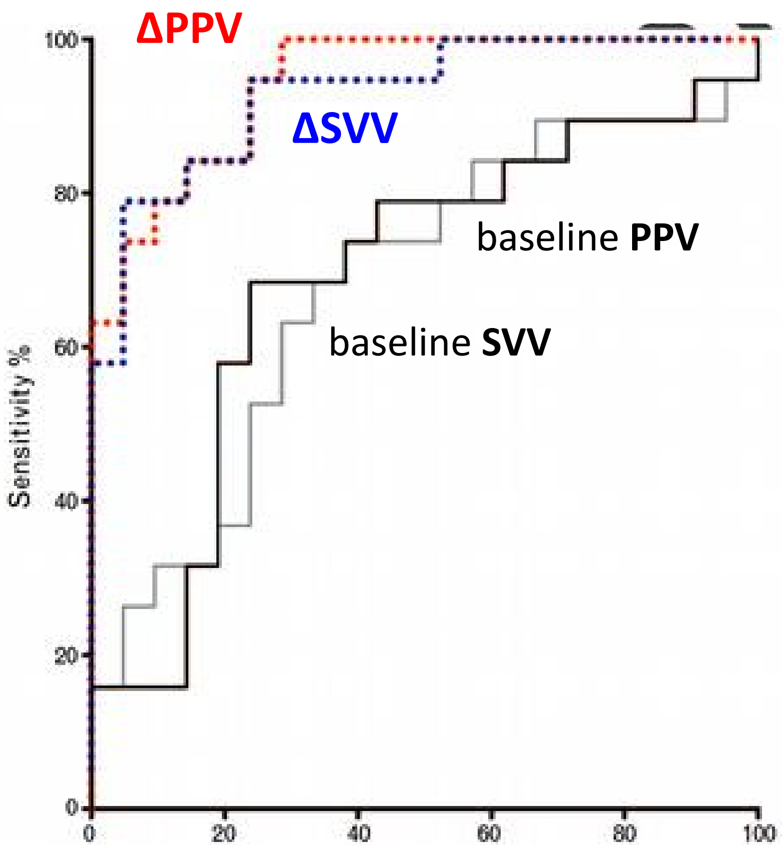


Tidal volume challenge to predict fluid responsiveness in the operating room

A prospective trial on neurosurgical patients undergoing protective ventilation

Antonio Messina, Claudia Montagnini, Gianmaria Cammarota, Silvia De Rosa, Fabiana Giuliani, Lara Muratore, Francesco Della Corte, Paolo Navalesi and Maurizio Cecconi

Eur J Anaesthesiol 2019; **36**:1–9



ΔPPV = increase in **PPV** during **TVC**

ΔSVV = increase in **SVV** during **TVC**

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Given that **hypovolemia** is present in 90% of shock states

(100% in septic shock),

it is logical to infuse a **fluid** bolus **early**

without *using any* ***predictor*** *of* ***fluid responsiveness***

- Be **smart** ….. but **not** too much
- **Don't waste** too much **time**

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Decision of **continuing** fluid infusion

- persistence of **hemodynamic instability/peripheral hypoperfusion** (mottled skin, hypotension, oliguria, hyperlactatemia…)
- <u>and</u> presence of **preload responsiveness**
- <u>and</u> **limited risks** of **fluid overload**

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Decision of **stopping** fluid infusion

- either **disappearance** of hemodynamic **instability**
- or presence of preload **unresponsiveness**
- or **high risks** of **fluid overload** (value of **EVLW** and **PVPI**)

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Thank you