Assessment of **fluid responsiveness**:

What's **new**?

Prof. Jean-Louis TEBOUL

Medical ICU

Bicetre hospital

University Paris-Saclay

France

Conflicts of interest

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

- **What is** fluid responsiveness?
- **Why** to assess fluid responsiveness?
- **When** to assess fluid responsiveness?
- **How** to assess fluid responsiveness?

- **What is** fluid responsiveness?
- **Why** to assess fluid responsiveness?
- **When** to assess fluid responsiveness?
- **How** to assess fluid responsiveness?

Fluid responsiveness

is defined

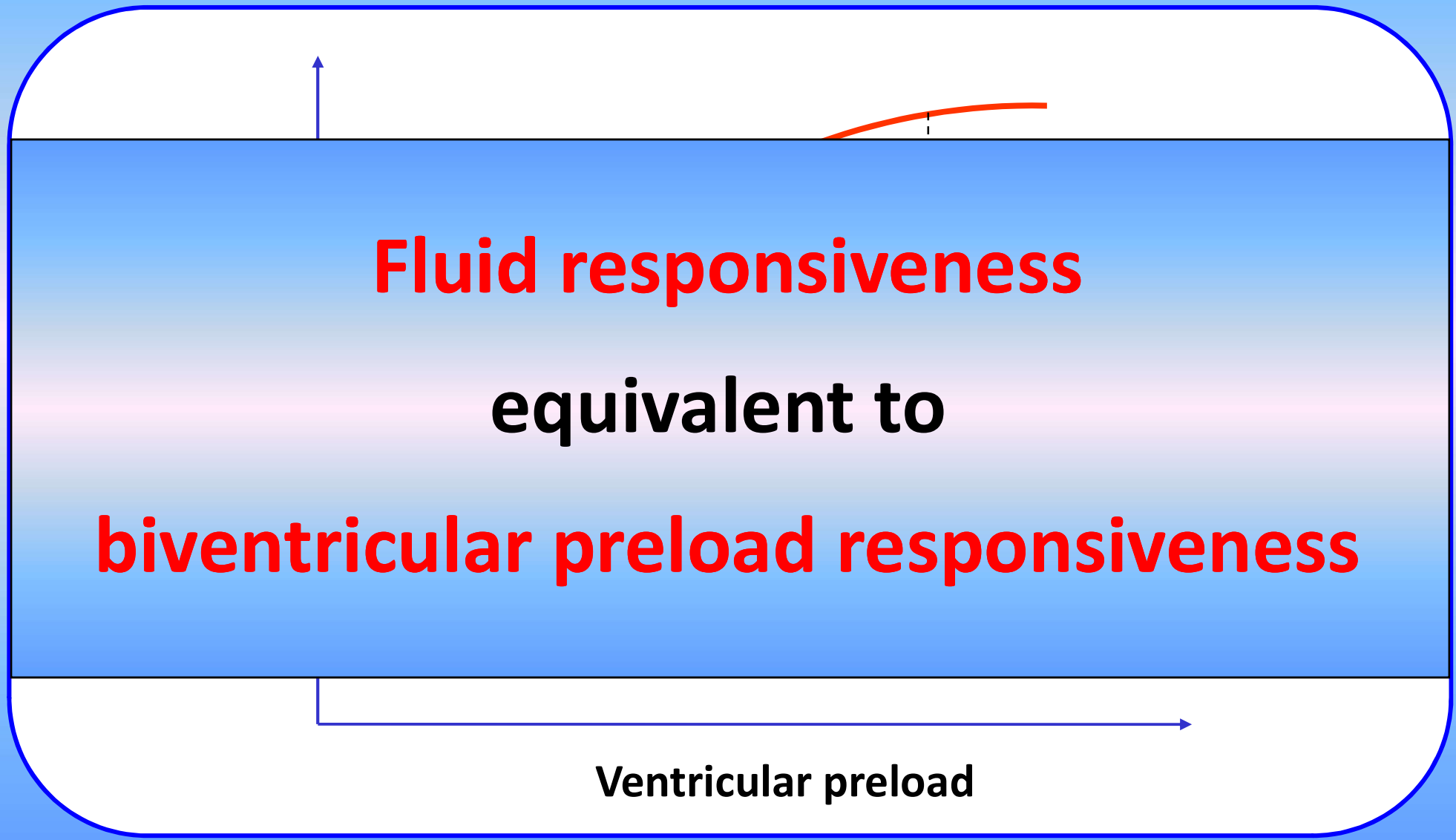
as the capacity of the heart

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

in response to a **volume challenge**

Fluid infusion will increase LV stroke volume

only if both ventricles are preload responsive



- **What is** fluid responsiveness?
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Why to assess **fluid responsiveness**?

- **Not all** patients even in shock are **fluid responsive**
- **Fluid responsiveness** is a **dynamic** phenomenon
- **Fluid** infusion in **nonresponders** is **risky**
- **Fluid overload** in general is **harmful**
- Use of **fluid responsiveness tests** is associated with **improved outcome**

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; 121:2000–2008

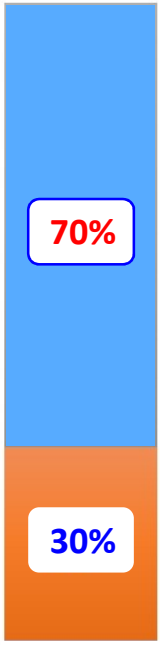
Only **52%** of patients **increase**

their **cardiac output** in response

to **fluid** administration

Source	Patients	EC	Fluid	Volume	Speed of	Definition of	Rate of Response, %
Calvin et al[2]							71
Schneider et							72
Reuse et al[4]							63
Magder et al[5]							52
Diebel et al[6]							59
Diebel et al[7]							40
Wagner and Leatherma							56
Tavernier et a							60
Magder and L							45
Tousignant et al[11]	40	40	HES	500	15	$\Delta SV > 20\%$	40
Michard et al[12]	40	40	HES	500	30	$\Delta CO > 15\%$	40
Feissel et al[13]	19	19	HES	8 mL/kg	30	$\Delta CO > 15\%$	53
Total	334	406					52

Non-Responders Responders



H_0

JAMA | Original Investigation | CARING FOR THE CRITICALLY ILL PATIENT

Effect of a Resuscitation Strategy Targeting Peripheral Perfusion Status vs Serum Lactate Levels on 28-Day Mortality Among Patients With Septic Shock

The ANDROMEDA-SHOCK Randomized Clinical Trial

Glenn Hernández, MD, PhD; Gustavo A. Ospina-Tascón, MD, PhD; Lucas Petri Damiani, MSc; Elisa Estenssoro, MD; Arnaldo Dubin, MD, PhD; Javier Hurtado, MD; Gilberto Friedman, MD, PhD; Ricardo Castro, MD, MPH; Leyla Alegría, RN, MSc; Jean-Louis Teboul, MD, PhD; Maurizio Cecconi, MD, FFICM; Giorgio Ferri, MD; Manuel Jibaja, MD; Ronald Pairumani, MD; Paula Fernández, MD; Diego Barahona, MD; Vladimir Granda-Luna, MD, PhD; Alexandre Biasi Cavalcanti, MD, PhD; Jan Bakker, MD, PhD; for the ANDROMEDA-SHOCK Investigators and the Latin America Intensive Care Network (LIVEN)

JAMA. 2019;321(7):654-664.

Hernandez et al. *JAMA* 2019

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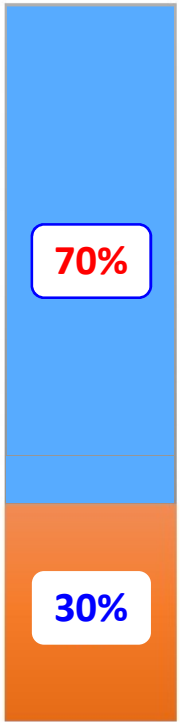
Non-Responders Responders



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JAMA. 2019;321(7):654-664.

H_0 H_2 H_4 H_6 H_8

Hernandez et al. *JAMA* 2019

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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
Blood		.004
Cirrho		.008
Pseud		.017
Medica		.049
Femal		.044

Positive cumulative **fluid balance**

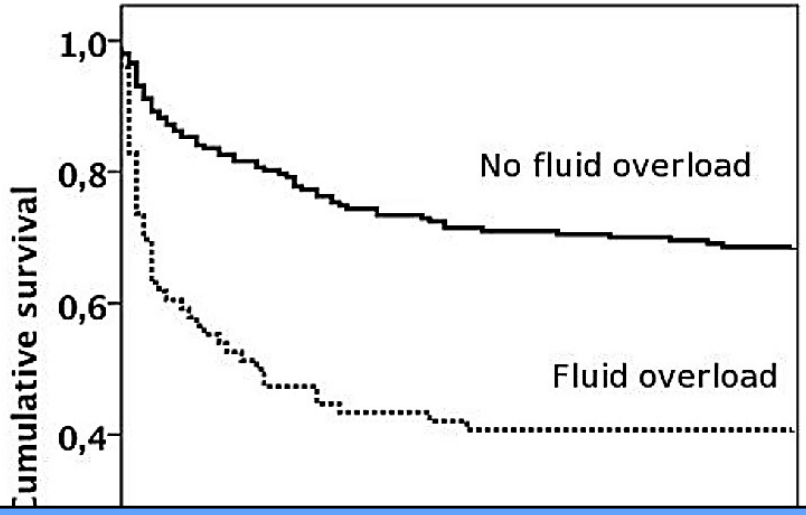
is an **independent** factor associated with **mortality**

