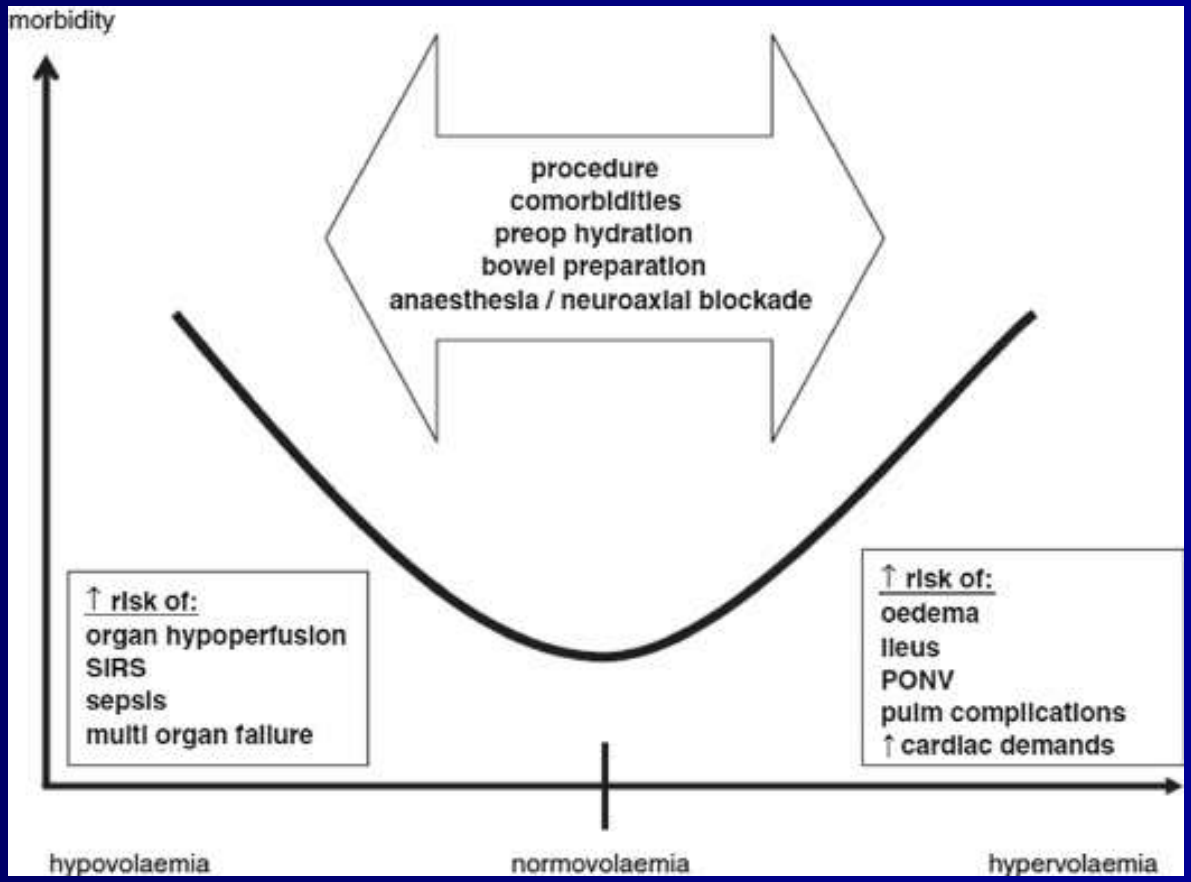
How ultrasound can help to evaluate volume status?

Michel Slama
Amiens
France

- No conflict of interest

Fluid balance and mortality



Fluid = drug

Then titration of fluid

Goal = improve the tissue perfusion and oxygenation

Surrogate = increase of cardiac output>15%=responders

Boyd et al. Critical Care (2016) 20:274
DOI 10.1186/s13054-016-1407-1

Critical Care

REVIEW Open Access

Echocardiography as a guide for fluid management

John H. Boyd[1,2,3*], Demetrios Sirounis[1,2], Julien Maizel[4,5] and Michel Slama[4,5]

Question 1: is there a clinical reason to do volume expansion?

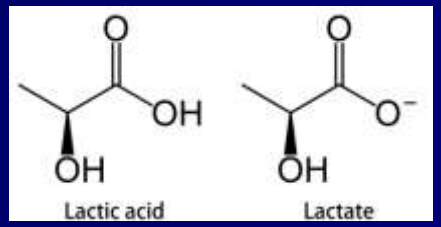
- Impaired hemodynamics
- Tissue hypoxemia

Intensive Care Med
https://doi.org/10.1007/s00134-018-5415-2

CONFERENCE REPORTS AND EXPERT PANEL

Fluid administration for acute circulatory dysfunction using basic monitoring: narrative review and expert panel recommendations from an ESICM task force

Maurizio Cecconi[1,2*], Glenn Hernandez[3], Martin Dunser[4], Massimo Antonelli[5], Tim Baker[6,7], Jan Bakker[3,8,9,10,11], Jacques Duranteau[12,13], Sharon Einav[14], A. B. Johan Groeneveld[15], Tim Harris[16,17], Sameer Jog[18], Flavia R. Machado[19], Mervyn Mer[20], M. Ignacio Monge Garcia[21], Sheila Nainan Myatra[22], Anders Perner[23], Jean-Louis Teboul[24,25], Jean-Louis Vincent[26] and Daniel De Backer[27]



Statements and recommendations on identification of circulatory dysfunction and triggering of fluid administration

1. Acute circulatory dysfunction can be recognized by a thorough clinical examination including assessment of the three windows of tissue perfusion—altered mentation, skin abnormalities, and oliguria—together with a combined analysis of heart rate and blood pressure
2. Whenever possible, we recommend measuring blood lactate concentrations and integrating this information with clinical examination
3. The purpose of fluid administration during hypovolemia is to improve tissue perfusion through increased cardiac output
4. We suggest that, in a clinical context of hypovolemia such as bleeding, severe diarrhea, and trauma, the presence of hypotension and tachycardia or oliguria should trigger fluid administration
5. The absence of arterial hypotension does not exclude hypovolemia and the need for fluid administration
6. We recommend individualizing fluid resuscitation in all patients

Question 2: is the hypovolemia obvious?

Case :

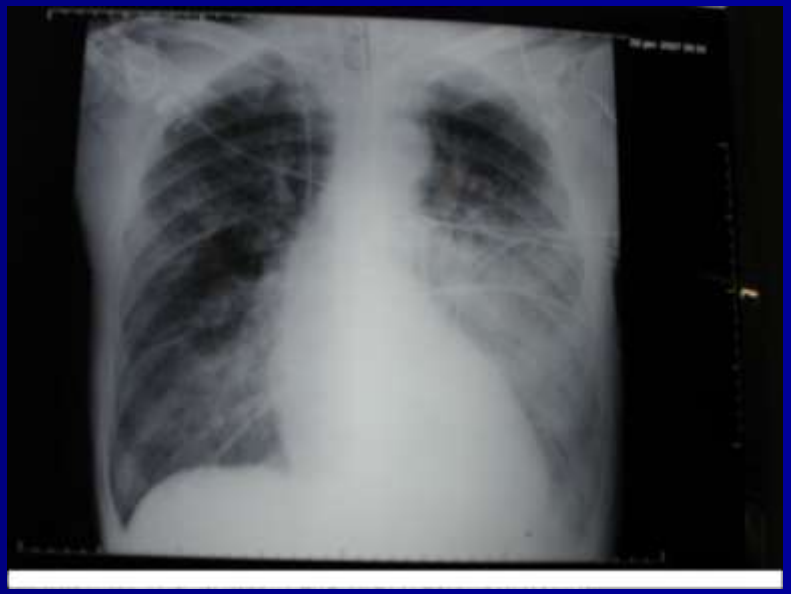
- 67 years old woman emergency room
- Severe sepsis pneumonia
- MAP 45 mmHg
- CVP = 5 mmHg
- Lactate blood level 4 mmol/l

Fluid infusion or not?

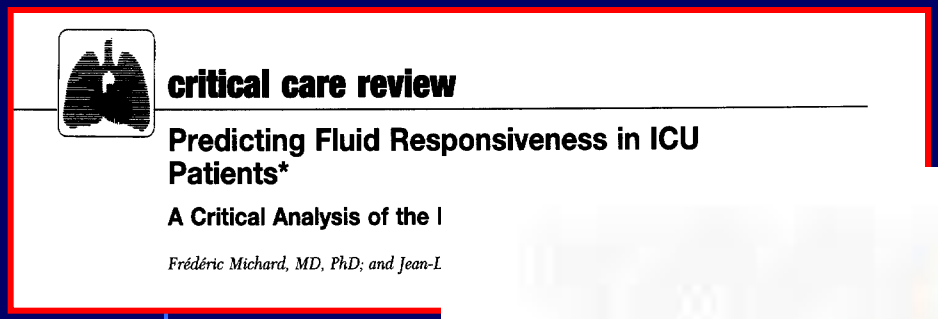
Case (continued) Yes of course!!!

- After fluid infusion of 2 liters :
  - MAP : 50 mmHg
  - CVP = 9 mmHg
  - Oliguria with ARF
  - Lactate blood level 4.5 mmol/l
- Mechanical ventilation TV 480 ml, PEEP 5 $cmHO_2$, FIO_2 80%
- ICU

Chiffre magique = 30 ml/kg



Fluid infusion or not???



critical care review

Predicting Fluid Responsiveness in ICU Patients*

A Critical Analysis of the I

Frédéric Michard, MD, PhD; and Jean-L

Calvin (S

Schneid

Reuse (

Magder

Diebel (A

Diebel (J

Wagner

Tavernie

Magder

Tousigna

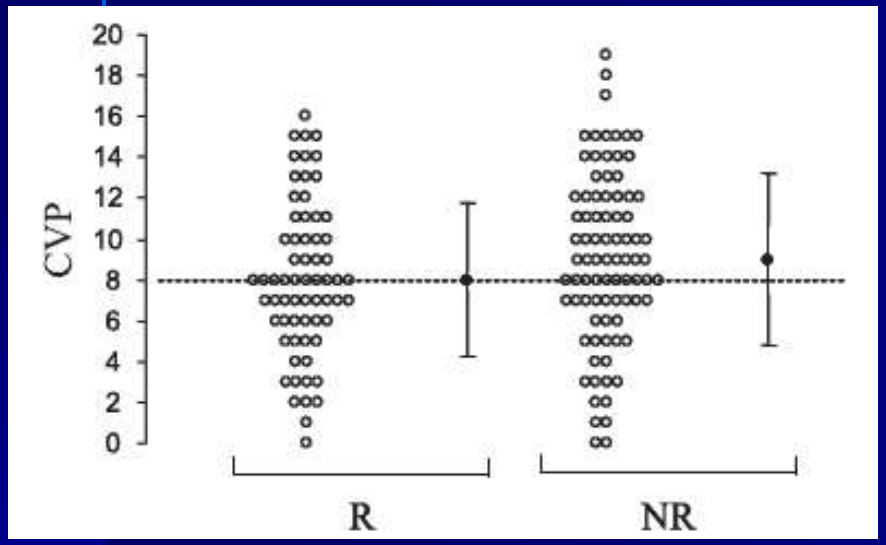
Michard

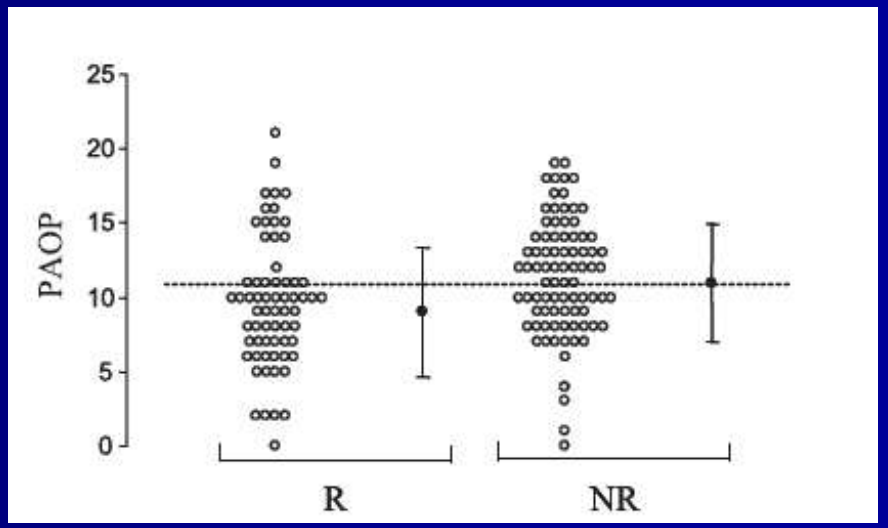
Feissel (C

Mean	**211 / 195**	**52 %**

Question 3: Which parameter to use to predict fluid-responsiveness?

CVP out.... PAOP out...





D Osman Crit care med 2007

Static parameters

Dynamic parameters

Passive leg raising

Static parameters

Dynamic parameters

Passive leg raising

Responder

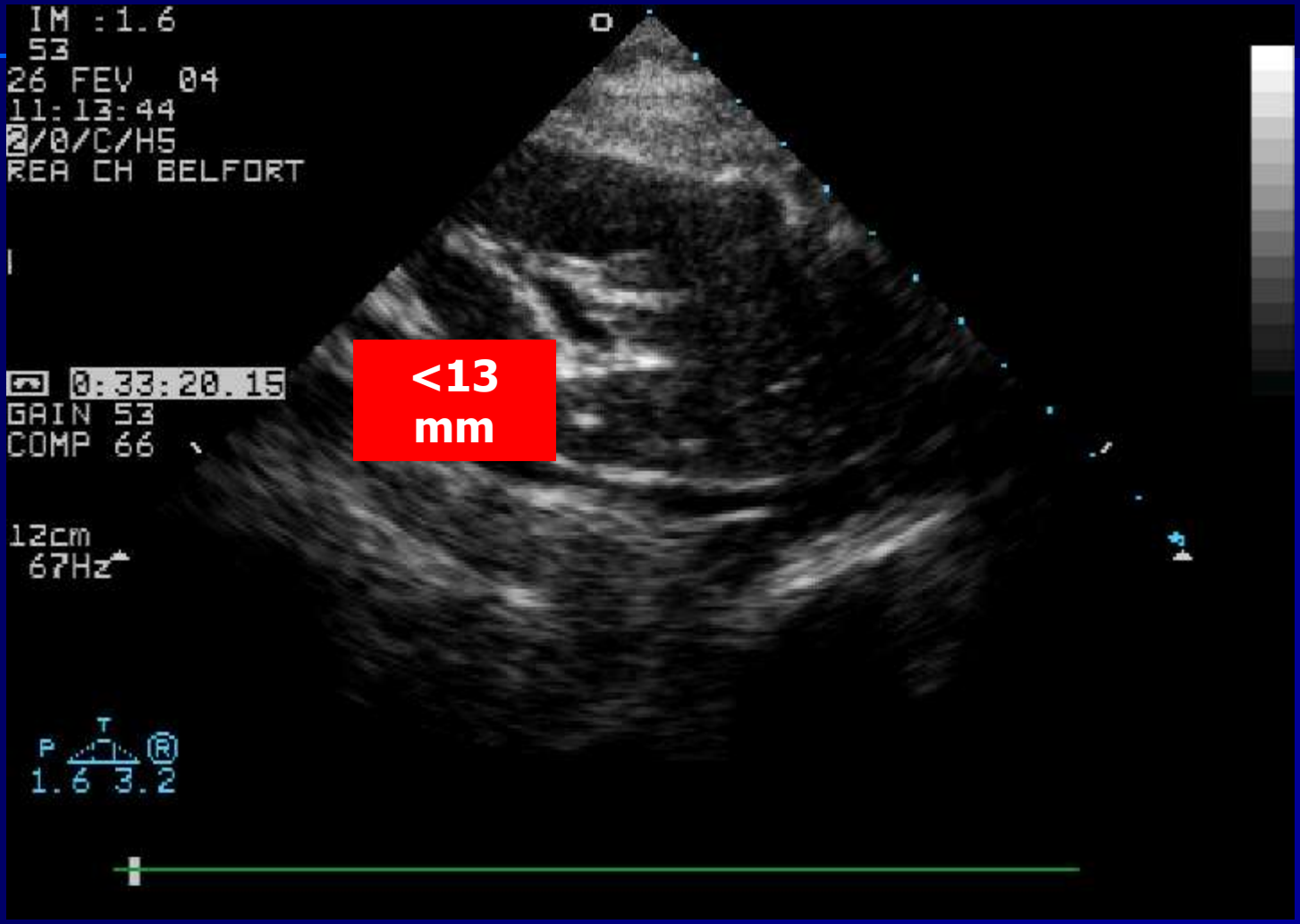
Non Responder

Stroke volume

Fluid

Ventricular preload

Inferior vena cava

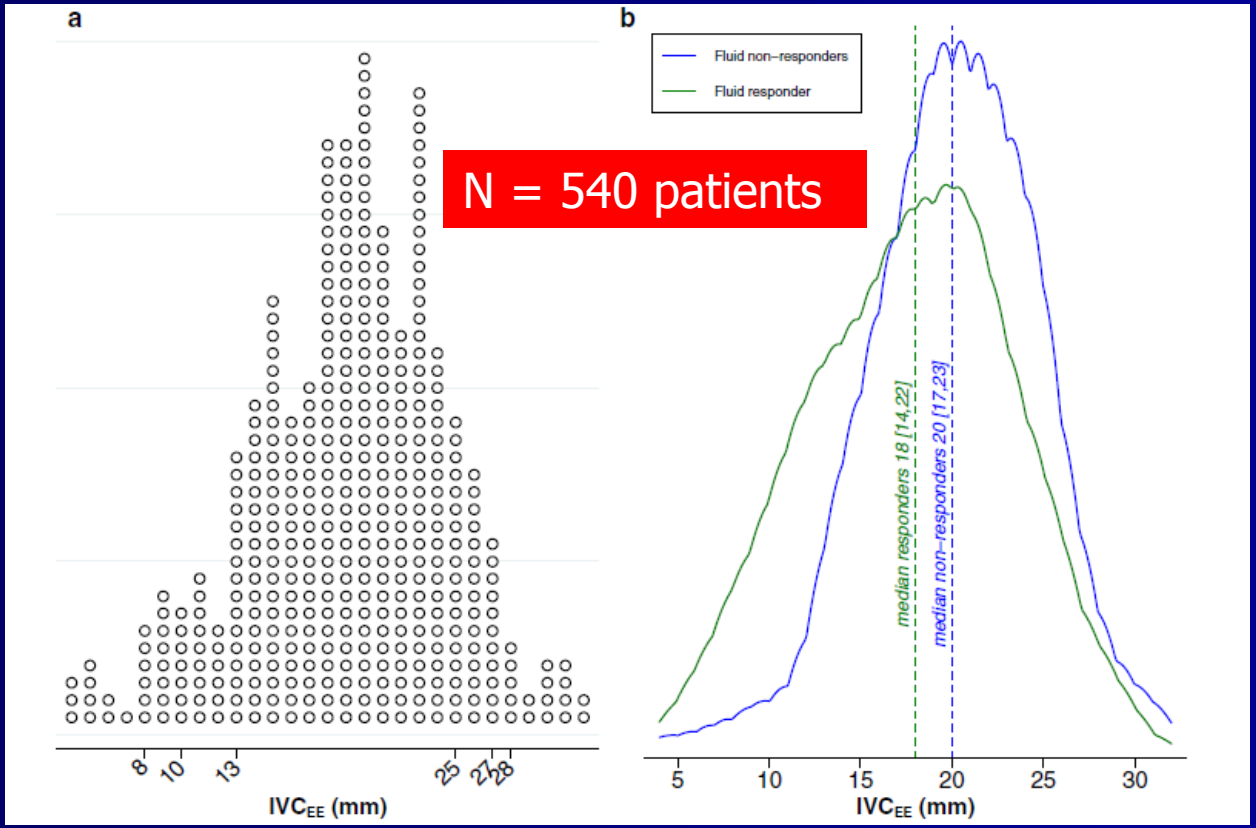

IM :1.6
53
26 FEV 04
11:13:44
2/0/C/H5
REA CH BELFORT
0:33:20.15
GAIN 53
COMP 66
12cm
67Hz
P
T
R
1.6 3.2
<13 mm

Intensive Care Med (2018) 44:197–203
https://doi.org/10.1007/s00134-018-5067-2

ORIGINAL

Limited value of end-expiratory inferior vena cava diameter to predict fluid responsiveness impact of intra-abdominal pressure

Antoine Vieillard-Baron[1,2,3*], Bruno Evrard[4,5], Xavier Repessé[1], Julien Maizel[6], Christophe Jacob[7], Marine Goudelin[4,5], Cyril Charron[1], Gwenaël Prat[7], Michel Slama[6], Guillaume Geri[1,2,3] and Philippe Vignon[4,5,8]



Intensive Care Med (2018) 44:197–203
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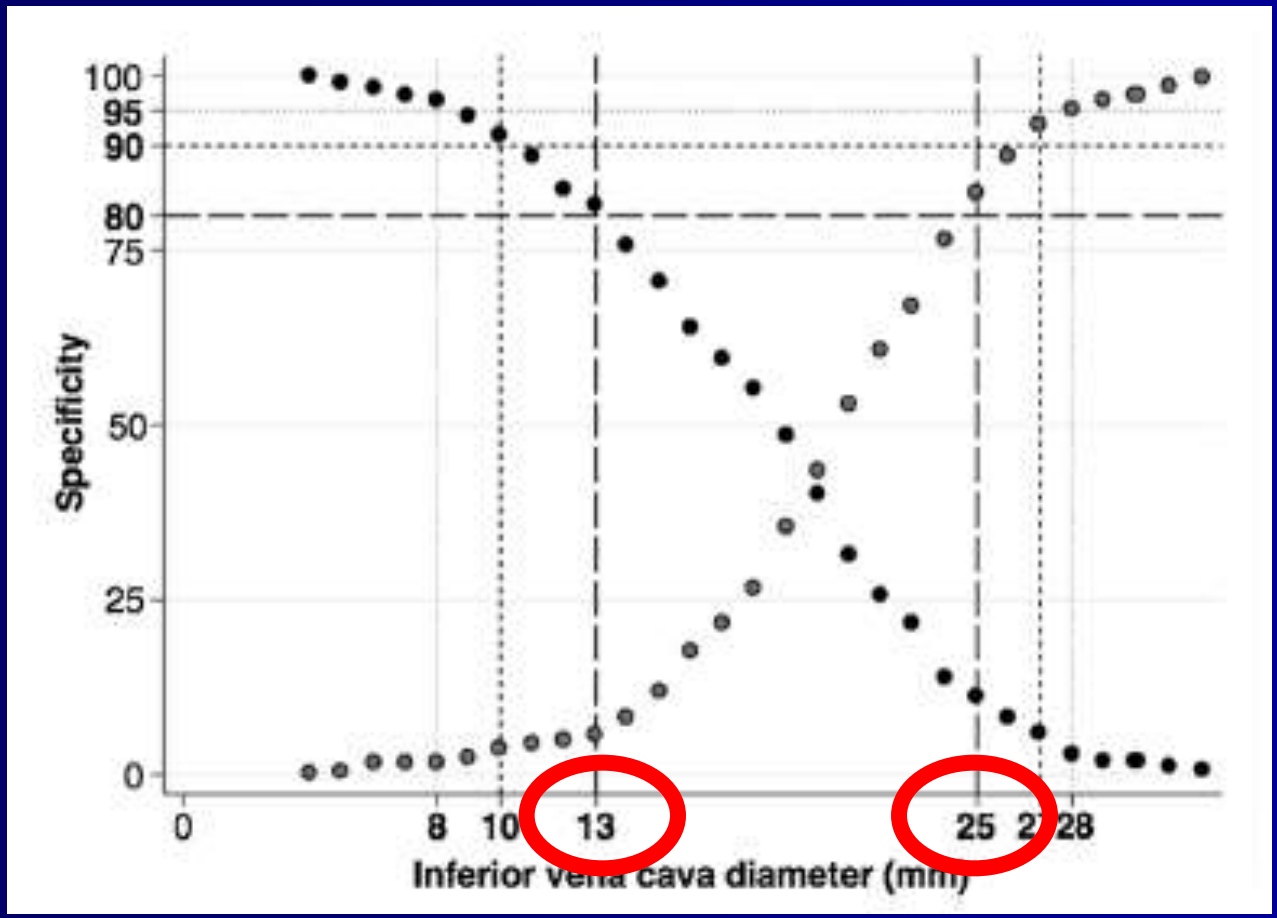
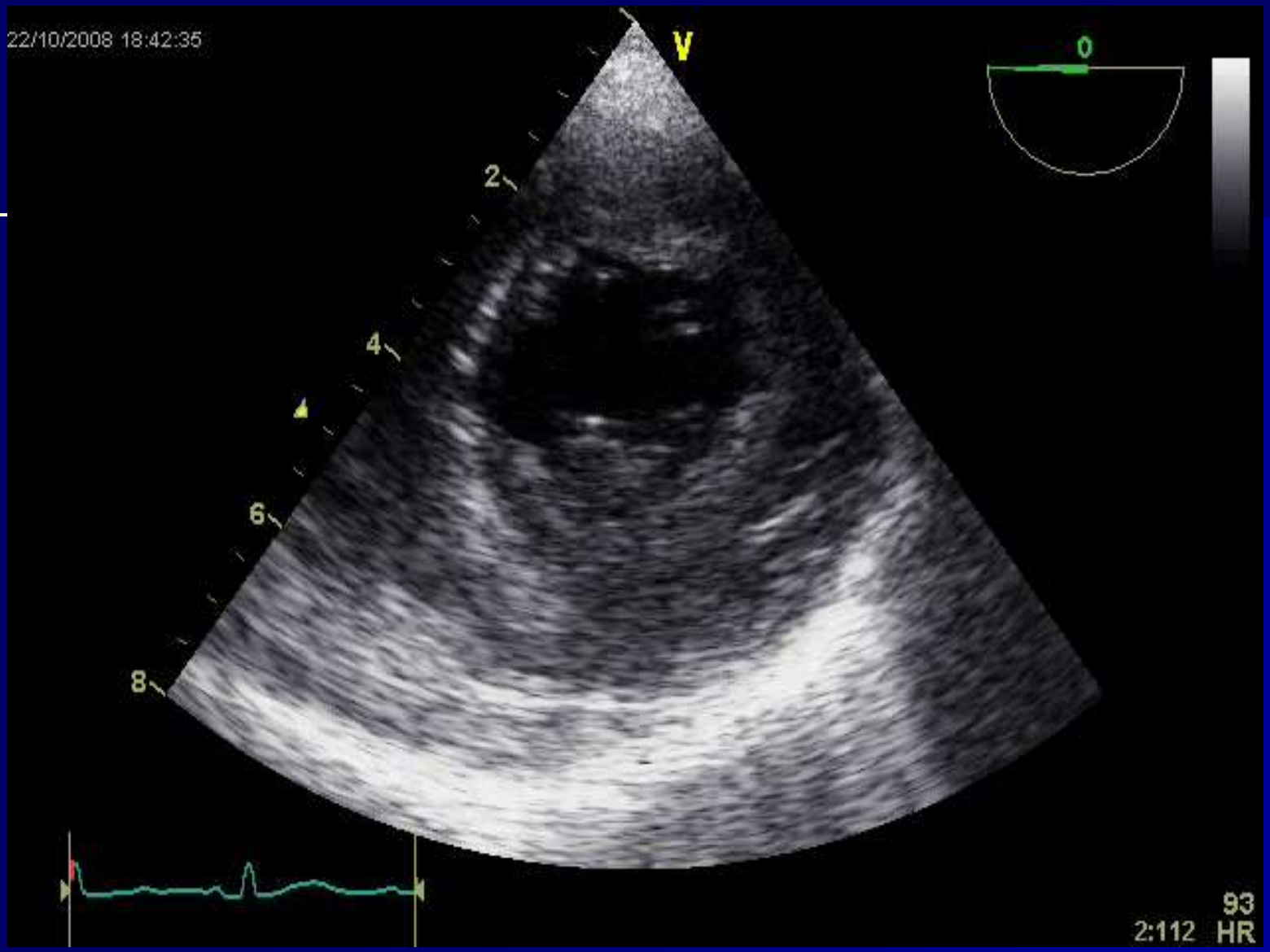
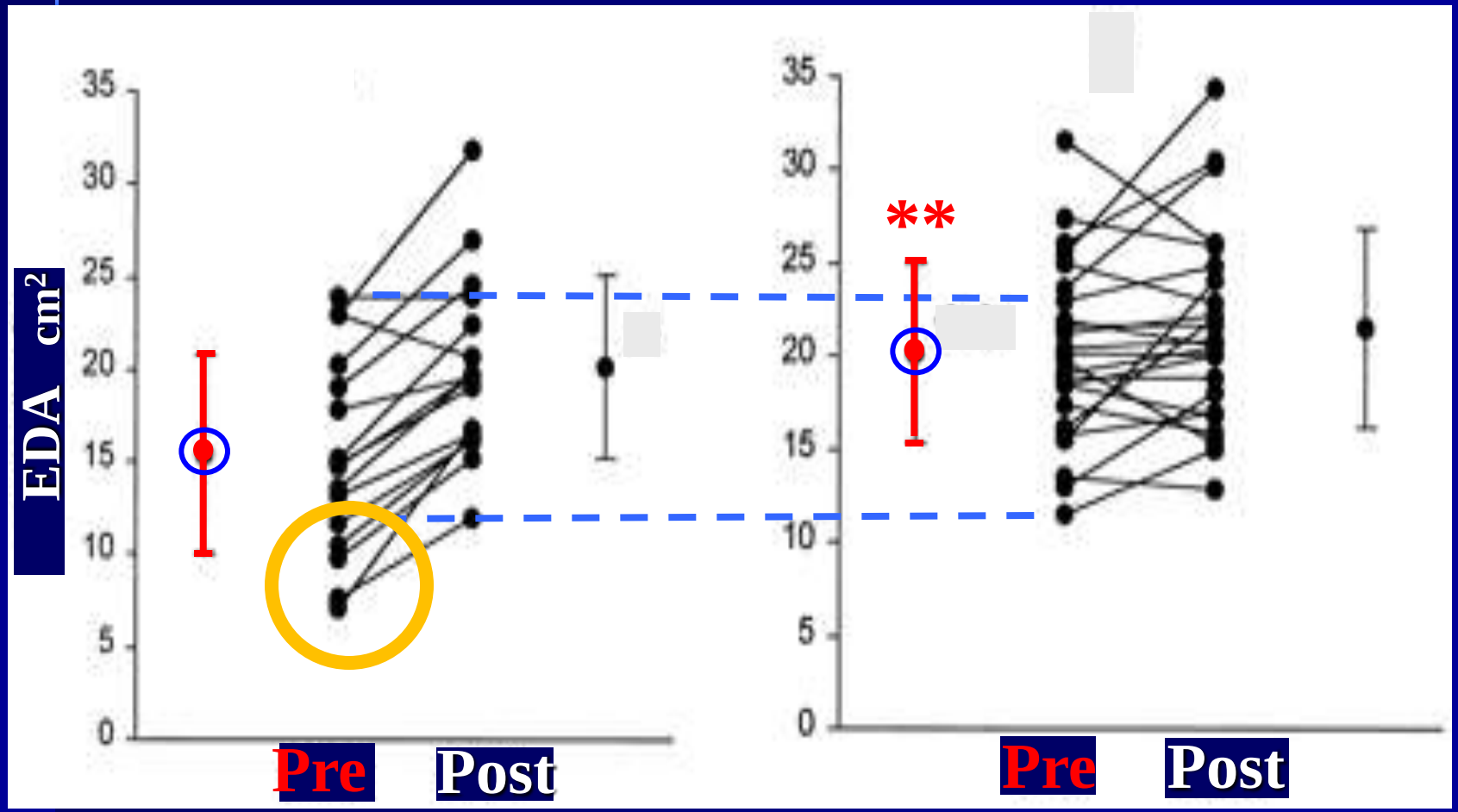


Left ventricular diameter and function


22/10/2008 18:42:35
V
0
2
4
6
8
93
2:112 HR

The use of transesophageal echocardiography for preload assessment in critically ill patients. Tousignant CP, Walsh F, Mazer CD. Anesth Analg 2000;90:351-355