Critical Care 2012, **16**:R197

RESEARCH Open Access

Fluid overload is associated with an increased risk for 90-day mortality in critically ill patients with renal replacement therapy: data from the prospective FINNAKI study

Suvi T Vaara[1*], Anna-Maija Korhonen[1], Kirsi-Maija Kaukonen[1], Sara Nisula[1], Outi Inkinen[2], Sanna Hoppu[3], Jouko J Laurila[4], Leena Mildh[1], Matti Reinikainen[5], Vesa Lund[6], Ilkka Parviainen[7] and Ville Pettilä[1,8], for The FINNAKI study group



Patients with **RRT**: **higher** 90-day **mortality**

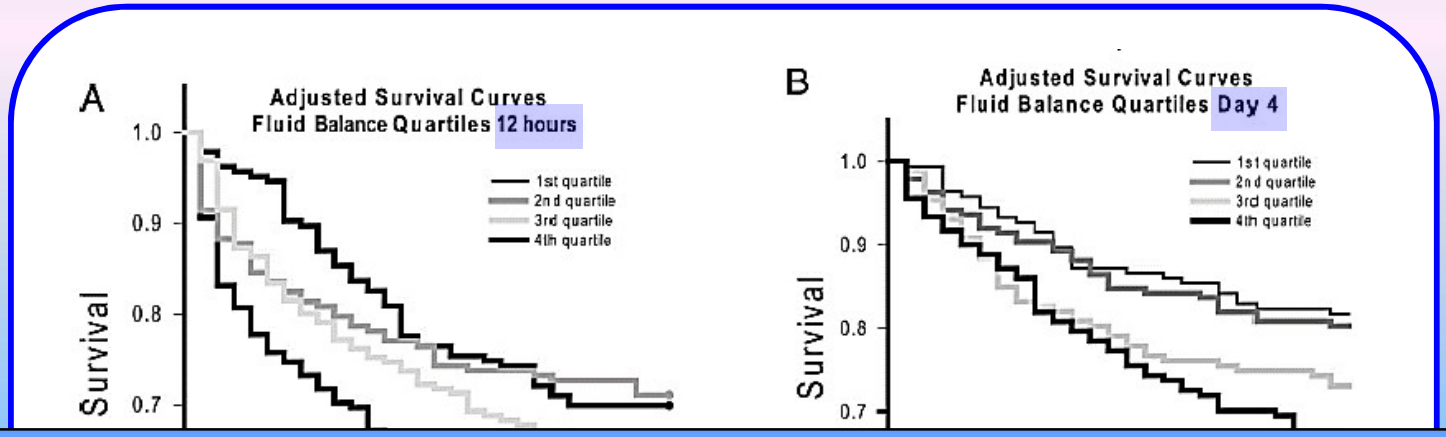
in the **fluid overload** group

Fluid resuscitation in septic shock: A positive fluid balance and elevated central venous pressure are associated with increased mortality*

John H. Boyd, MD, FRCP(C); Jason Forbes, MD; Taka-aki Nakada, MD, PhD; Keith R. Walley, MD, FRCP(C); James A. Russell, MD, FRCP(C)

Crit Care Med 2011; 39:259-65

- **A retrospective review of the VASST data**
- **Use of fluids during the first 4 days**
- **778 patients with septic shock**
- **Quartiles 1-4: dry to wet**



Patients with **septic shock**: patients with **cumulative positive fluid balance** at **H_{12}** and at **Day_4** had **decreased survival**

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
Maximal blood lactate	1.29	(1.14 - 1.46)	0.0001
Mean PEEP	0.78	(0.67 – 0.91)	0.002
Minimal PaO_2 / FiO_2	0.98	(0.97 - 0.99)	0.006
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

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Characteristics of resuscitation, and association between use of dynamic tests of fluid responsiveness and outcomes in septic patients: results of a multicenter prospective cohort study in Argentina

Arnaldo Dubin[1*], Cecilia Loudet[2], Vanina S. Kanoore Edul[3], Javier Osatnik[4], Fernando Ríos[5], Daniela Vásquez[6], Mario Pozo[7], Bernardo Lattanzio[8], Fernando Pálizas[7], Francisco Klein[9], Damián Piezny[5], Paolo N. Rubatto Birri[1], Graciela Tuhay[9], Analía García[10], Analía Santamaría[11], Graciela Zakalik[12], Cecilia González[13] and Elisa Estenssoro[2] on behalf of the investigators of the SATISEPSIS group

Ann. Intensive Care (2020) 10:40

Table 4 Independent determinants of mortality according to logistic regression analysis

Variable	Odds ratio	[CI 95%]	*P*
Charlson score	1.21	[1.07–1.36]	0.002
SOFA score	1.16	[1.07–1.26]	< 0.0001
Serum lactate	1.21	[1.08–1.37]	0.001
Mechanical ventilation	12.2	[5.73–26.00]	< 0.0001
Dynamic tests of fluid responsiveness	0.37	[0.21–0.67]	0.001

Incorporating Dynamic Assessment of Fluid Responsiveness Into Goal-Directed Therapy: A Systematic Review and Meta-Analysis

Joseph M. Bednarczyk, MD, FRCPC[1]; Jason A. Fridfinnson, MD[2]; Anand Kumar, MD, FRCPC[1]; Laurie Blanchard, MLIS[3]; Rasheda Rabbani, PhD[3,4]; Dean Bell, MD, FRCPC[1]; Duane Funk, MD, FRCPC[1]; Alexis F. Turgeon, MD, MSc, FRCPC[5]; Ahmed M. Abou-Setta, MD, PhD[4]; Ryan Zarychanski, MD, MSc, FRCPC[1,3,4]

Crit Care Med 2017; 45:1538–1545

Study or Subgroup	Dynamic therapy Events	Total	Control Events	Total	Weight	Risk Ratio M-H, Random, 95% CI
Kapoor 2008	0	15	0	15		Not estimable
Goepfert 2013	0	50	0	50		Not estimable
Kumar 2016	0	30	0	30		Not estimable
Colantonio 2015	0	42	4	44	1.4%	0.12 [0.01, 2.10]
Scheeren 2013	0	32	2	32	1.3%	0.20 [0.01, 4.01]
Buettner 2009	0	40	1	40	1.1%	0.33 [0.01, 7.95]
Parke 2015	0	70	1	74	1.1%	0.35 [0.01, 8.50]
Lopes 2007	2	17	5	16	5.1%	0.38 [0.08, 1.67]
Richard 2015	7	30	14	30	20%	0.50 [0.24, 1.06]
Pearse 2015	28	368	42	366	54.7%	0.66 [0.42, 1.05]
Jhanji 2010	9	90	6	45	12.1%	0.75 [0.28, 1.98]
Mayer 2010	2	30	2	30	3.2%	1.00 [0.15, 6.64]
Total (95% CI)		**814**		**772**	**100.0%**	**0.59 [0.42, 0.83]**
Total events	48		77			

Heterogeneity: Tau² = 0.00; Chi² = 3.28, df = 8 (P = 0.92); I² = 0%

Test for overall effect: Z = 3.04 (P = 0.002)

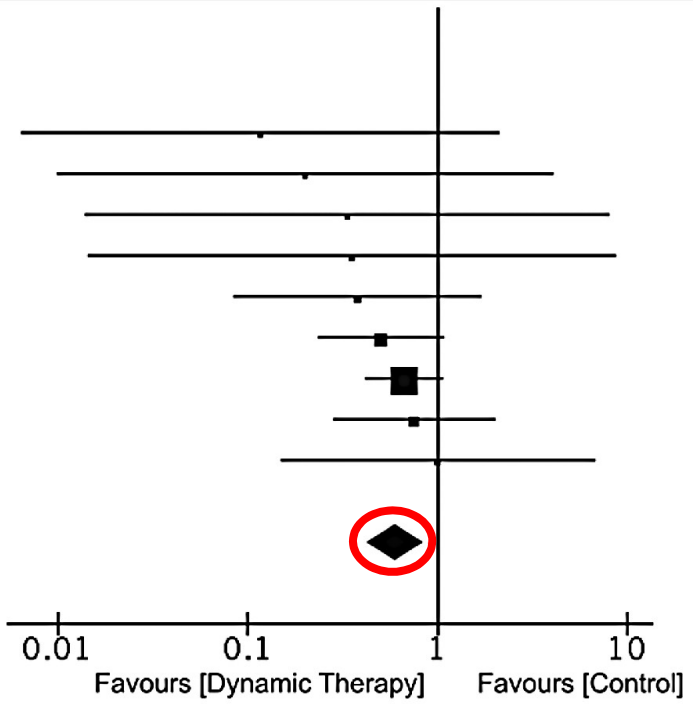

Figure 2. Effect of goal-directed fluid therapy guided by dynamic assessment of fluid responsiveness on mortality.

- **What is** fluid responsiveness?
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- **How** to assess fluid responsiveness?

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

Initial resuscitation

Recommendations

5 … we … d

- Risk of **under-resuscitation** in some patients…!!
- Risk of **over-resuscitation** in some others…!!

One size does not fit all…!

Re-assessing after **3 hours**, it's **too late**…!

Fluid resuscitation during early sepsis: a need for individualization

Mathieu JOZWIAK [1, 2], Olfa HAMZAOUI [3], Xavier MONNET [1, 2], Jean-Louis TEBOUL [1, 2] *

Minerva Anestesiologica 2018 August;84(8):987-92

Pt presenting with **septic shock**

Infuse around **10 mL/kg** crystalloids within the **first hour**

→ **Increase** infusion rate if:

- . Fluid losses
- . Abdominal sepsis
- . Mottling or ↗ CRT
- . Low PP

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Pt presenting with **septic shock**

Decrease infusion rate if:
. Worsening of tachypnea
. Fall in O_2 saturation

←

Infuse around **10 mL/kg** crystalloids within the **first hour**

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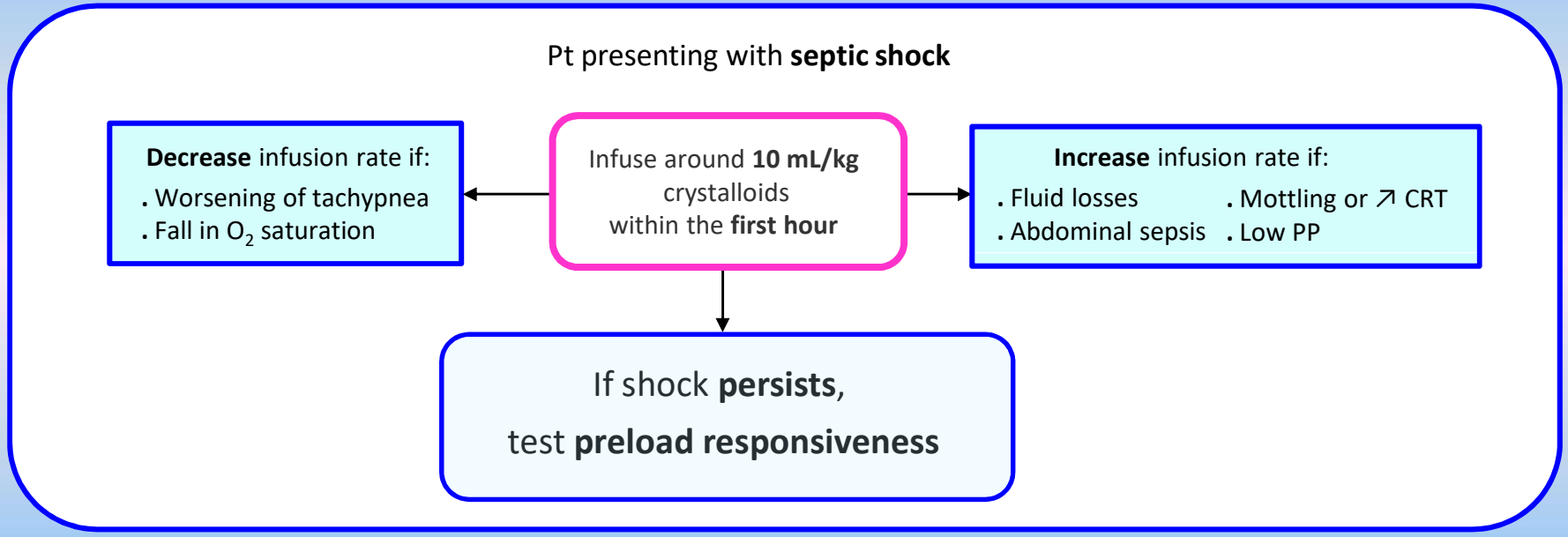
Importance of **individualization** of the initial **fluid therapy**

Fluid resuscitation during early sepsis: a need for individualization

Mathieu JOZWIAK [1, 2], Olfa HAMZAOUI [3], Xavier MONNET [1, 2], Jean-Louis TEBOUL [1, 2] *

Minerva Anestesiologica 2018 August;84(8):987-92



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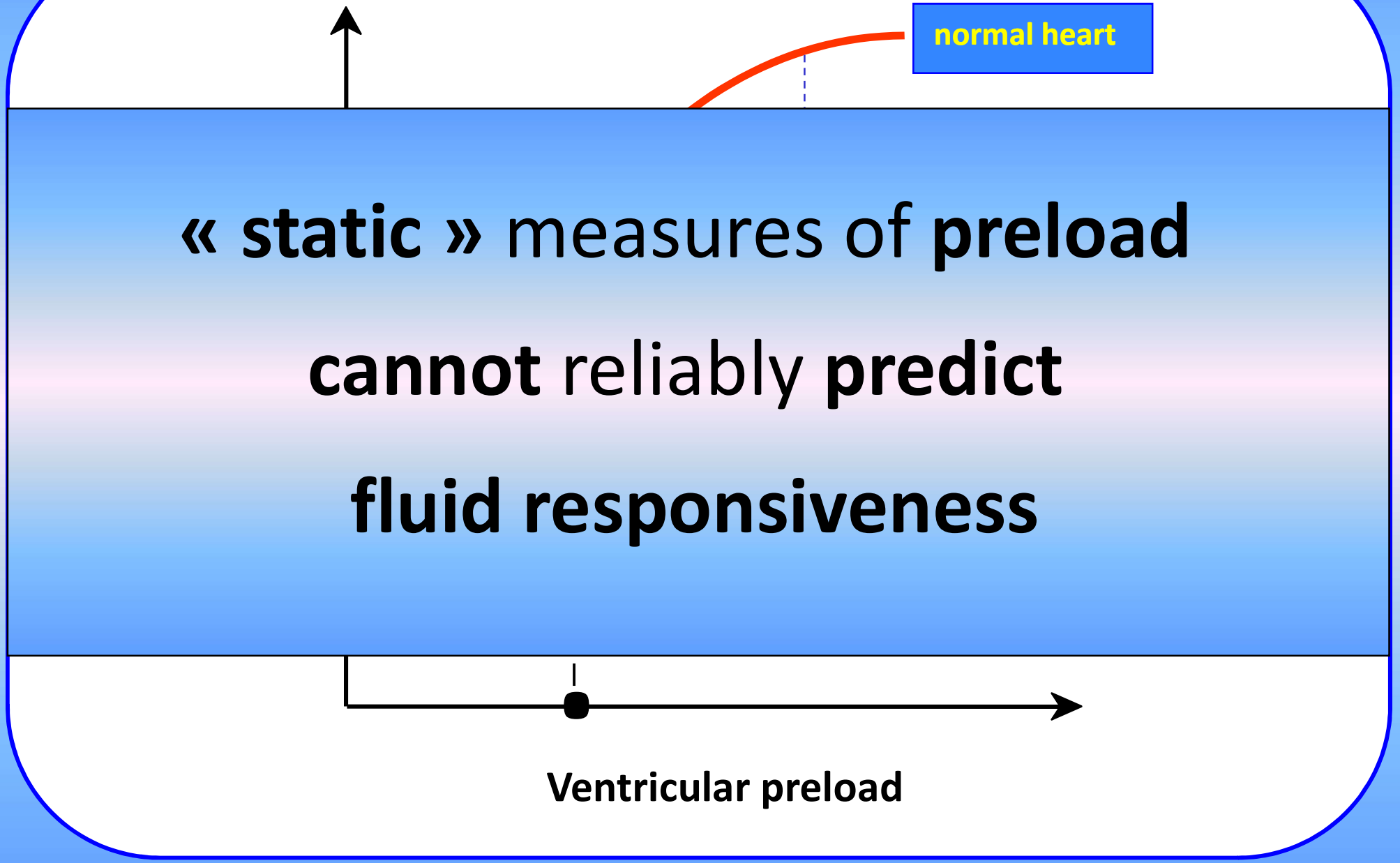
normal heart
« static » measures of preload
cannot reliably predict
fluid responsiveness
Ventricular preload

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

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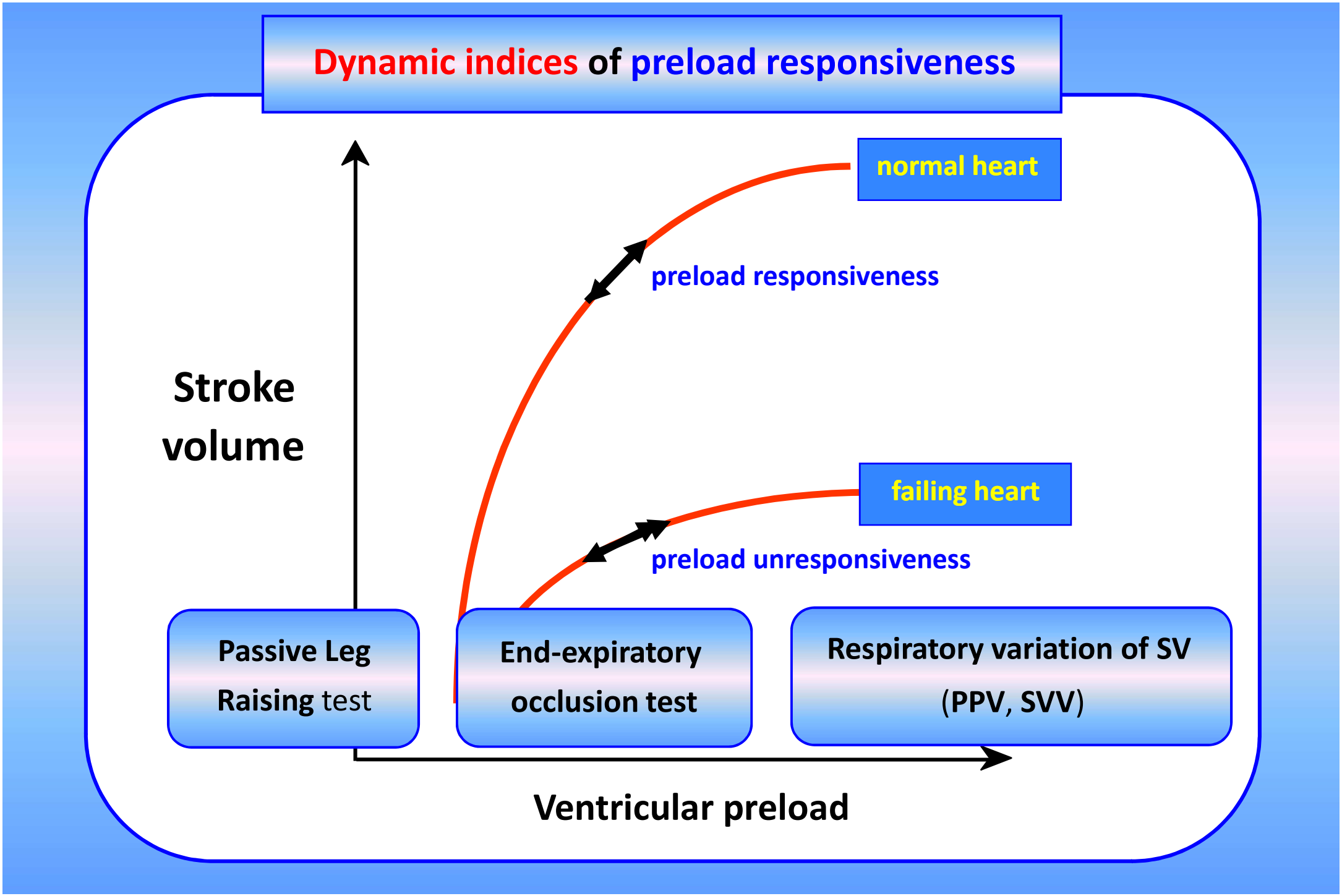
We suggest that **dynamic** measures to guide fluid resuscitation over static parameters