A specific finding: Left ventricular obstruction

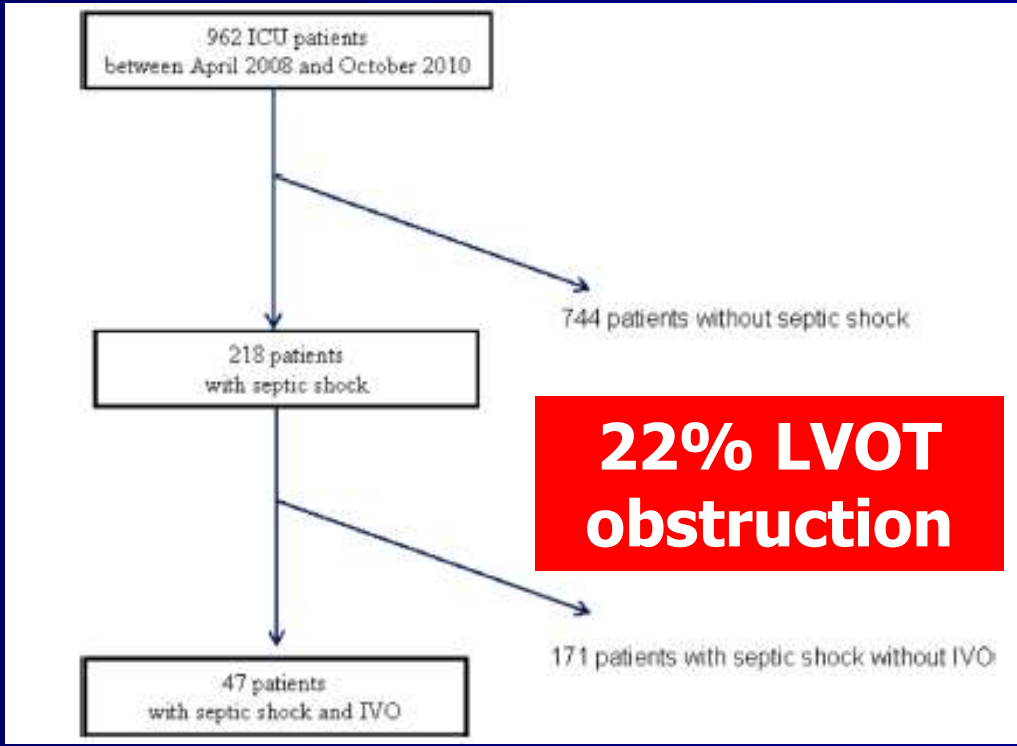
Chauvet *et al. Critical Care* (2015) 19:262
DOI 10.1186/s13054-015-0980-z

CRITICAL CARE

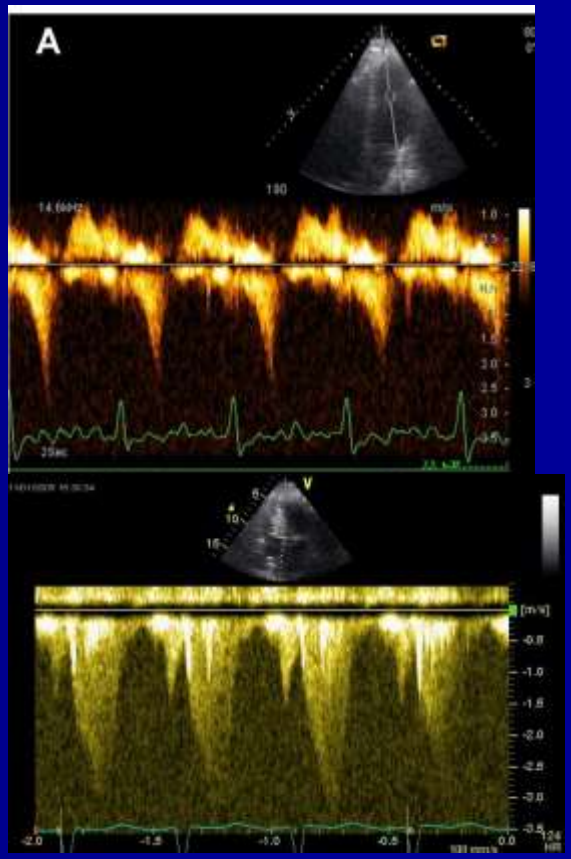
RESEARCH Open Access

Early dynamic left intraventricular obstruction is associated with hypovolemia and high mortality in septic shock patients

Jean-Louis Chauvet[1], Shari El-Dash[2,3], Olivier Delastre[1], Bernard Bouffandeau[1], Dominique Jusserand[1], Jean-Baptiste Michot[1], Fabrice Bauer[4], Julien Maizel[2,5] and Michel Slama[2,5*]



22% LVOT obstruction



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CRITICAL CARE

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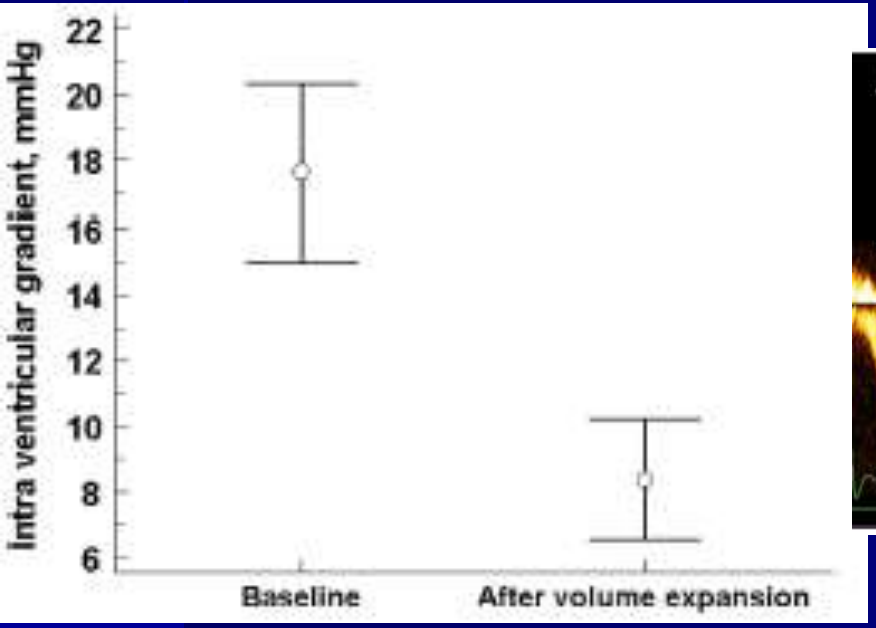
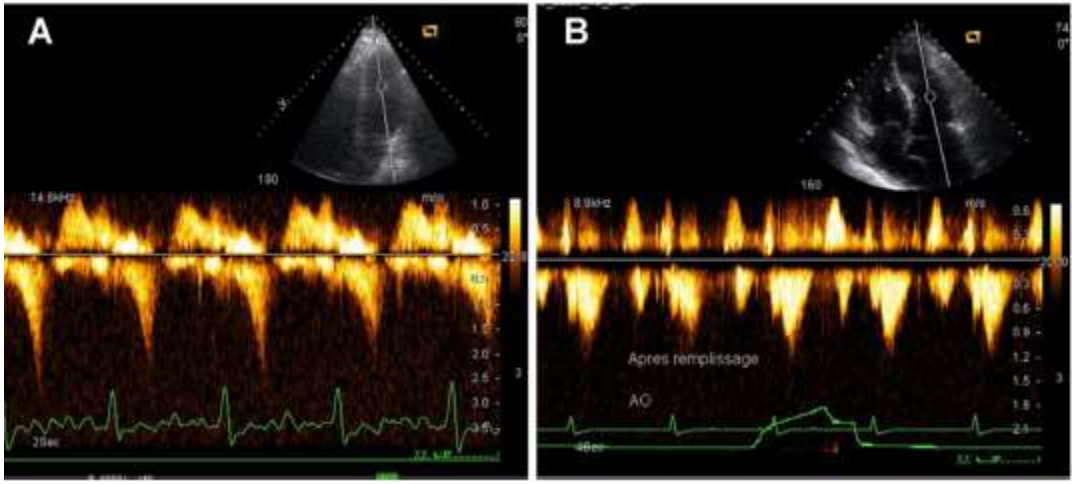




Static parameters

Dynamic parameters

Passive leg raising

Fonctional hemodynamics: dynamic parameters based on heart lung interactions

Mechanical Insufflation

RV Preload *

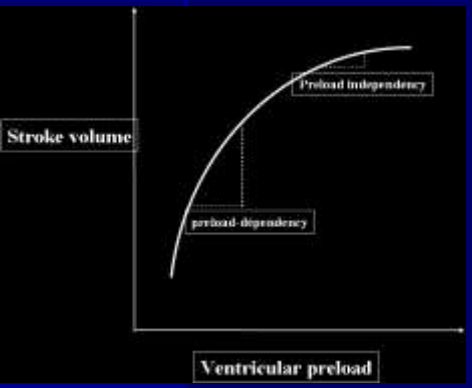
RV ejection

Inspiration

Pulmonary transit

LV Preload

2 à 3 cardiac cycle **



LV ejection

expiration

* If RV is preload dependent

** If LV is preload dependent

Am J Physiol Heart Circ Physiol 283: H1729–H1733, 2002.
First published June 20, 2002; 10.1152/ajpheart.00908.2002.

special communication

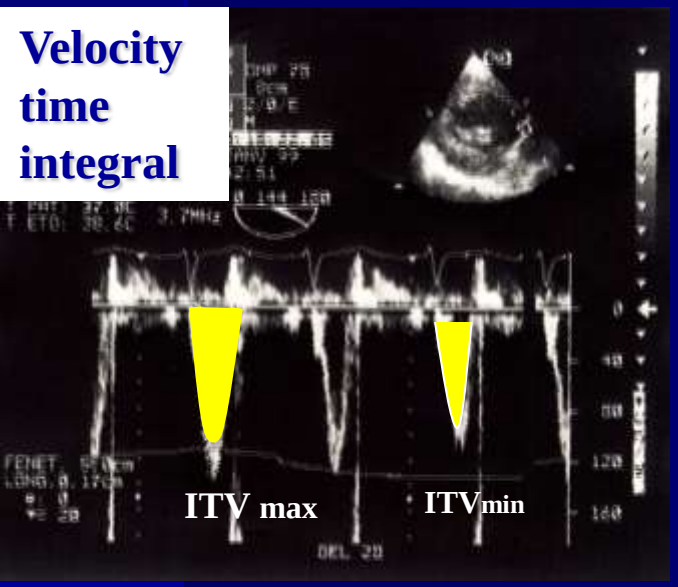
Respiratory variations of aortic VTI: a new index of hypovolemia and fluid responsiveness

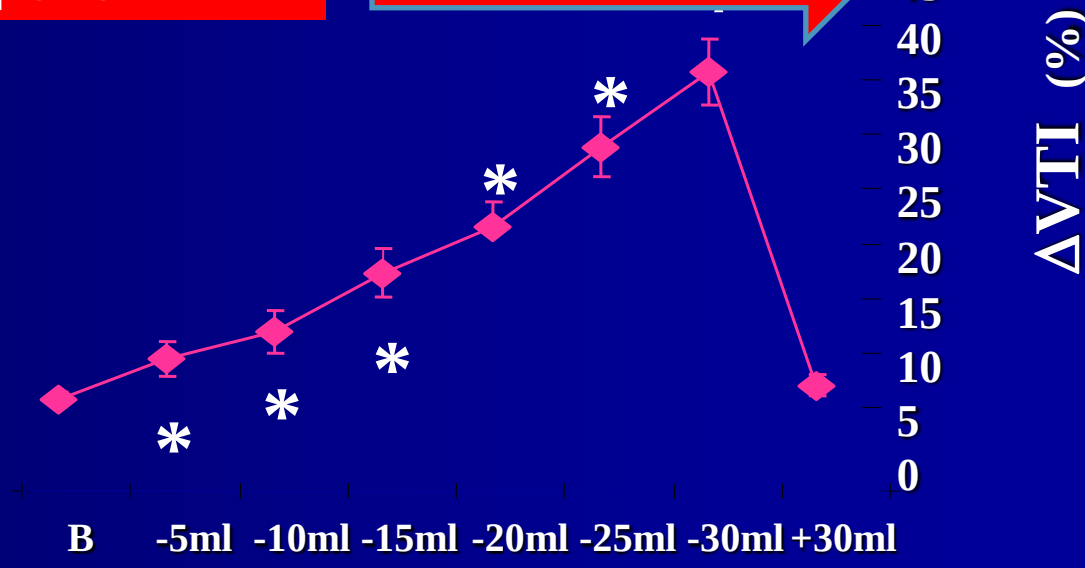
MICHEL SLAMA,[1] HENRI MASSON,[1] JEAN-LOUIS TEBOUL,[2] MARIE-LUCE ARNOUT,[1] DINKO SUSIC,[2] EDWARD FROHLICH,[3] AND MICHEL ANDREJAK[1]
[1]*Laboratoire de Pharmacologie et de Physiologie Cardiovasculaire, Université de Picardie Jules Verne, Amiens 80054;* [2]*Service de Réanimation Médicale, Centre Hospitalier Universitaire Bicêtre, Le Kremlin-Bicêtre 94275, France; and* [3]*Research Division, Ochsner Clinic Foundation, New Orleans, Louisiana 70121*