Dynamic indices of preload responsiveness
normal heart
preload responsiveness
Stroke volume
failing heart
preload unresponsiveness
Passive Leg Raising test
End-expiratory occlusion test
Respiratory variation of SV (PPV, SVV)
Ventricular preload

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

PLR mimics fluid challenge

The **hemodynamic response** to **PLR**
should **predict fluid responsiveness**

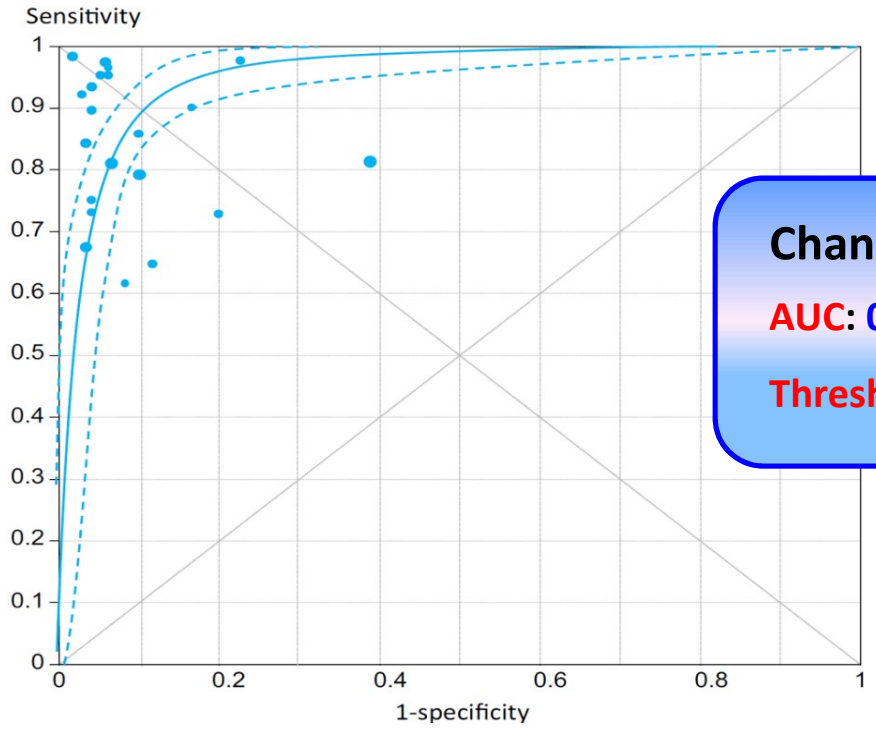
Intensive Care Med (2016) 42:1935–1947

ORIGINAL

Xavier Monnet
Paul Marik
Jean-Louis Teboul

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

21 ***clinical studies***



Changes in CO

AUC: 0.95±0.01

Threshold: 10%

995 pts

GUIDELINES

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Intensive Care Med

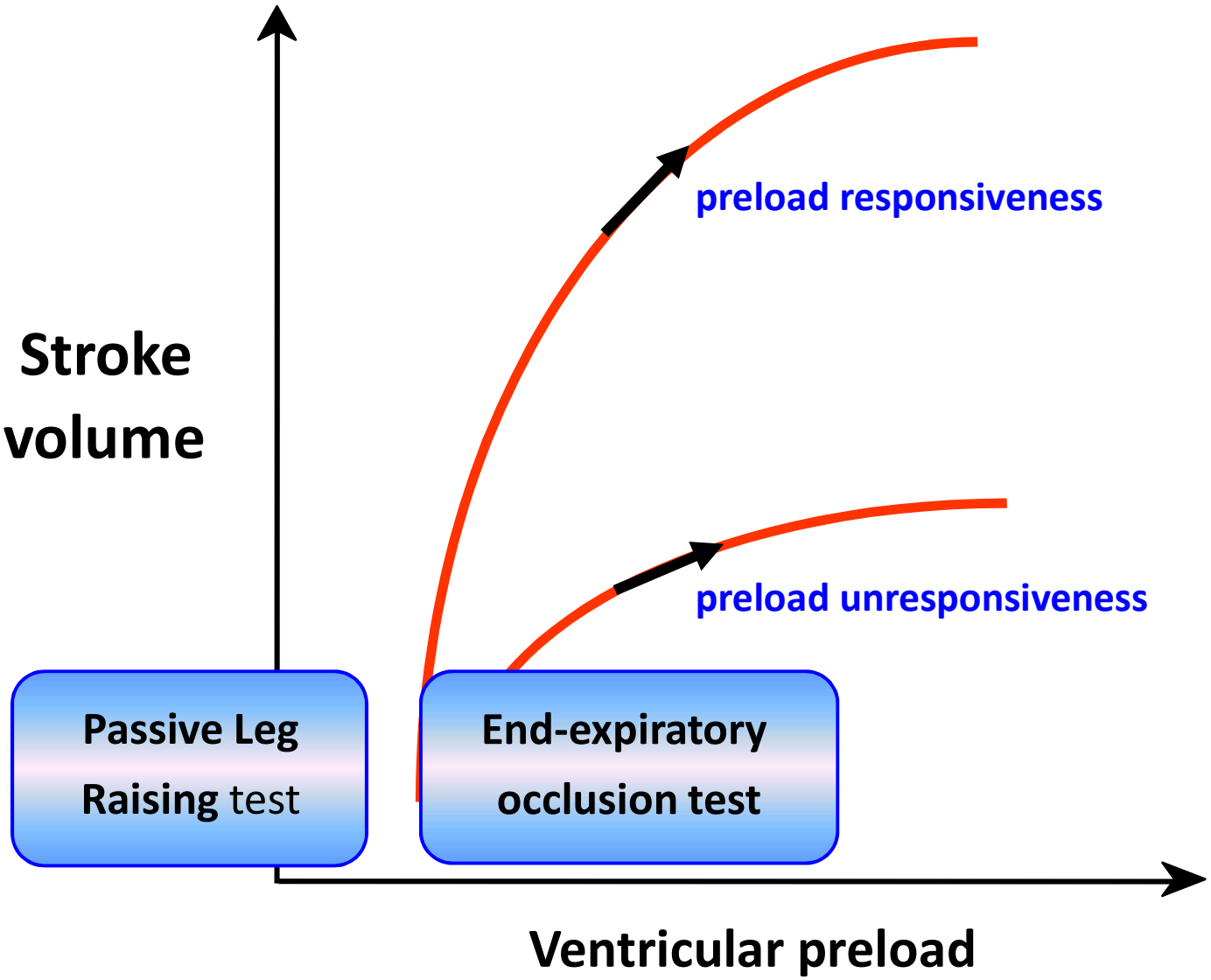
6. For adults with sepsis or septic shock, we suggest using **dynamic measures** to **guide fluid resuscitation**, over physical examination or static parameters alone

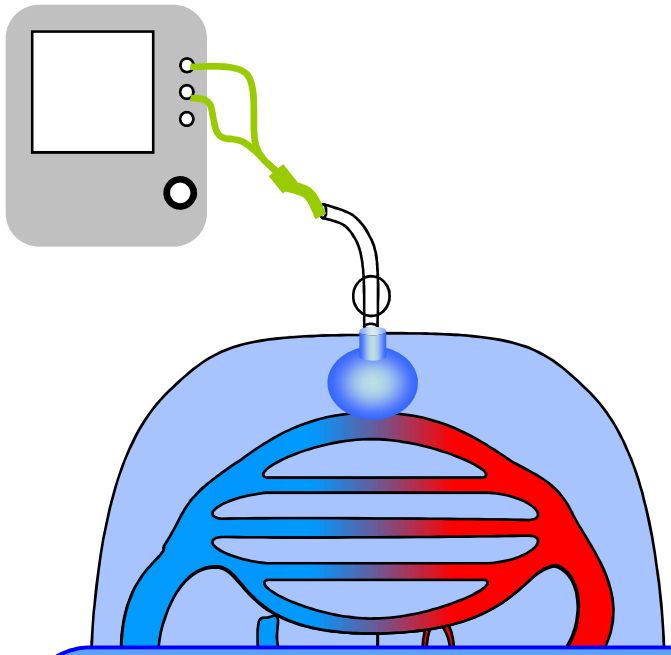
Weak recommendation, very low-quality evidence