Received 25 February 20

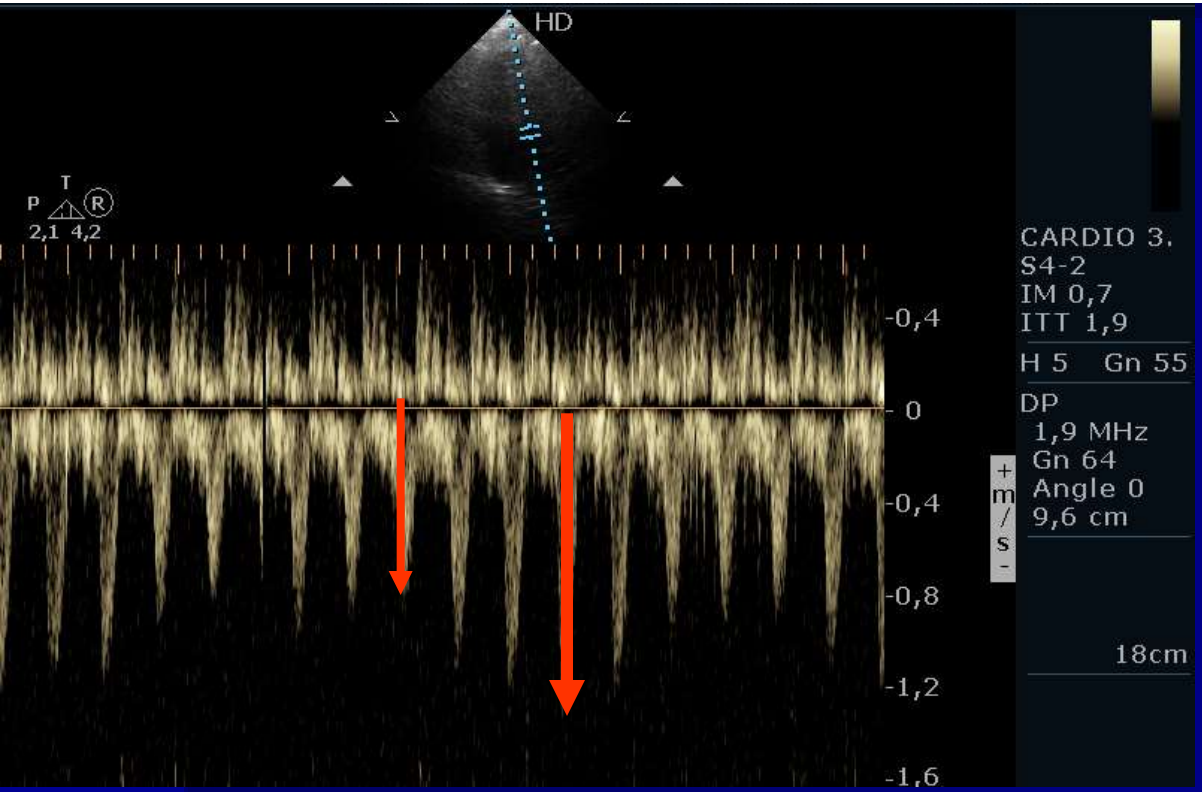
Hypovolemia

Velocity time integral





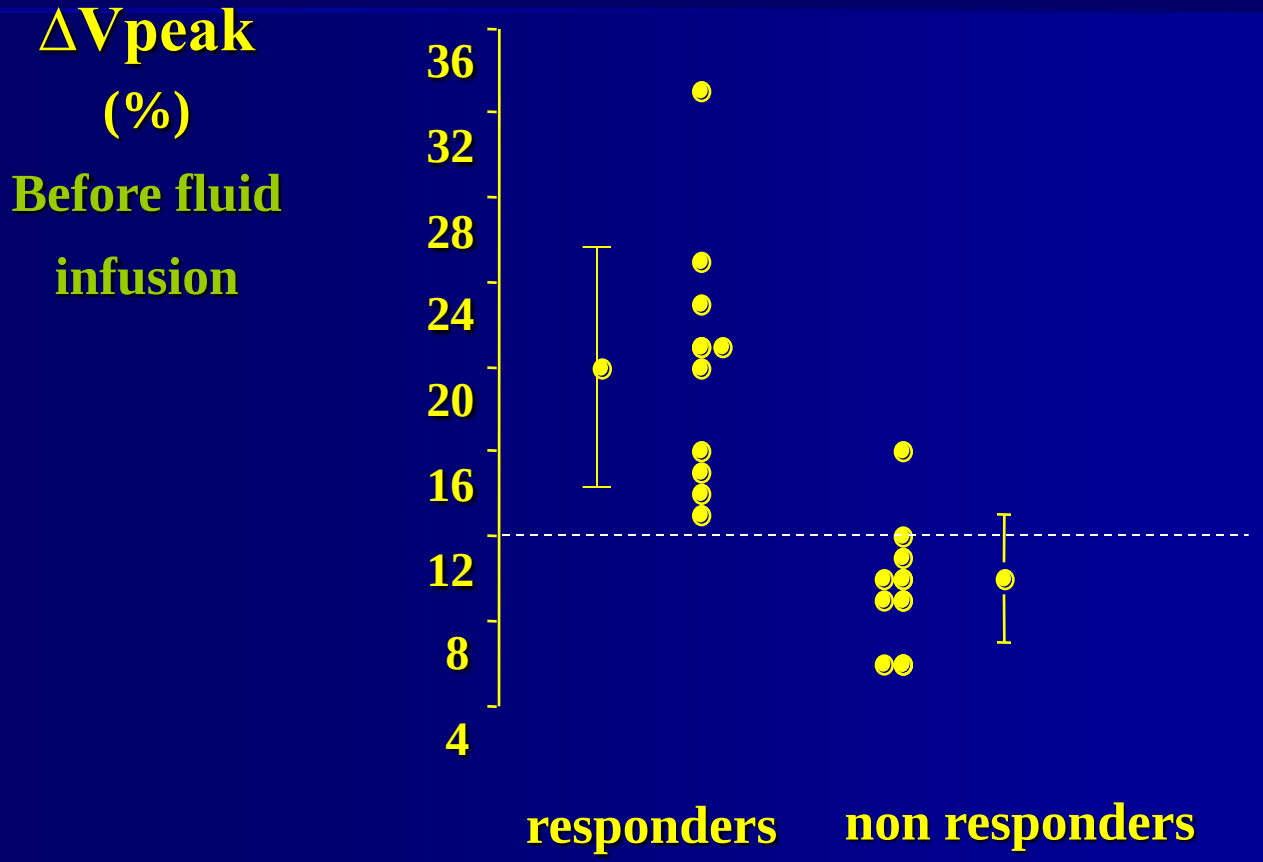
Pulsed Doppler



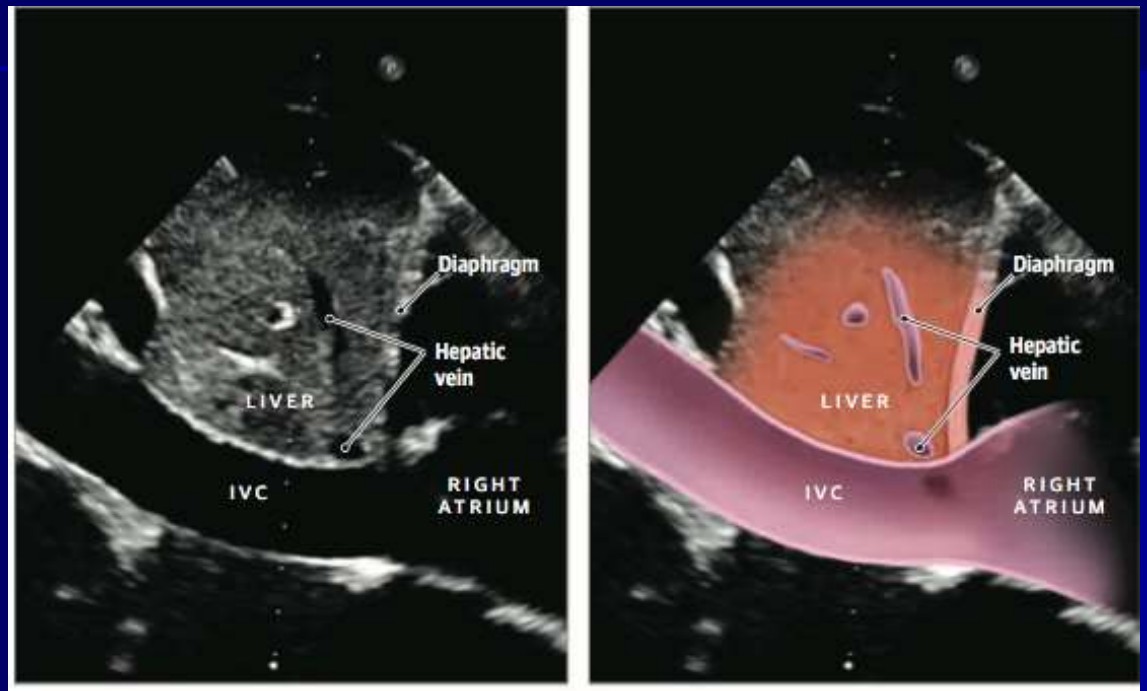
- Delta peak=28%

Respiratory changes in aortic blood velocity as an indicator of fluid responsiveness in ventilated patients with septic shock.

Feissel M, Michard F, Mangin I, Ruyer O, Faller JP, Teboul JL. ***Chest 2001; 119:867-873***

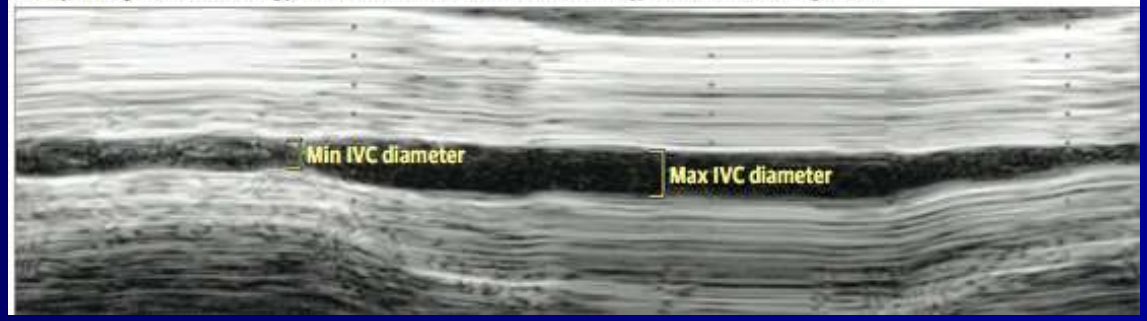


ΔIVC



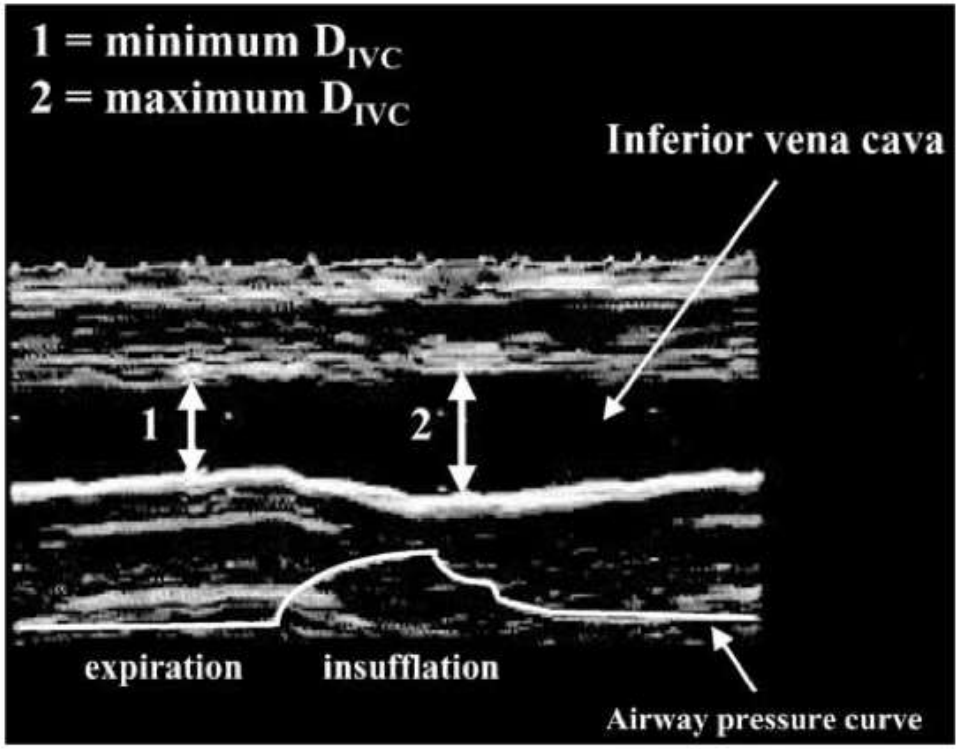
B M-mode ultrasound of IVC in spontaneously breathing patient

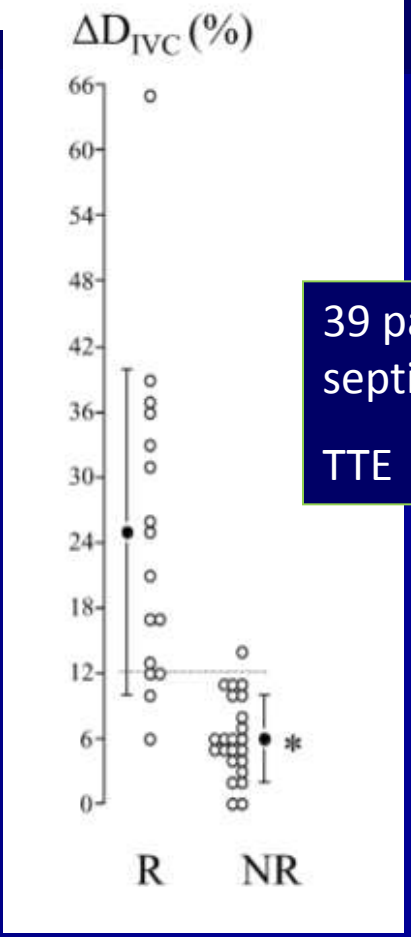
Collapsibility index of IVC = [(max IVC diameter - min IVC diameter)/max IVC diameter] x 100



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

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





39 patients septic shock

TTE

Intensive Care Med 2004; 30: 1834–1837

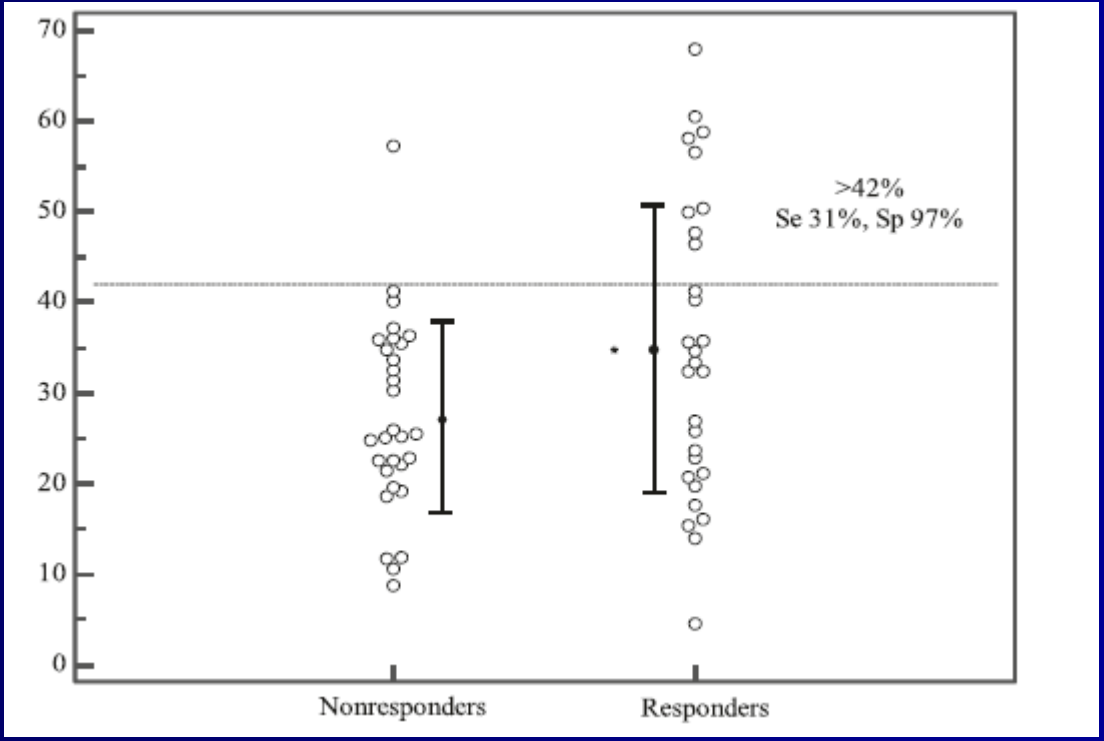
Airapetian *et al. Critical Care* (2015) 19:400
DOI 10.1186/s13054-015-1100-9

CRITICAL CARE

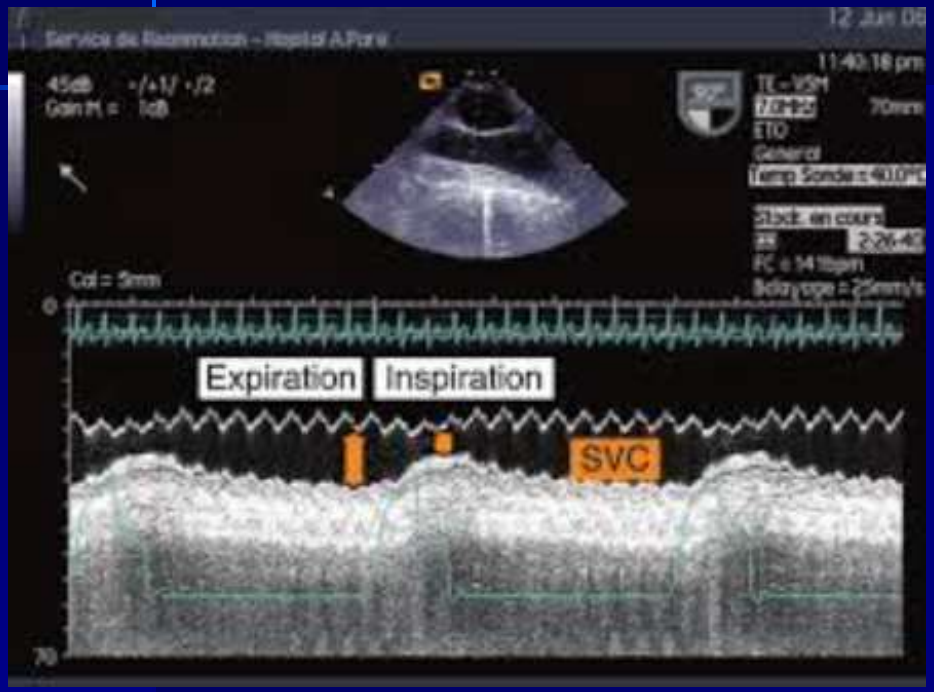
RESEARCH Open Access

Does inferior vena cava respiratory variability predict fluid responsiveness in spontaneously breathing patients?

Norair Airapetian[1,2], Julien Maizel[1,3], Ola Alyamani[2], Yazine Mahjoub[2,3], Emmanuel Lorne[2,3], Melanie Levrard[2], Nacim Ammenouche[2], Aziz Seydi[2], François Tinturier[2], Eric Lobjoie[2], Hervé Dupont[2,3] and Michel Slama[1,3*]



SVC respiratory variation with full mandatory ventilation



TOE - SVC assessment
36% respiratory variation = fluid responsive

Antoine VB et al, ICM 2004

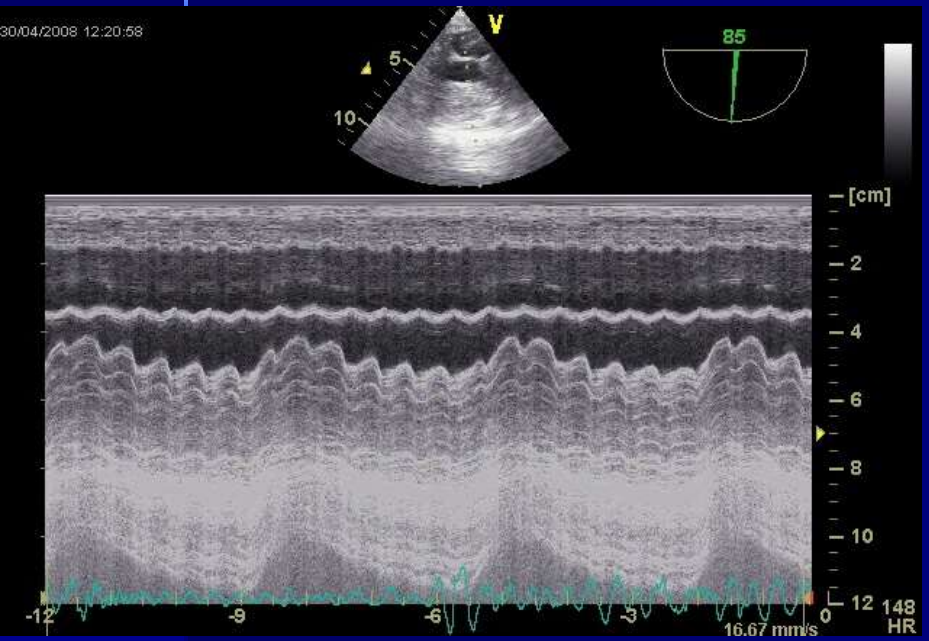
Advantages:

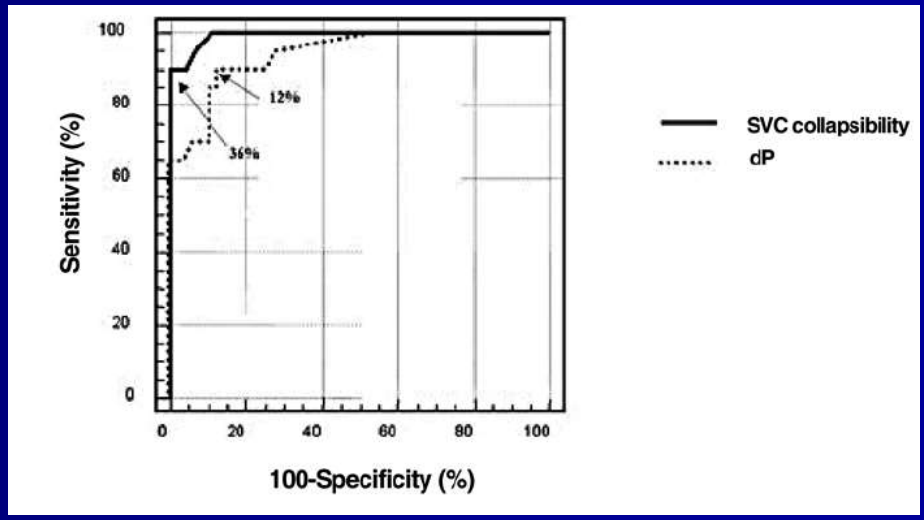
- No further manoeuvres required
- High specificity and sensitivity

Disadvantages:

- Only full MV patients
- Requires TOE

Superior vena cava respiratory variations

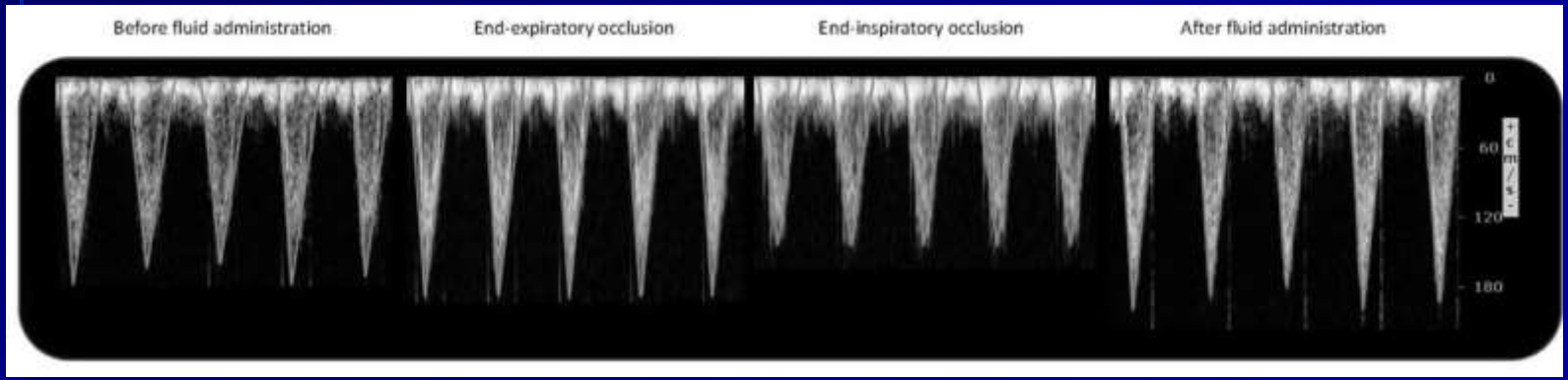




Vieillard-Baron et al. ICM 2004

Predicting Fluid Responsiveness in Critically Ill Patients by Using Combined End-Expiratory and End-Inspiratory Occlusions With Echocardiography

Mathieu Jozwiak, MD[1,2]; François Depret, MD[1,2]; Jean-Louis Teboul, MD, PhD[1,2]; Jean-Emmanuel Alphonsine, MD[1,2]; Christopher Lai, MD[1,2]; Christian Richard, MD[1,2]; Xavier Monnet, MD, PhD[1,2]



Crit Care Med 2017; 45:e1131–e1138

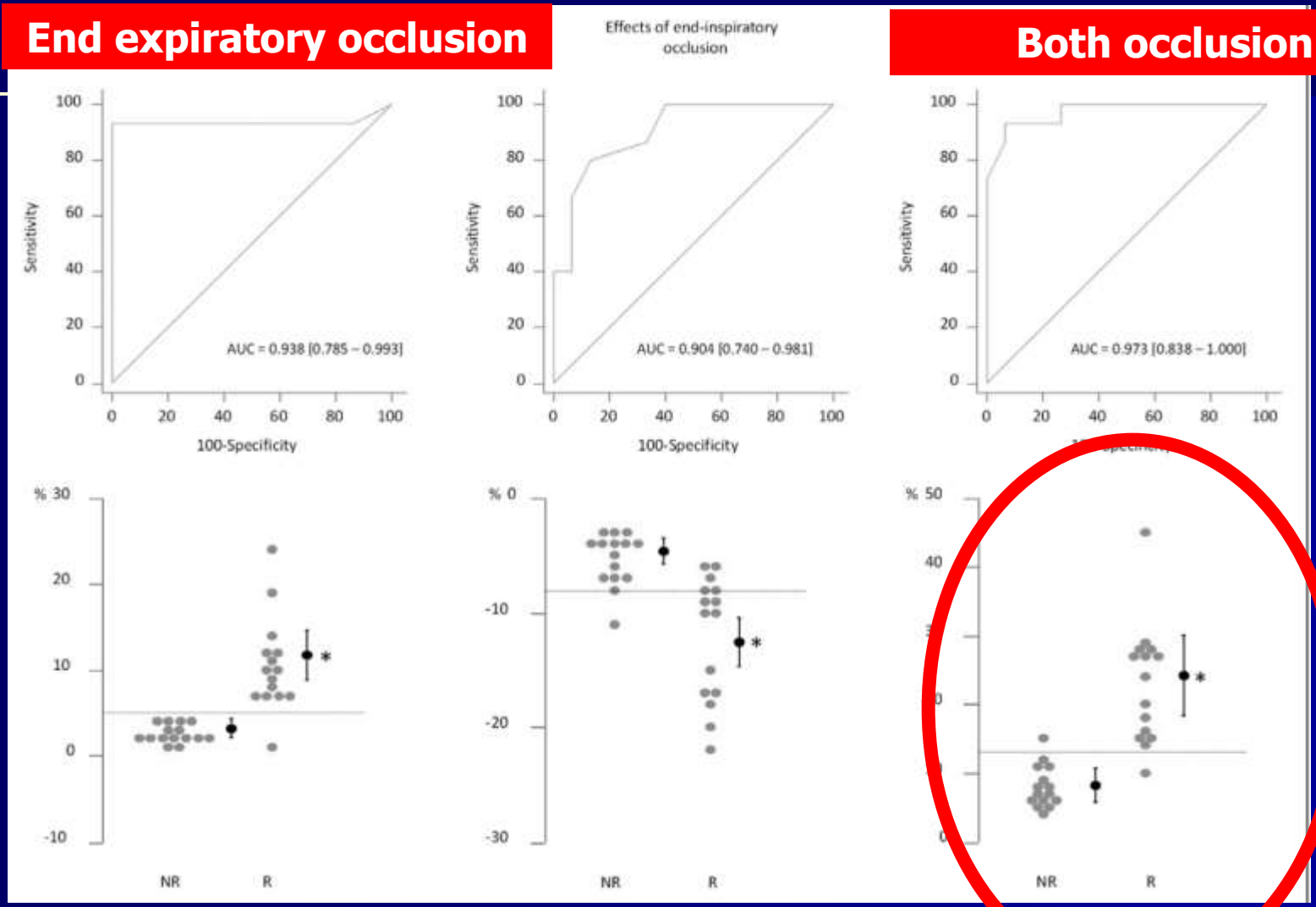
Predicting Fluid Responsiveness in Critically Ill Patients by Using Combined End-Expiratory and End-Inspiratory Occlusions With Echocardiography

Mathieu Jozwiak, MD[1,2]; François Depret, MD[1,2]; Jean-Louis Teboul, MD, PhD[1,2]; Jean-Emmanuel Alphonsine, MD[1,2]; Christopher Lai, MD[1,2]; Christian Richard, MD[1,2]; Xavier Monnet, MD, PhD[1,2]

End inspiratory occlusion

End expiratory occlusion

Both occlusion



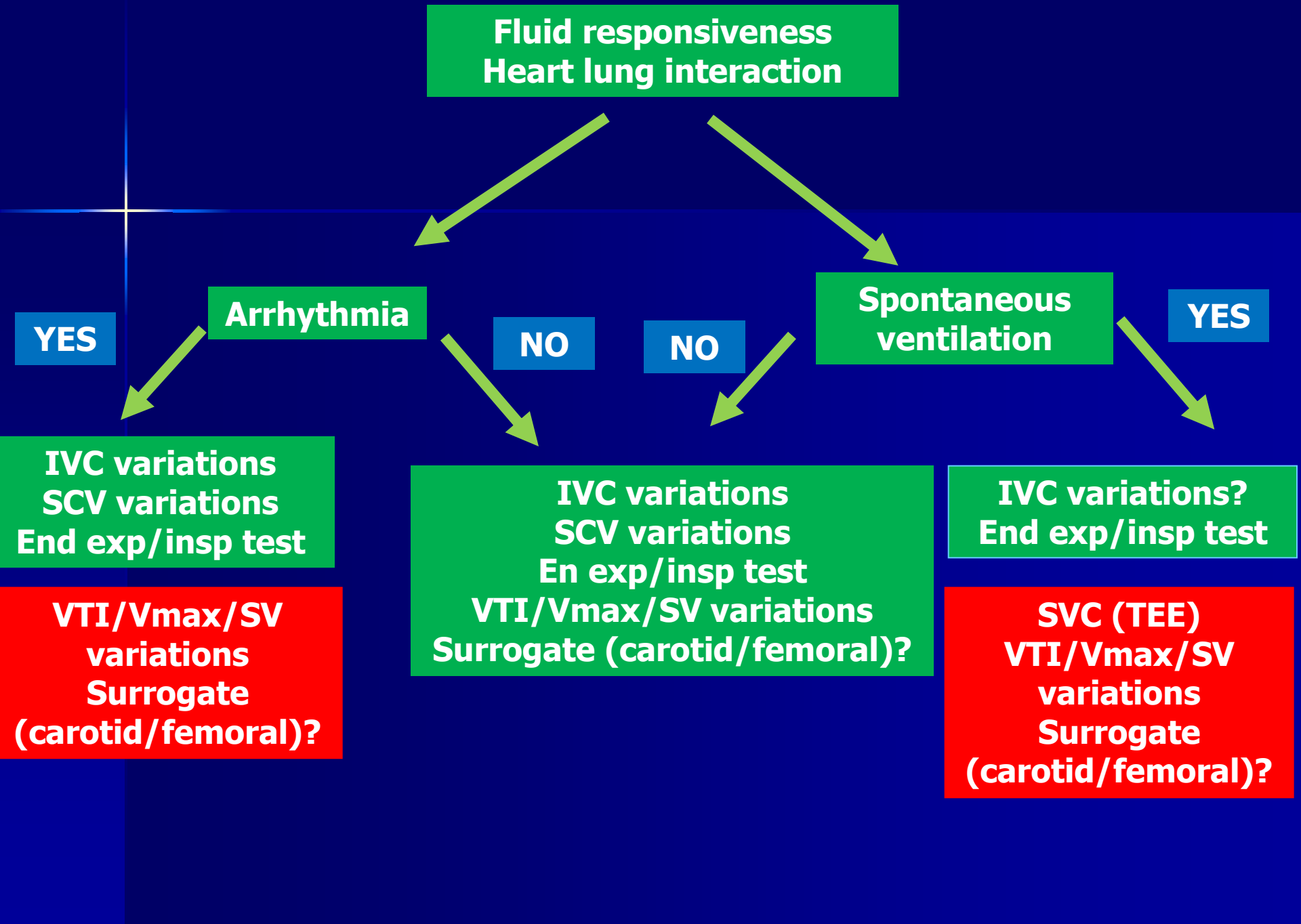
Crit Care Med 2017; 45:e1131–e1138

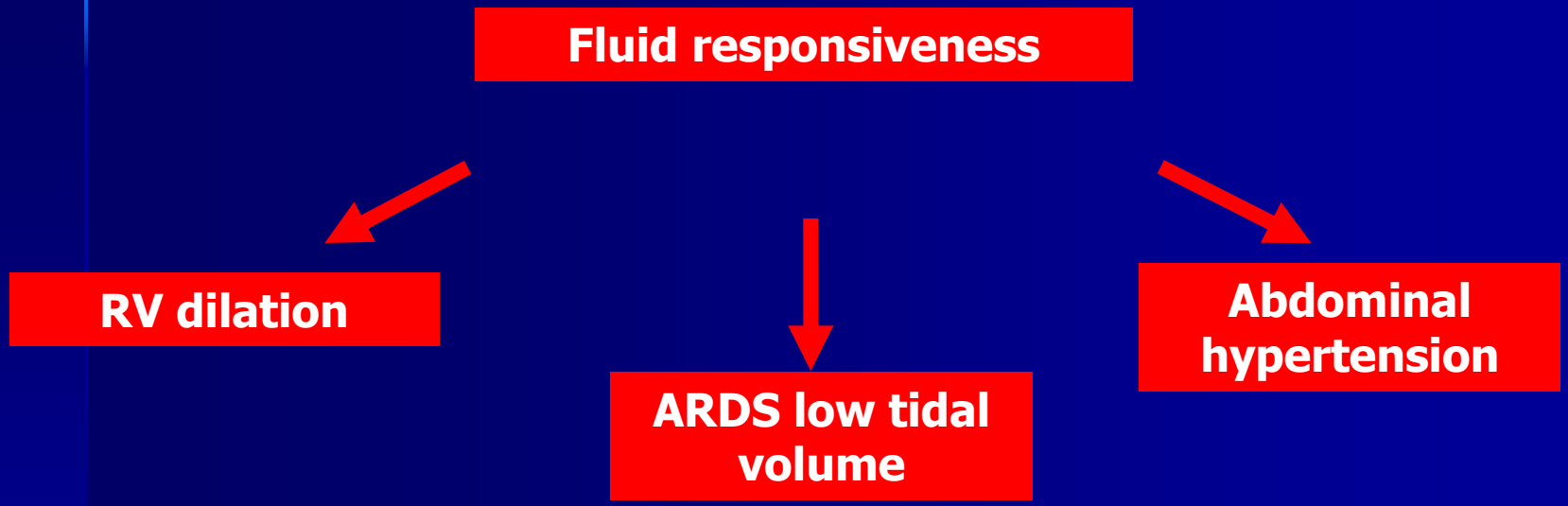
Pulse Pressure Variations in Acute Respiratory Distress Syndrome: "Fifty Shades of Grey"*

Michel Slama, MD, PhD, FAHA, FACC
Julien Maizel, MD, PhD
Service de réanimation médicale
Amiens, France

in ARDS patients, in whom lung and thoracic elastanc
greatly modified (11). Hence, the same tidal volume in
ent ARDS patients may induce different intrathoracic
sure variations (depending on lung and chest complianc