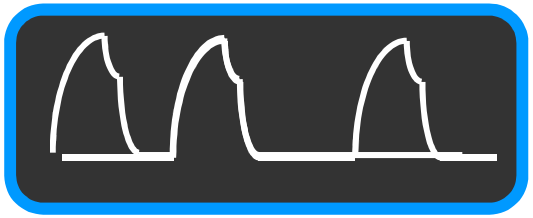
Remarks

Dynamic parameters include response to **passive leg raise** or a fluid bolus, using stroke volume (SV), stroke volume variation (SVV), pulse pressure variation (PPV), or echocardiography, where available

Dynamic indices of preload responsiveness







End-expiratory occlusion

for 15 sec

Fluid responders should be identified

by an **increase** in their **CO**

during the **end-expiration occlusion** test

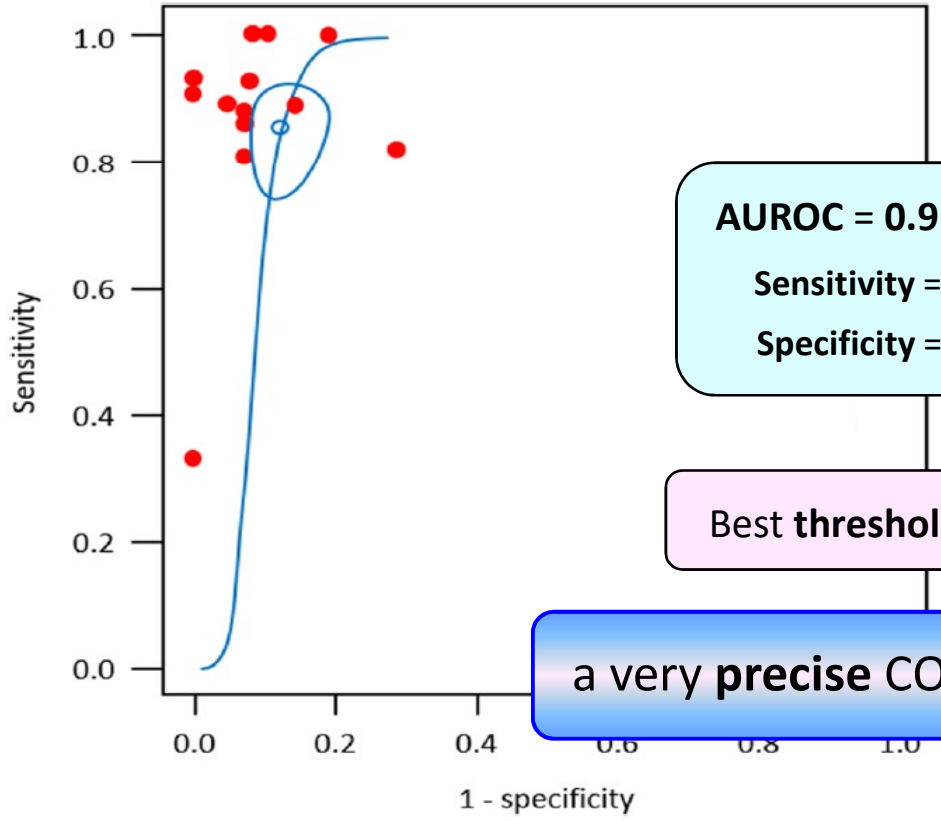
Tran

Ann. Intensive Care (2020) 10:65 Annals of Intensive Care

RESEARCH Open Access

The end-expiratory occlusion test for detecting preload responsiveness: a systematic review and meta-analysis

Francesco Gavelli[1,2,3*], Rui Shi[1,2], Jean-Louis Teboul[1,2], Danila Azzolina[4] and Xavier Monnet[1,2]



AUROC = **0.91** [0.86-0.94]

Sensitivity = **0.85** [0.77-0.91]

Specificity = **0.88** [0.83-0.91]

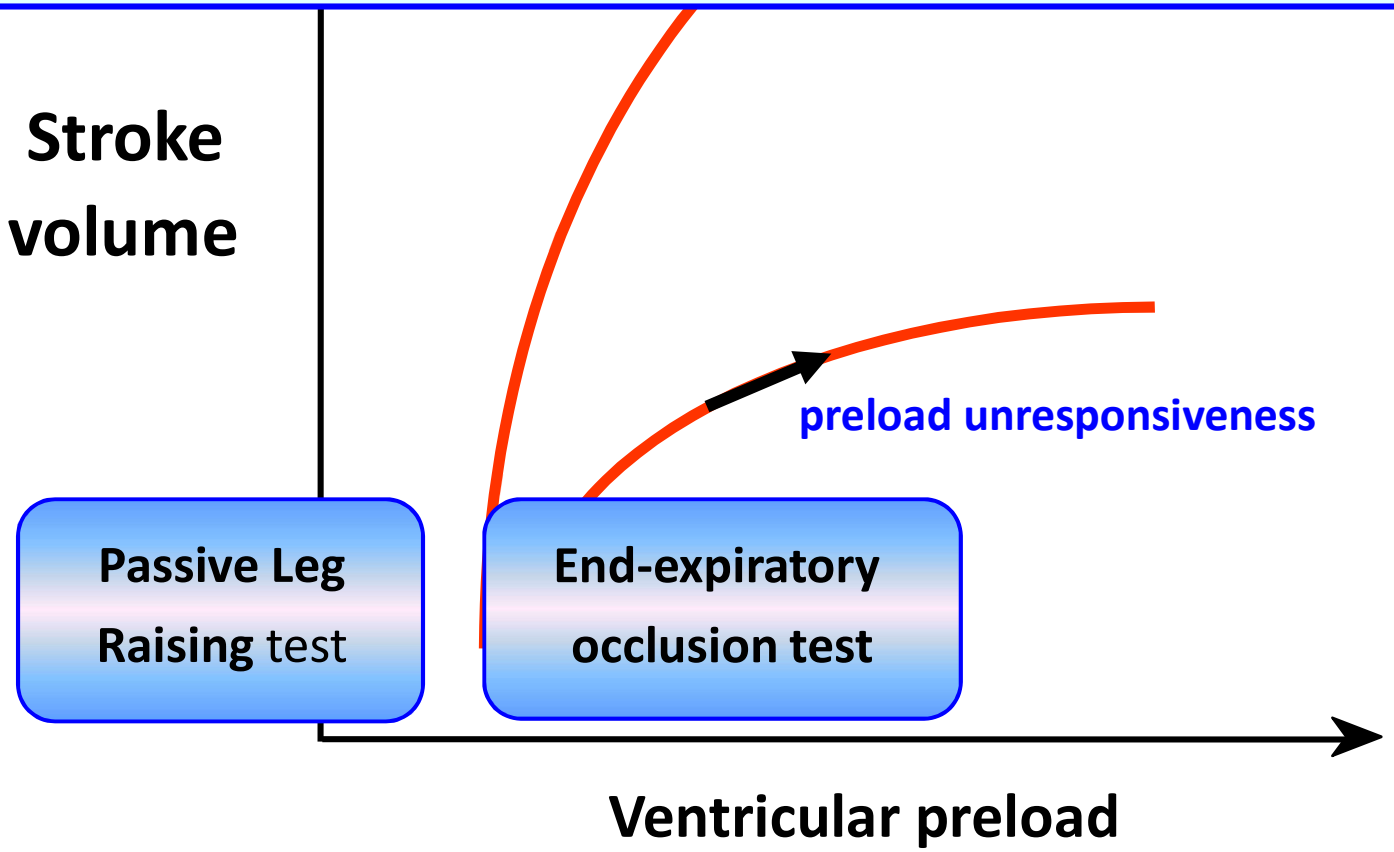
Best **threshold** = **5.1**±0.2**%**

a very **precise** CO monitor is **required**

Dynamic indices of preload responsiveness

Major **limitation**

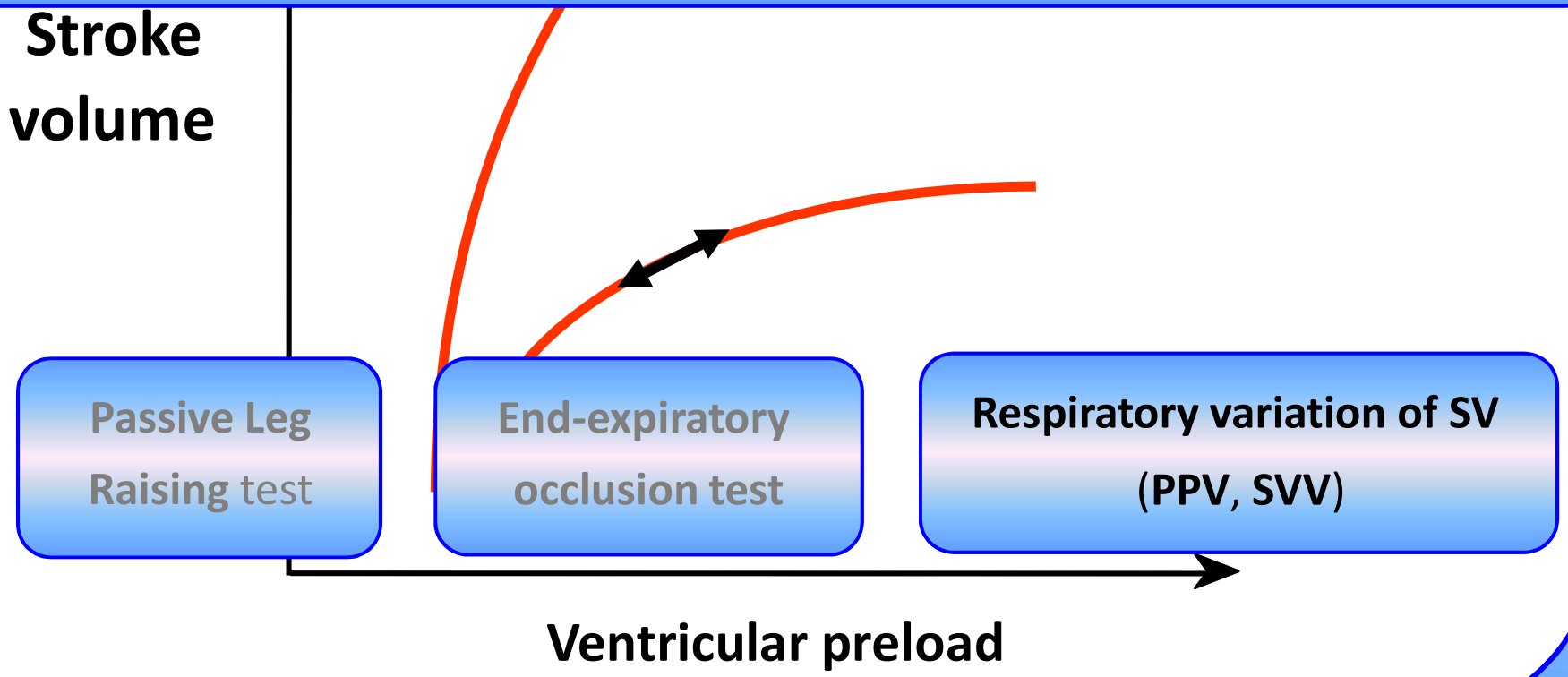
Real-time **stroke volume** or **cardiac output** measurements are **mandatory**



Dynamic indices of preload responsiveness

Major **advantage**

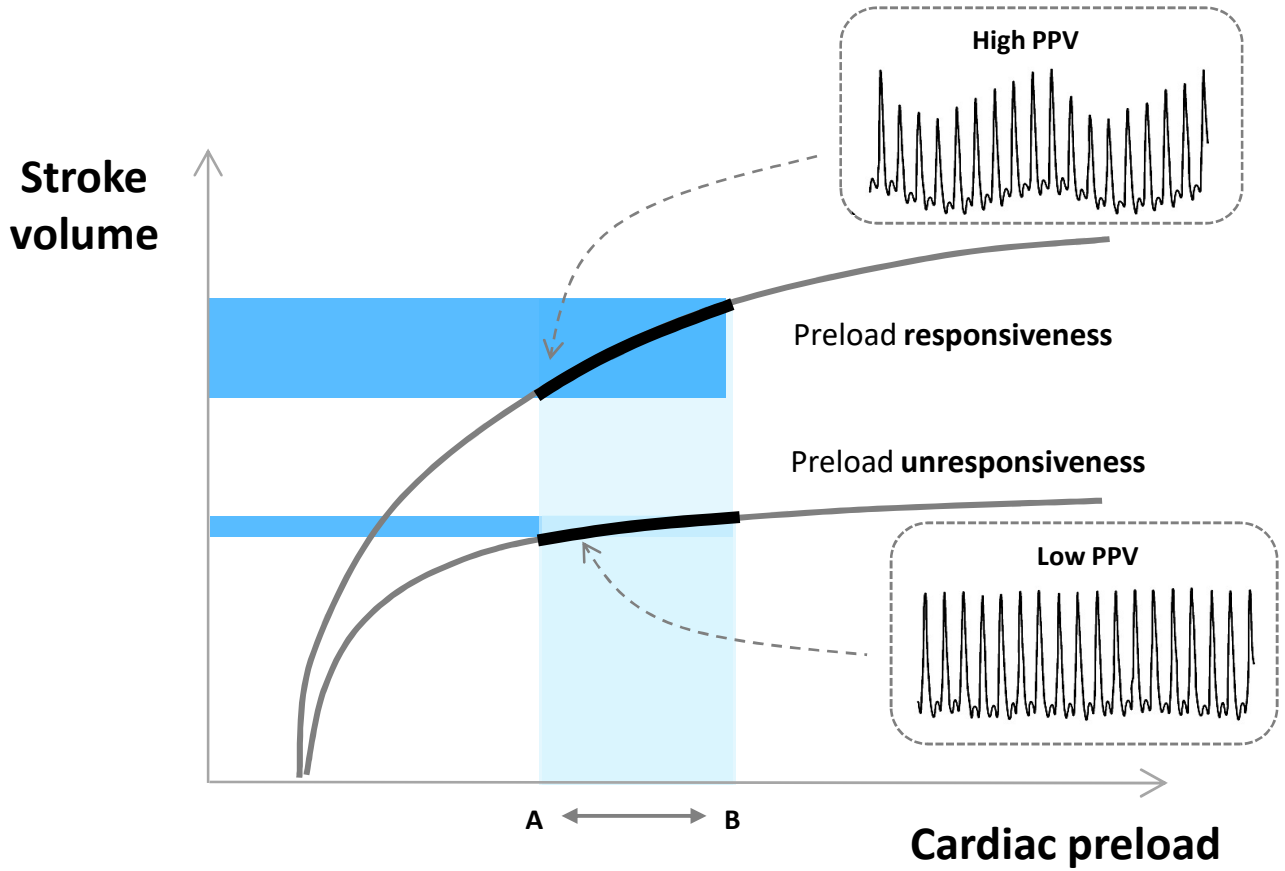
Pulse Pressure Variation does **not** require **CO** measurements



Arterial Pulse Pressure Variation with Mechanical Ventilation

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

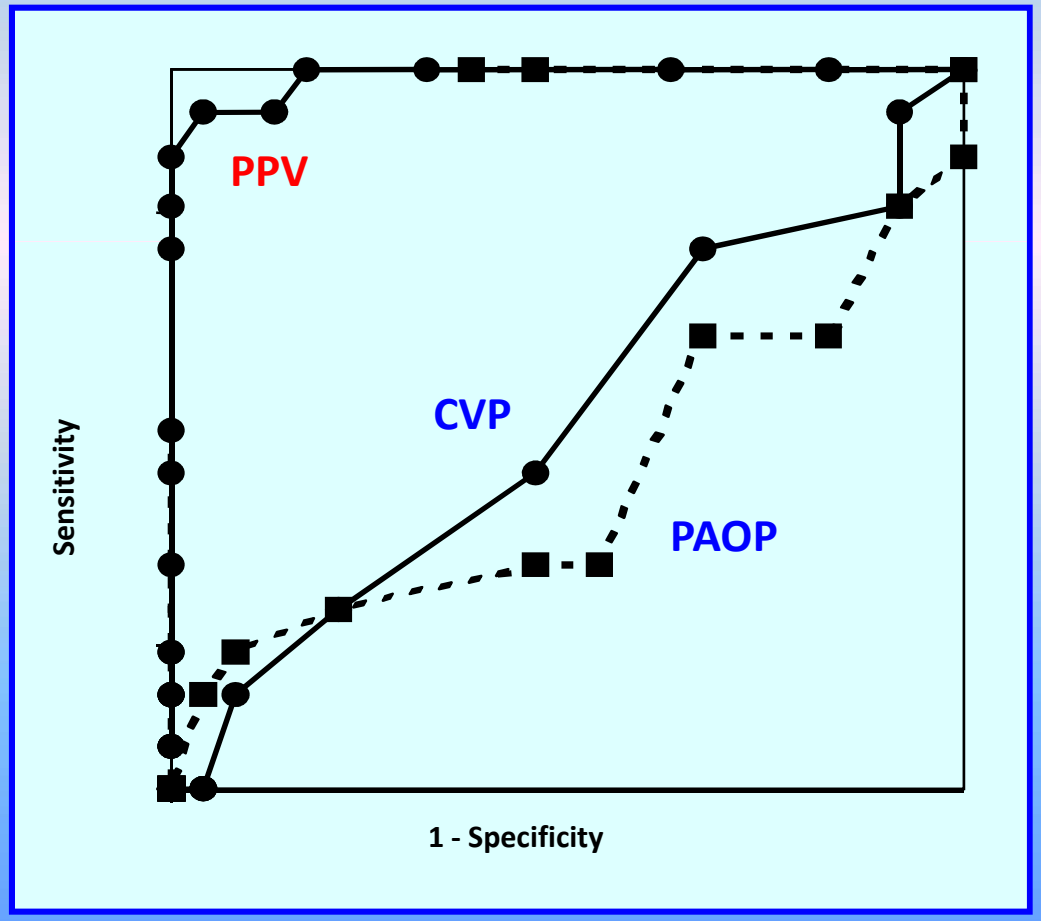
Am J Respir Crit Care Med Vol 199, Iss 1, pp 22–31, Jan 1, 2019