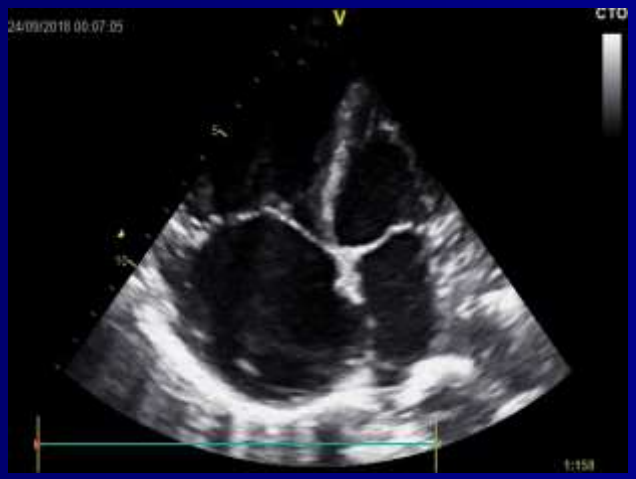
Limits of fluid responsiveness based on heart lung interactions

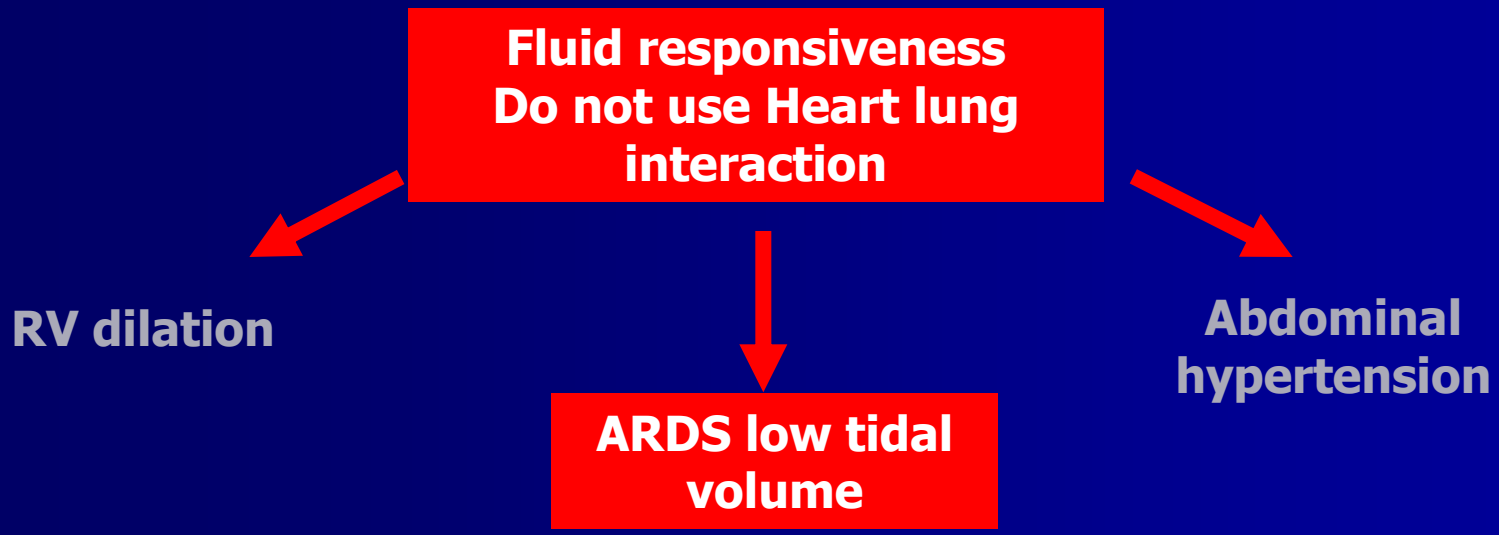

Fluid responsiveness
Heart lung interaction
Arrhythmia
YES
NO
Spontaneous ventilation
NO
YES
IVC variations
SCV variations
End exp/insp test
VTI/Vmax/SV variations
Surrogate (carotid/femoral)?
IVC variations
SCV variations
En exp/insp test
VTI/Vmax/SV variations
Surrogate (carotid/femoral)?
IVC variations?
End exp/insp test
SVC (TEE)
VTI/Vmax/SV variations
Surrogate (carotid/femoral)?


Fluid responsiveness
RV dilation
ARDS low tidal volume
Abdominal hypertension

Fluid responsiveness
Do not use Heart lung interaction

RV dilation




Fluid responsiveness
Do not use Heart lung interaction
RV dilation
ARDS low tidal volume
Abdominal hypertension

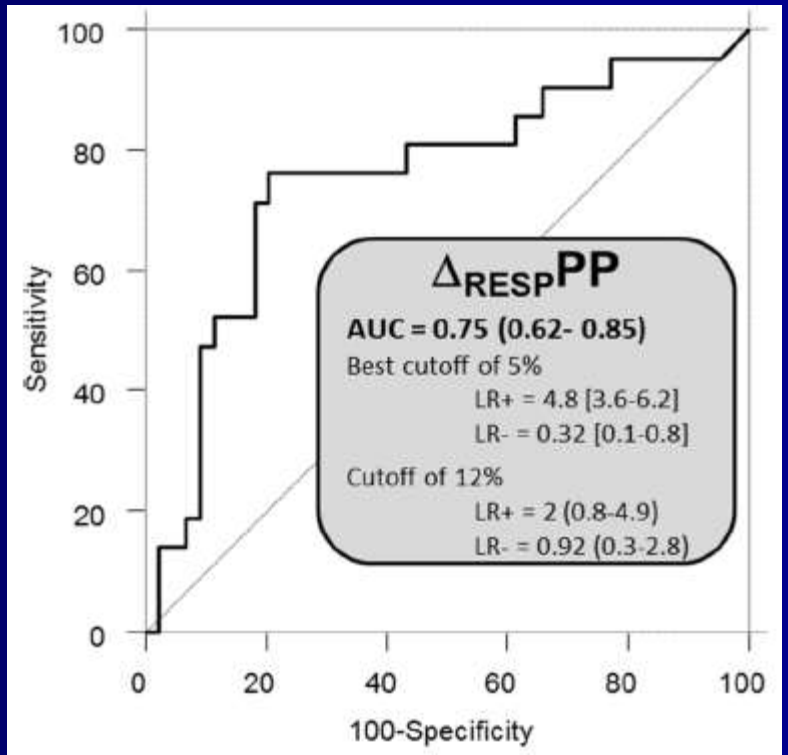
Lakhal *et al. Critical Care* 2011, **15**:R85
http://ccforum.com/content/15/2/R85

CRITICAL CARE

RESEARCH Open Access

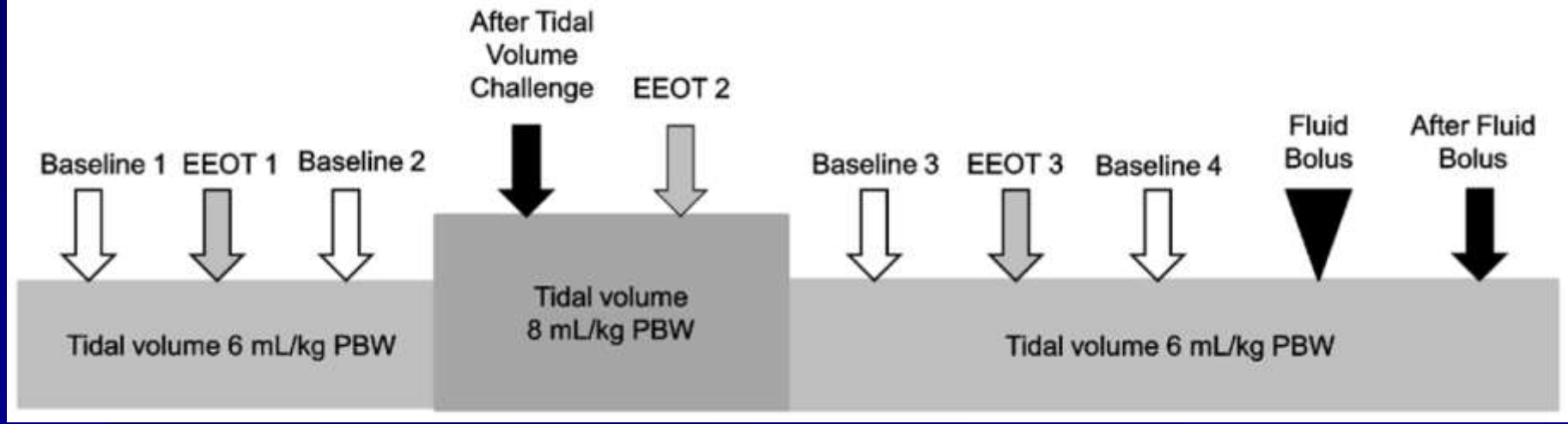
Respiratory pulse pressure variation fails to predict fluid responsiveness in acute respiratory distress syndrome

Karim Lakhal[1], Stephan Ehrmann[2], Dalila Benzekri-Lefèvre[3], Isabelle Runge[3], Annick Legras[2], Pierre-François Dequin[2], Emmanuelle Mercier[2], Michel Wolff[1], Bernard Régnier[1], Thierry Boulain[3*]



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

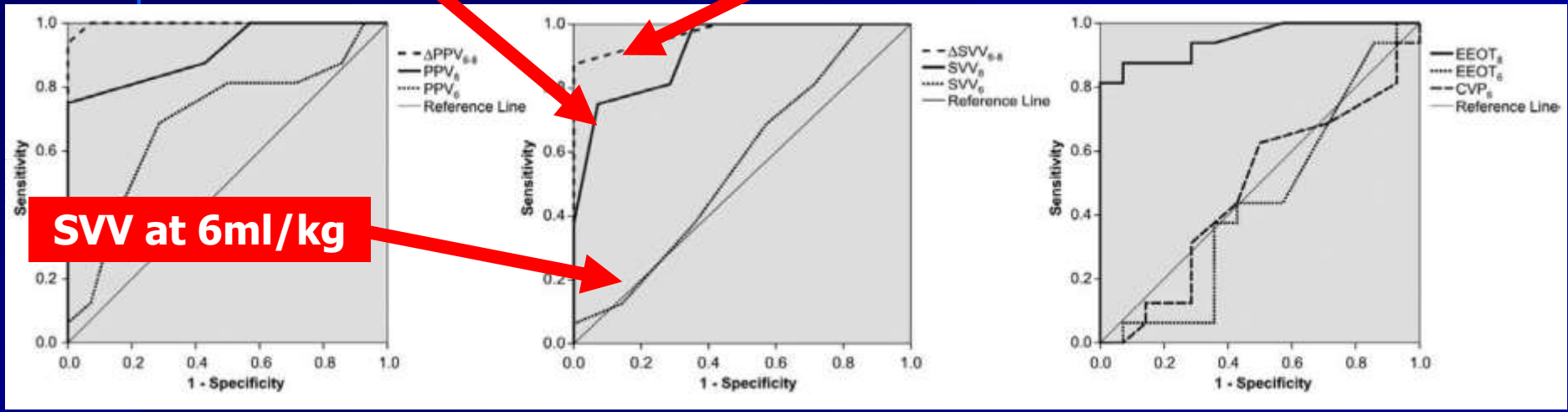
The Changes in Pulse Pressure Variation or Stroke Volume Variation After a "Tidal Volume Challenge" Reliably Predict Fluid Responsiveness During Low Tidal Volume Ventilation*

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]

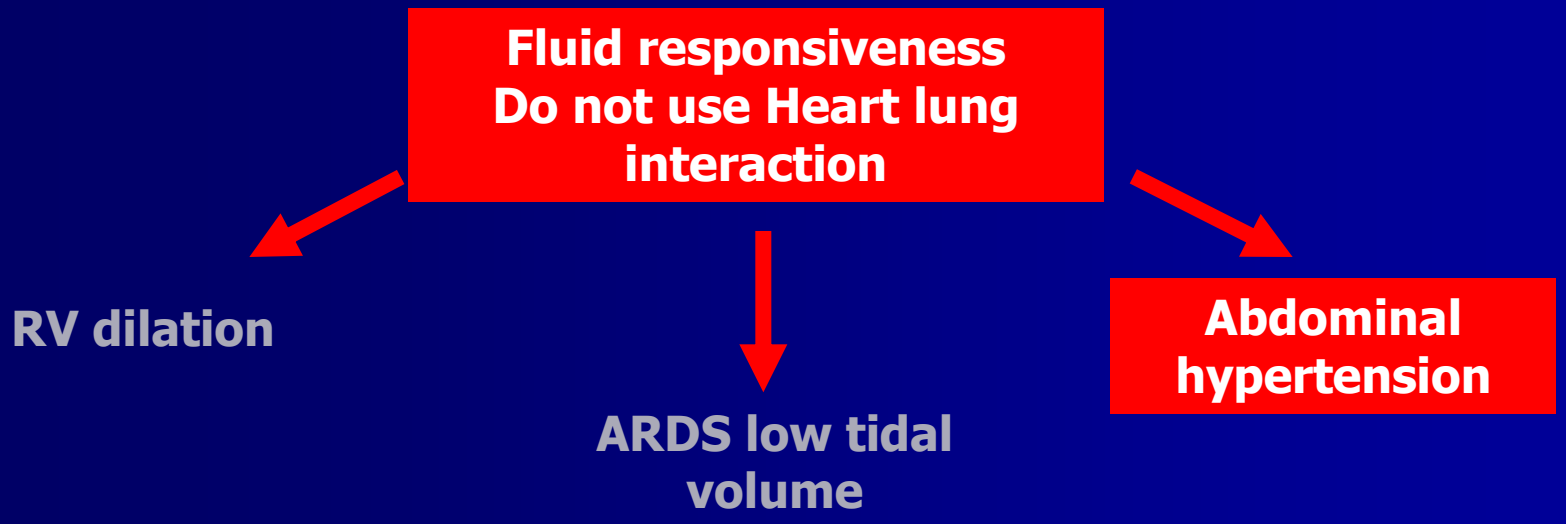
Delta SVV

SVV at 8ml/kg

SVV at 6ml/kg



Variables	Area Under the Receiver-Operating Characteristic Curve (95% CI)	p	Best Cutoff Value (%)	Sensitivity (%)	Specificity (%)	Positive Predictive Value (95% CI)	Negative Predictive Value (95% CI)
Percentage change in PPV from V_t 6 to 8 mL/kg PBW	0.97 (0.92–1.00)	< 0.001	48	94	100	100 (80–100)	93 (70–99)
Percentage change in SVV from V_t 6 to 8 mL/kg PBW	0.96 (0.89–1.00)	< 0.001	43	88	93	93 (70–99)	87 (62–96)


Fluid responsiveness
Do not use Heart lung interaction
RV dilation
ARDS low tidal volume
Abdominal hypertension