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

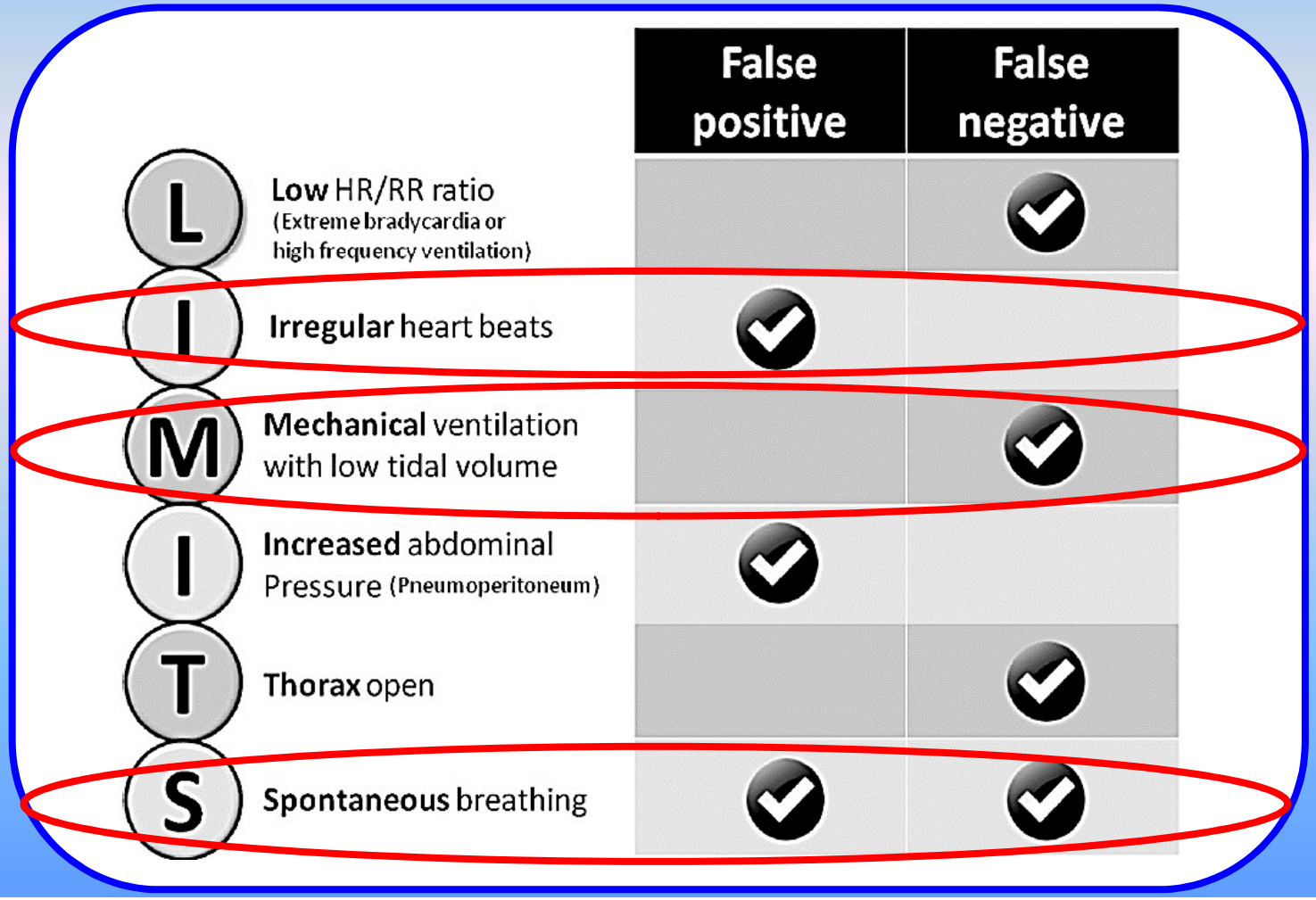
Am J Respir Crit Care Med Vol 162. pp 134–138, 2000



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



In some of these situations,

it has been proposed to use the **changes** of **PPV**

- during a **Tidal Volume Challenge**
- during **Passive Leg Raising**

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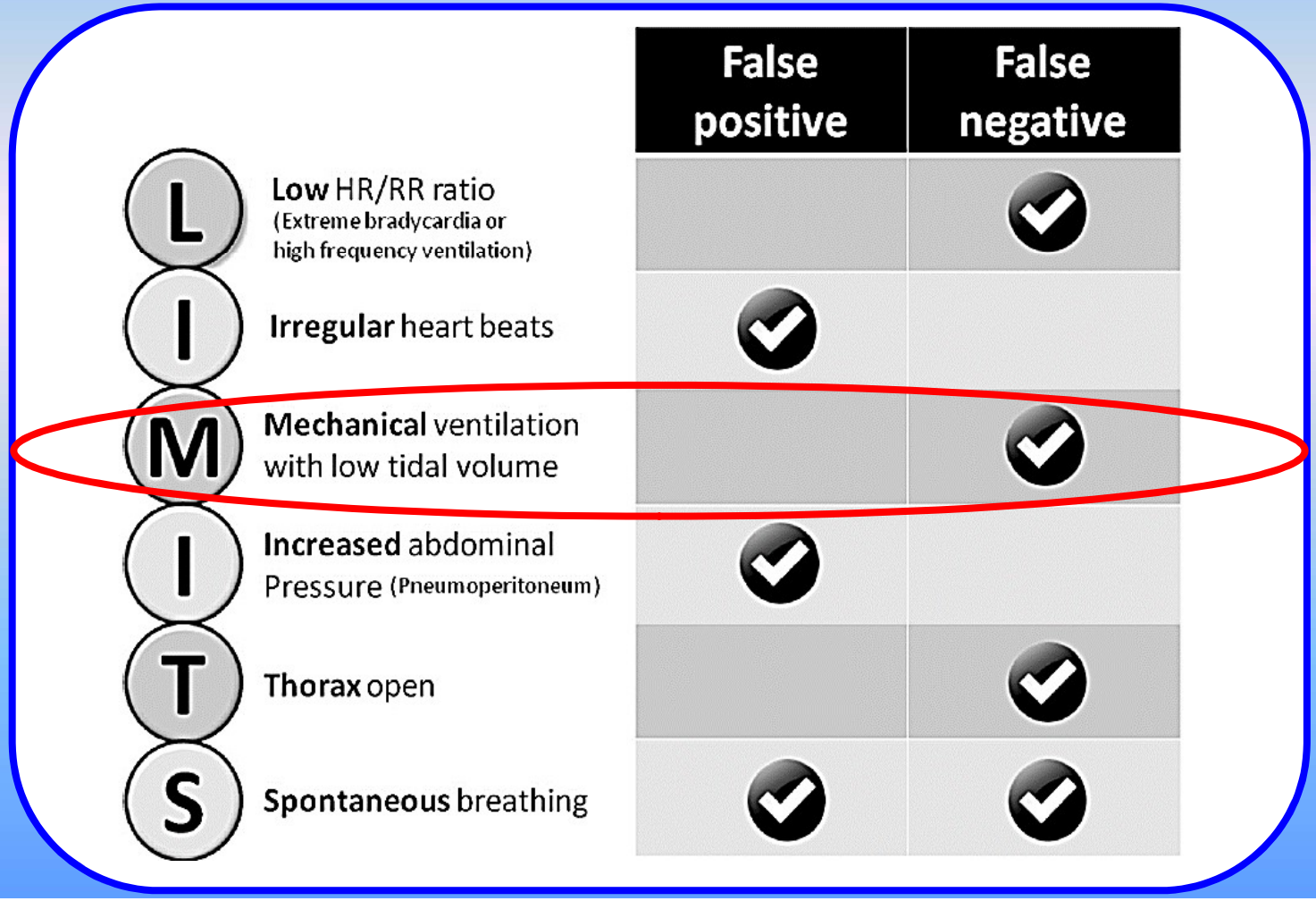
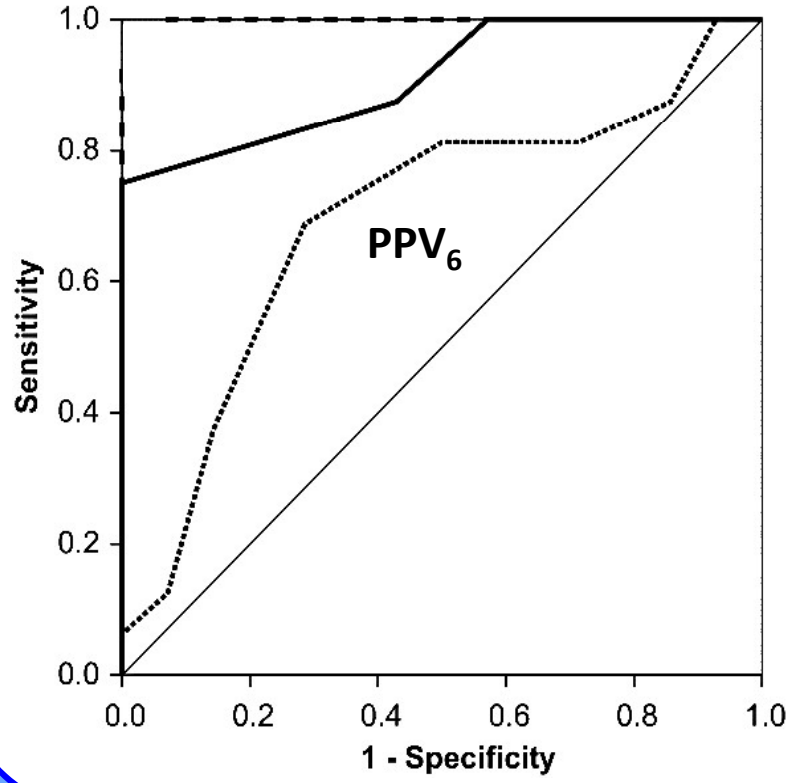