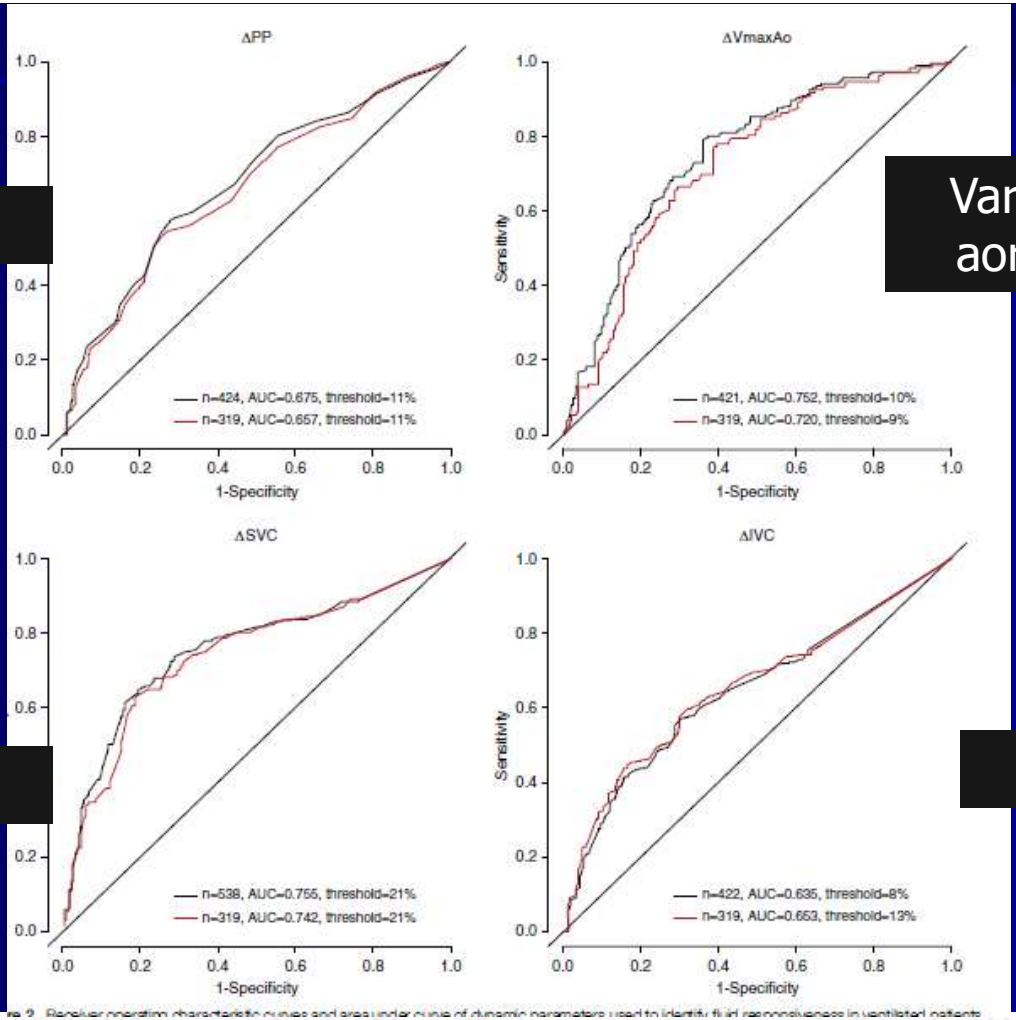
True life

Comparison of Echocardiographic Indices Used to Predict Fluid Responsiveness in Ventilated Patients

Philippe Vignon[1,2,3], Xavier Repessé[4*], Emmanuelle Bégot[1,2*], Julie Léger[5], Christophe Jacob[6], Koceila Bouferrache[7], Michel Slama[8], Gwenaël Prat[6], and Antoine Vieillard-Baron[4,9,10]

PPV

Variations of aortic Vmax



540 patients

Delta SVC

Delta IVC

Am J Respir Crit Care Med Vol 195, Iss 8, pp 1022–1032, Apr 15, 2017

Static parameters

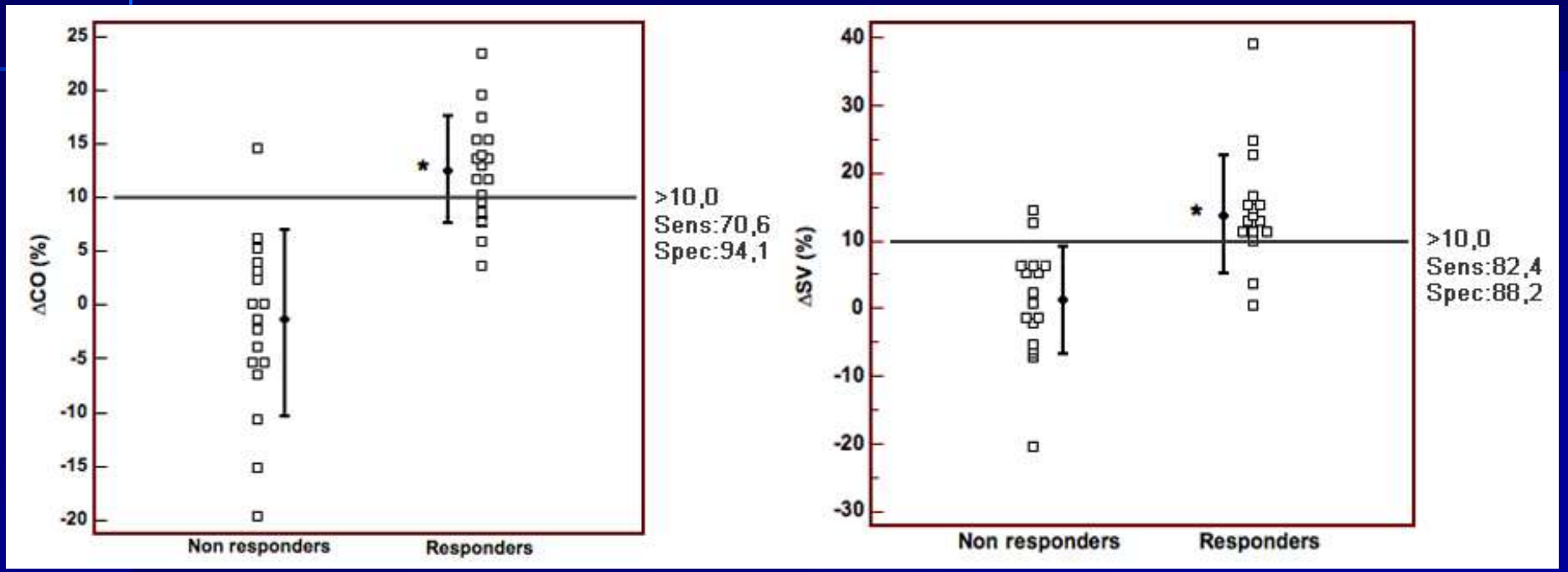
Dynamic parameters

Passive leg raising

Passive Leg Raising

Blood shift

Passive Leg Raising



Increase in CO or SV by >10%

Maizel Int care med 2007

Intensive Care Med (2016) 42:1935–1947
DOI 10.1007/s00134-015-4134-1

ORIGINAL

Xavier Monnet
Paul Marik
Jean-Louis Teboul

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

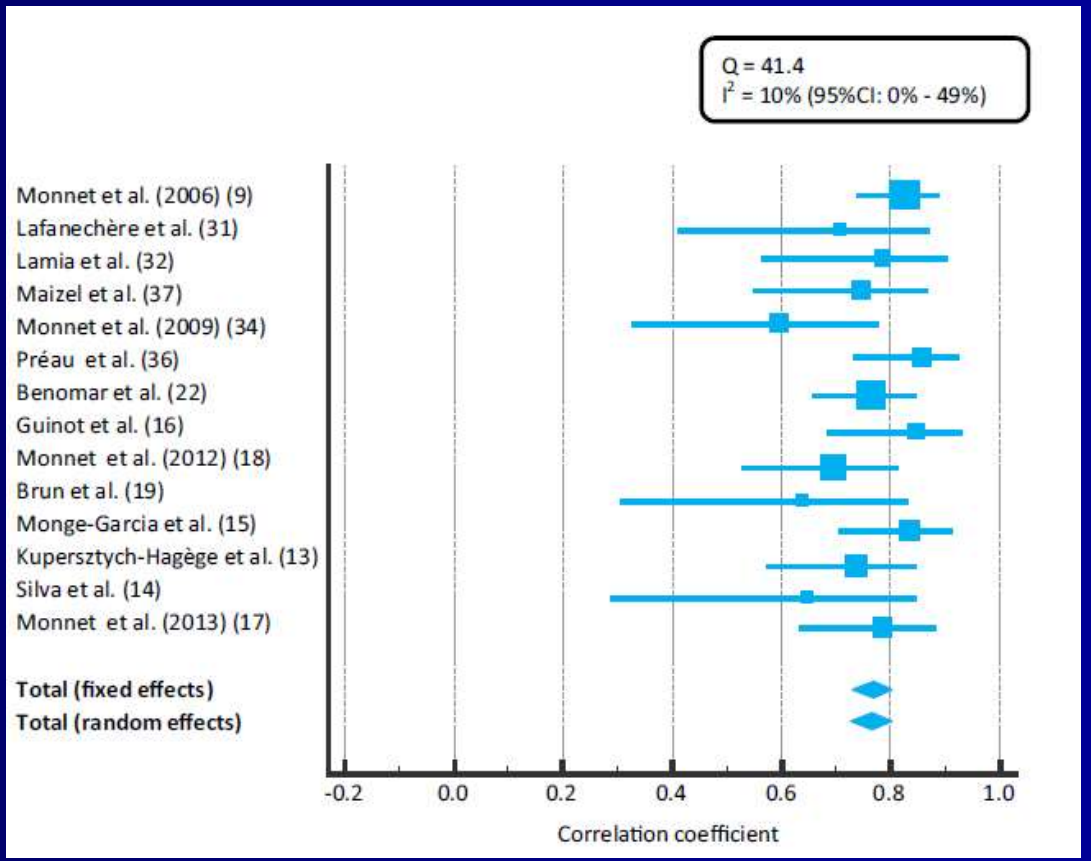


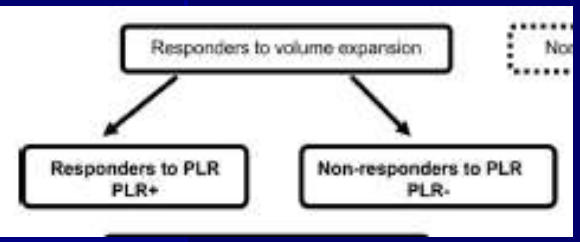
Fig. 3 Forest plot for the correlation coefficients (with 95 % confidence intervals) between the changes in cardiac output or surrogates induced by passive leg raising and those induced by volume expansion

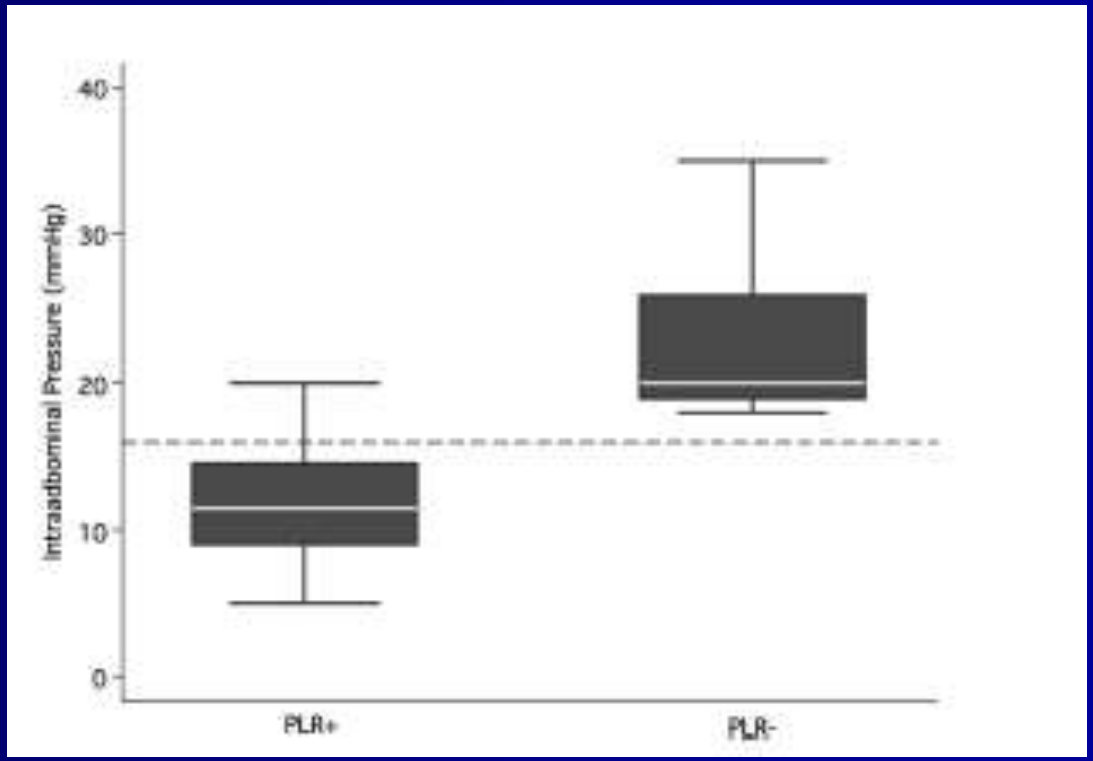
Limitations of PLR

- Elastic socks
- High abdominal pressure
- Severe incra cranial hypertension

The passive leg-raising maneuver cannot accurately predict fluid responsiveness in patients with intra-abdominal hypertension*

Yazine Mahjoub, MD; Jérémie Touzeau, MD; Norair Airapetian, MD; Emmanuel Lorne, MD; Mustapha Hijazi, MD; Elie Zogheib, MD; François Tinturier, MD; Michel Slama, MD, PhD; Hervé Dupont, MD, PhD



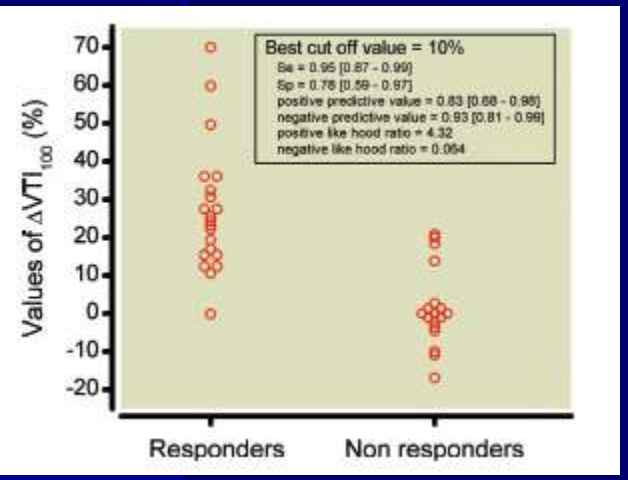


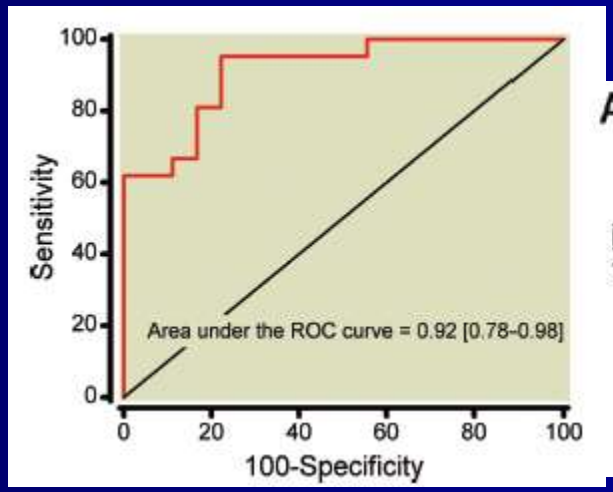
Question 4: what to do when all parameters failed to predict fluid-reponsiveness?

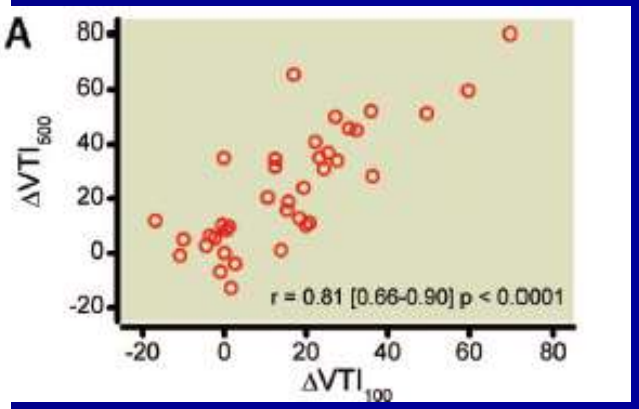
An Increase in Aortic Blood Flow after an Infusion of 100 ml Colloid over 1 Minute Can Predict Fluid Responsiveness

The Mini-fluid Challenge Study

Laurent Muller, M.D., M.Sc.,* Medhi Toumi, M.D.,* Philippe-Jean Bousquet, M.D.,† Béatrice Riu-Poulenc, M.D.,‡ Guillaume Louart, M.D.,* Damien Candela, M.D.,* Lana Zoric, M.D.,* Carey Suehs, Ph.D.,† Jean-Emmanuel de La Coussaye, M.D., Ph.D.,§ Nicolas Molinari, Ph.D.,† Jean-Yves Lefrant, M.D., Ph.D.,§ in the AzuRéa Group







Muller Anesthesia 2010

Question 5: When to stop? Efficiency and tolerance…

Efficency

Bouchier et al. Critical Care (2017) 21:155
DOI 10.1186/s13054-017-1742-x

Critical Care

RESEARCH Open Access

Marked regional endothelial dysfunction in mottled skin area in patients with severe infections

Simon Bouchier[1,2,3], Jérémie Joffre[1,2,4], Vincent Dubée[1,2], Gabriel Preda[1], Jean-Luc Baudel[1], Naïke Bigé[1], Guillaume Leblanc[1,5], Bernard I. Levy[4], Bertrand Guidet[1,2,3], Eric Maury[1,2,3] and Hafid Ait-Oufella[1,2,4*]

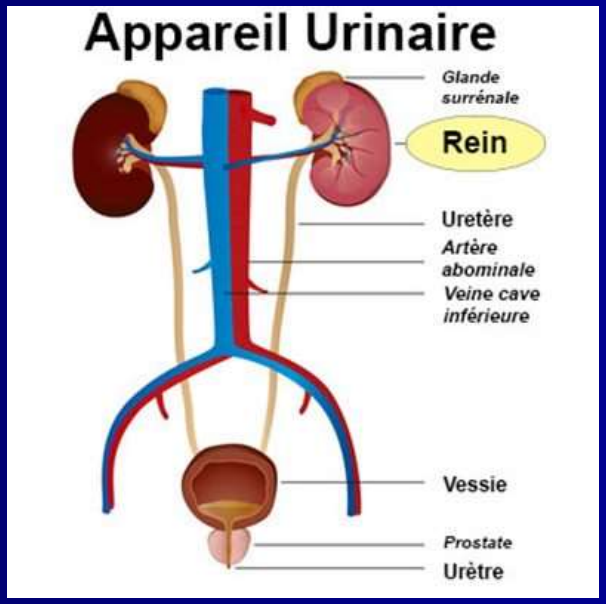
Intensive Care Med (2014) 40:958–964
DOI 10.1007/s00134-014-3326-4

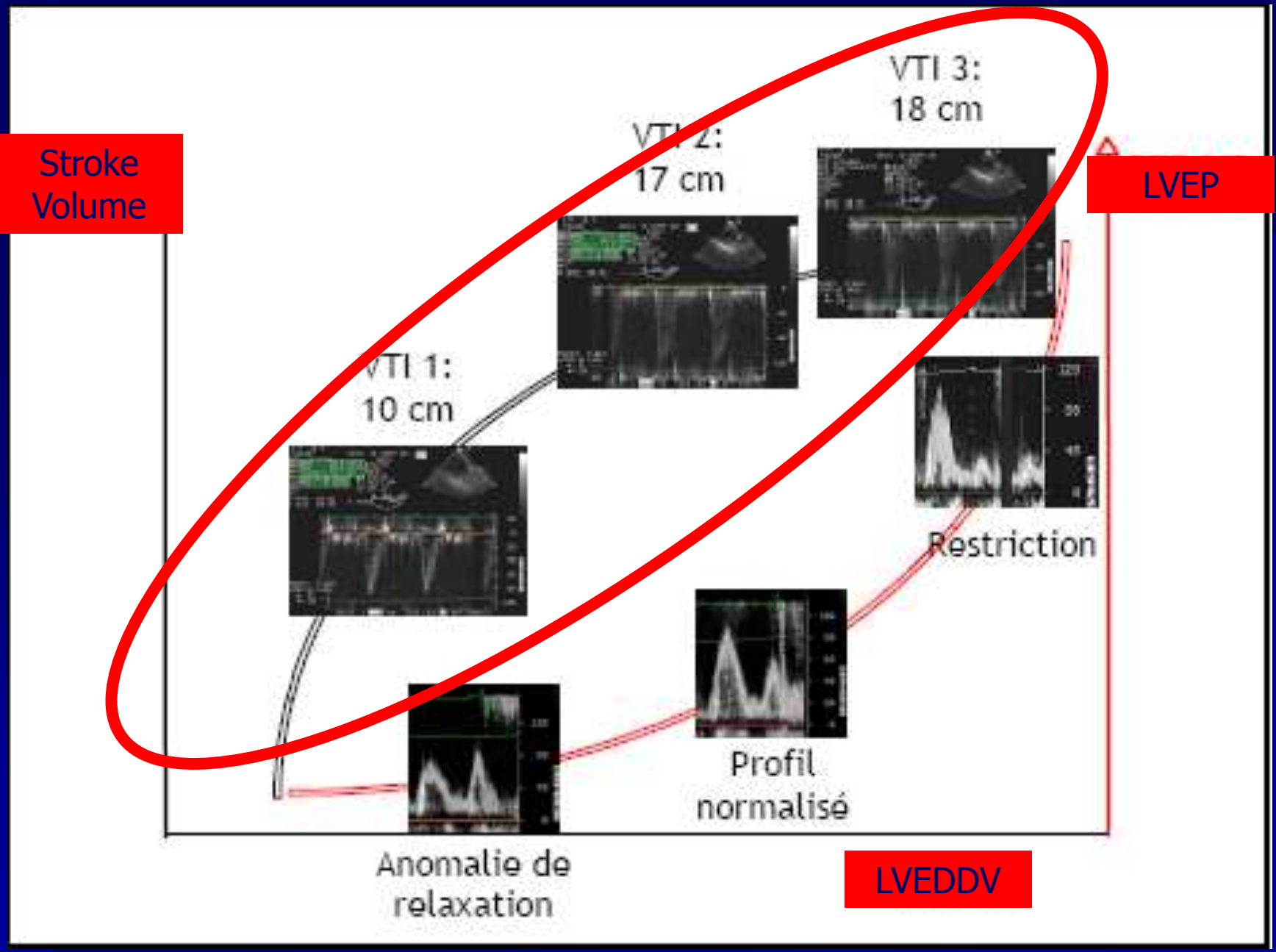
ORIGINAL

H. Ait-Oufella
N. Bige
P. Y. Boelle
C. Pichereau
M. Alves

Capillary refill time exploration during septic shock

Marbrure

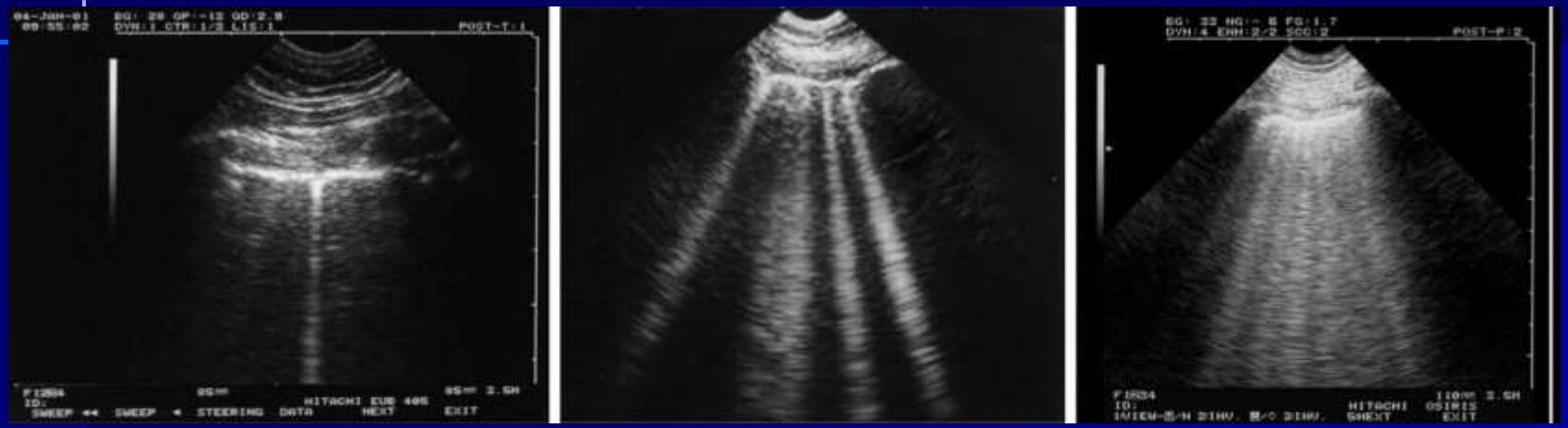


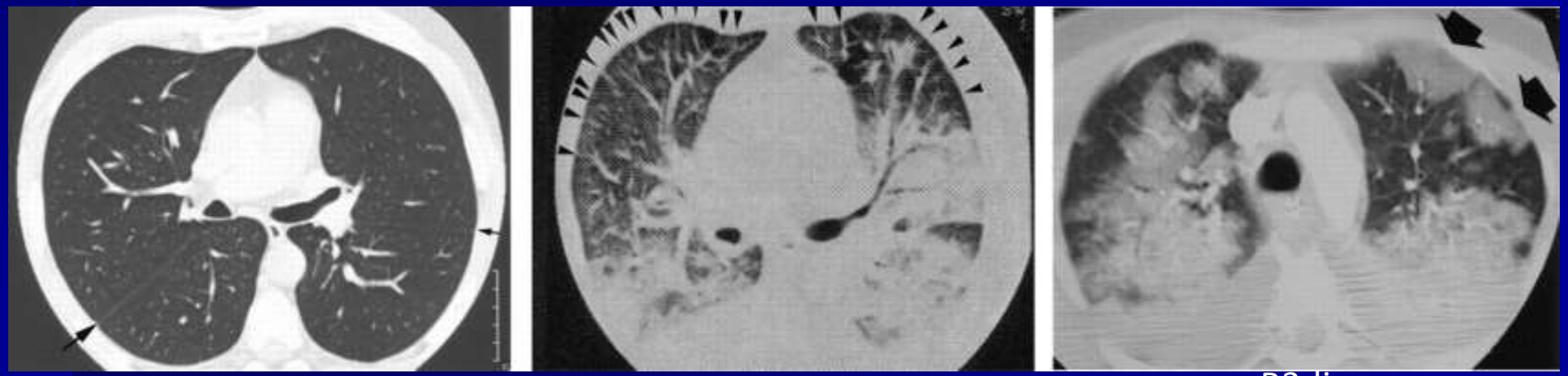

Stroke Volume
VTI 3: 18 cm
VTI 2: 17 cm
VTI 1: 10 cm
LVEP
Restriction
Profil normalisé
Anomalie de relaxation
LVEDDV

Tolerance

B-lines

CT Scan correlations



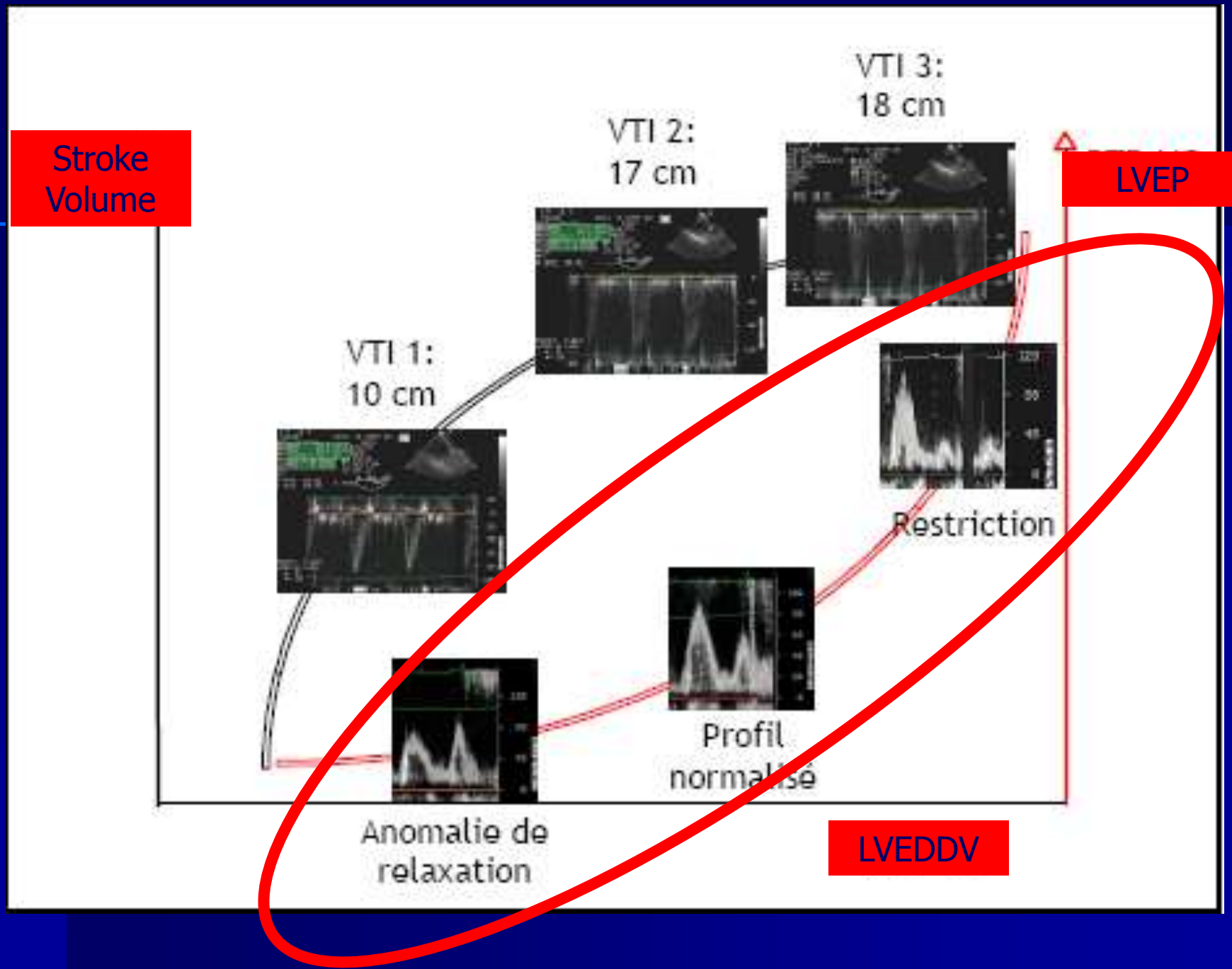


b-line
No pathologic meaning
(possibly minor fissura)

B7-lines
Subpleural interlobular septa

B3-lines
Subpleural ground-glass lesions

Lichtenstein DA et al. CHEST. 2009;136(4):1014


Stroke Volume
VTI 3: 18 cm
VTI 2: 17 cm
LVEP
VTI 1: 10 cm
Restriction
Profil normalisé
Anomalie de relaxation
LVEDDV

Question 6: Is fluid-responsiveness using echocardiography improves the prognosis of ICU patients?

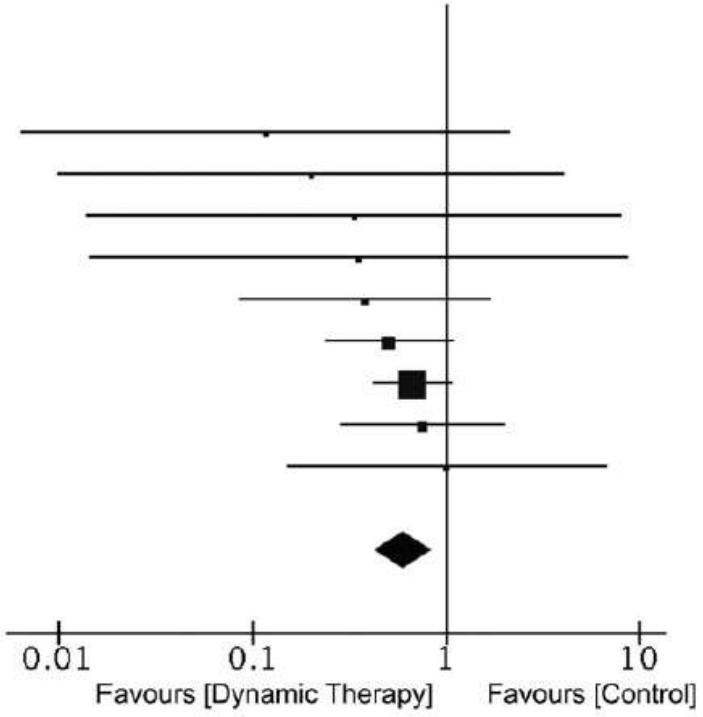
Incorporating Dynamic Assessment of Fluid Responsiveness Into Goal-Directed Therapy: A Systematic Review and Meta-Analysis

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[6]; Ryan Zarychanski, MD, MSc, FRCPC[1,2,4]

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: $Tau^2 = 0.00$; $Chi^2 = 3.28$, df = 8 (P = 0.92); $I^2 = 0\%$

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



Mortality

Crit Care Med 2017

Summary fluid responsiveness

Indices

- Static parameters
- Passive Leg Raising
- Pulsed pressure variations
- Aortic velocity or VTI changes
- IVC or SVC changes
- Other maneuvers (inspiratory pause, tidal challenge…)
- Fluid challenge

Follow-up

- Cardiac output or SV
- Tolerance : clinical signs, mitral flow, E/e’

Conclusion

- Echocardiographie is very useful in ICU at the bedside to assess fluid-responsiveness
- Echocardiography should be repeated as many times as needed to titrate fluid infusion