The Changes in Pulse Pressure Variation or Stroke Volume Variation After a "Tidal Volume Challenge" Reliably Predict Fluid Responsiveness During Low Tidal Volume Ventilation*

Sheila Nainan Myatra, MD, FCCM[1]; Natesh R Prabu, MD, 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



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Crit Care Med 2017; 45:415–421

Tidal volum

Transient (1 min) **increase**

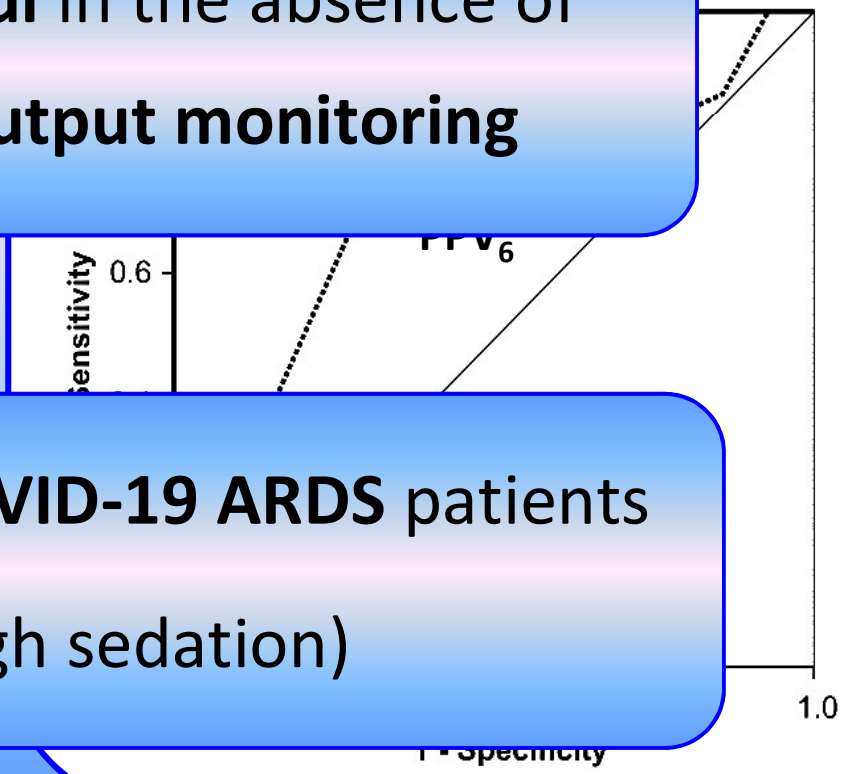
in **tidal volume**

fr

Very **helpful** in the absence of **cardiac output monitoring**

Very **helpful** in **COVID-19 ARDS** patients

(low V_T, high sedation)



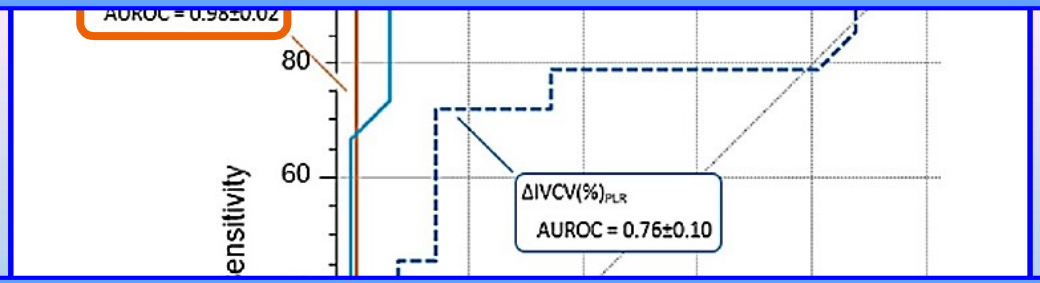
RESEARCH Open Access

Do changes in pulse pressure variation and inferior vena cava distensibility during passive leg raising and tidal volume challenge detect preload responsiveness in case of low tidal volume ventilation?

Temistocle Taccheri*, Francesco Gavelli, Jean-Louis Teboul, Rui Shi and Xavier Monnet

Very **helpful** in the absence of

cardiac output monitoring



An **increase** in **PPV** during **TVC** is **reliable**

to predict fluid responsiveness

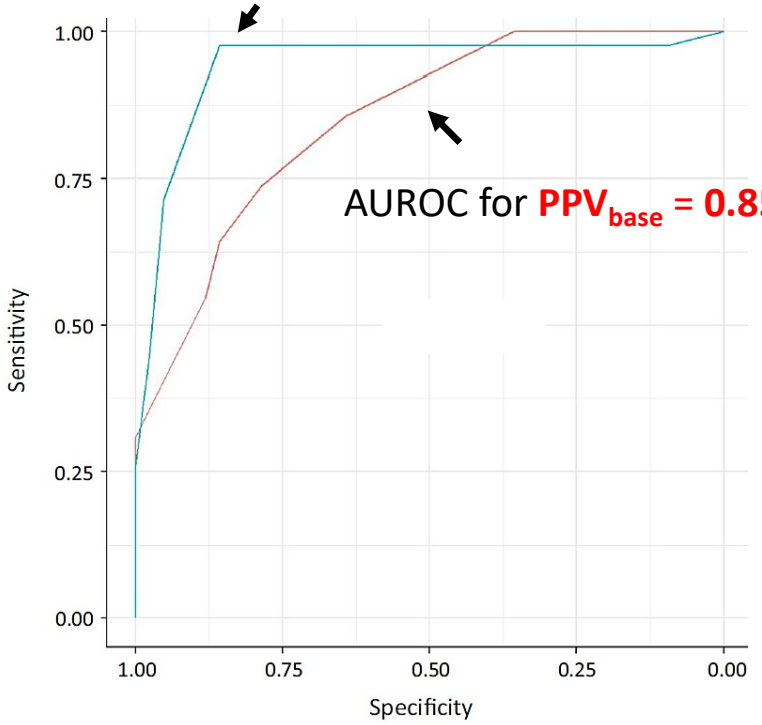
RESEARCH Open Access

Tidal volume challenge to predict preload responsiveness in patients with acute respiratory distress syndrome under prone position

Rui Shi[1], Soufia Ayed[1], Francesca Moretto[1], Danila Azzolina[2], Nello De Vita[1], Francesco Gavelli[1], Simone Carelli[1], Arthur Pavot[1], Christopher Lai[1], Xavier Monnet[1] and Jean-Louis Teboul[1*]

Critical Care (2022) 26:219

AUROC for **ΔPPV** during **TVC** = **0.94 ± 0.03**



p = 0.047

AUROC for PPV_{base} = **0.85 ± 0.05**

In some of these situations,

it has been proposed to use the **changes** of **PPV**

- during a **Tidal Volume Challenge**
- during **Passive Leg Raising**

RESEARCH Open Access

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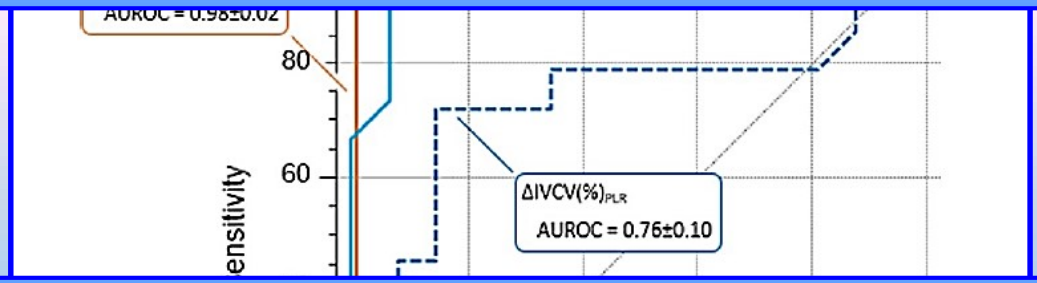

An **decrease** in **PPV** during **PLR** is **reliable**

to predict fluid responsiveness

Conclusion -1-

- **PLR** and **EEO** tests **mimic** fluid challenge without the need of infusing any drop of fluid
- The **changes** in **CO** in response to **PLR** or **EEO** tests were shown to **reliably** predict **fluid responsiveness** in various situations
- **PPV** has the advantage of **not** requiring **CO monitoring**, but it is not interpretable as a predictor of fluid responsiveness in several situations
- An **increase** in **PPV** during a **tidal volume challenge** (in supine or prone position) or a **decrease** in **PPV** during **PLR** can be helpful to predict fluid responsiveness in patients ventilated with low tidal volume
- The major **advantage** of these novel tests using **dynamics of PPV** is to be used with a **simple arterial line**

Conclusion -2-

- Even in case of fluid responsiveness, it is important to assess the **benefit/risk** ratio of fluids **before** any infusion, especially in patients with **associated ARDS**.
  - benefit = **degree** of fluid responsiveness
  - risk = indices of **lung tolerance** (P/F ratio, EVLW, PAOP, B-lines, etc.)

REVIEW Open Access

Prediction of fluid responsiveness. What's new?

Xavier Monnet*, Rui Shi and Jean-Louis Teboul

Annals of Intensive Care (2022) 12:46

Merci