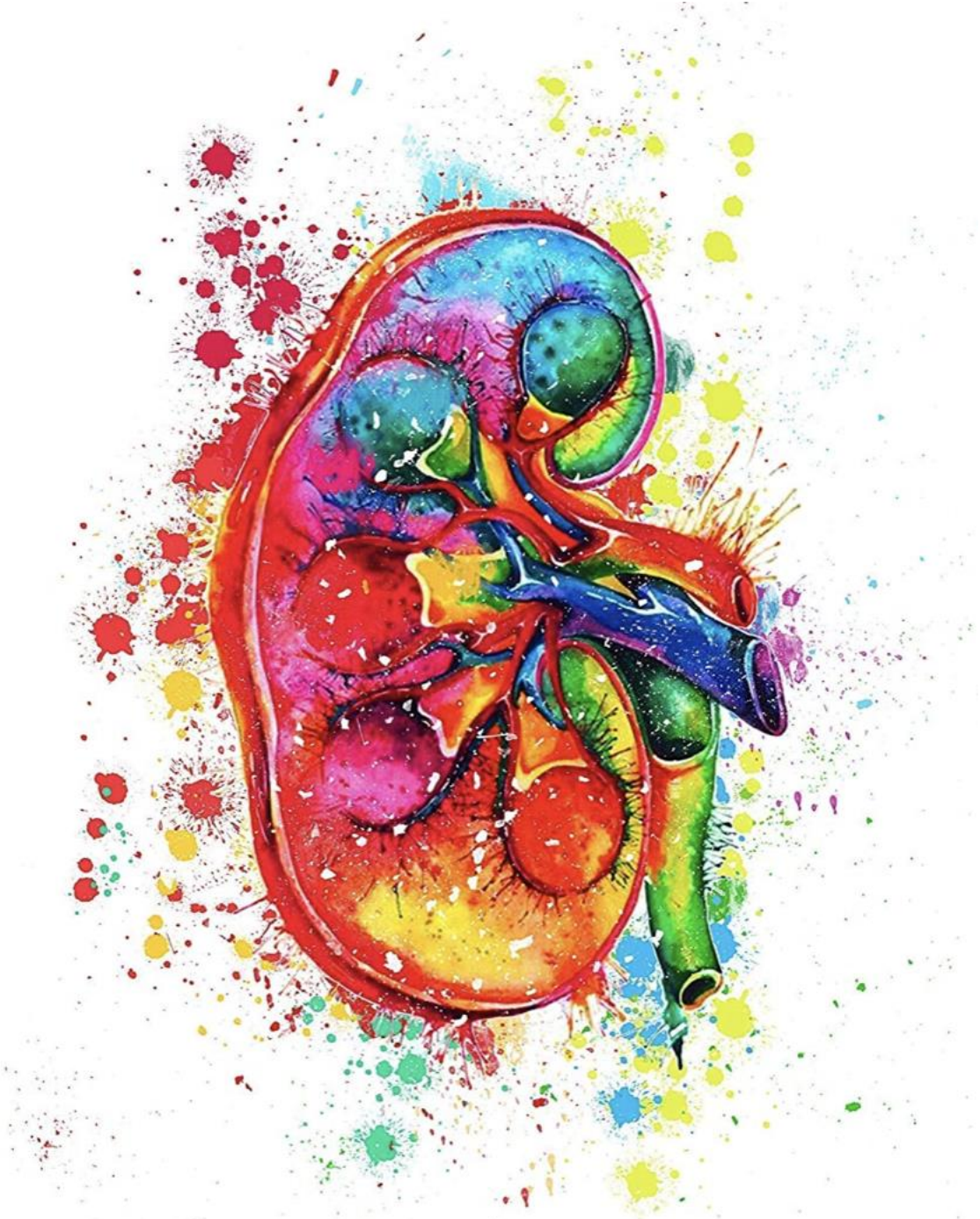


Assessment of Volume Status in Critically ill Patients

Nooshin Dalili

MD , Assistant Prof of Nephrology

SBMU, Dr. Labbafinejad Medical Center

Feb 3rd, 202

FLUID RESPSONSIVENSS

Definition:

fluid responsiveness denotes an increase in cardiac index after infusion of a fluid either crystalloid or colloid.

Cumulative fluid balance and mortality

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

Crit Care Med 2011 Vol. 39, No. 2; John H. Boyd, Jason Forbes, MD; Taka-aki Nakada, Keith R. Walley, James A. Russell,

retrospective review of the use of intravenous fluids during the first 4 days of care.

Patients: VASST study enrolled 778 patients
septic shock and receiving a minimum of 5 ug of norepinephrine per minute.

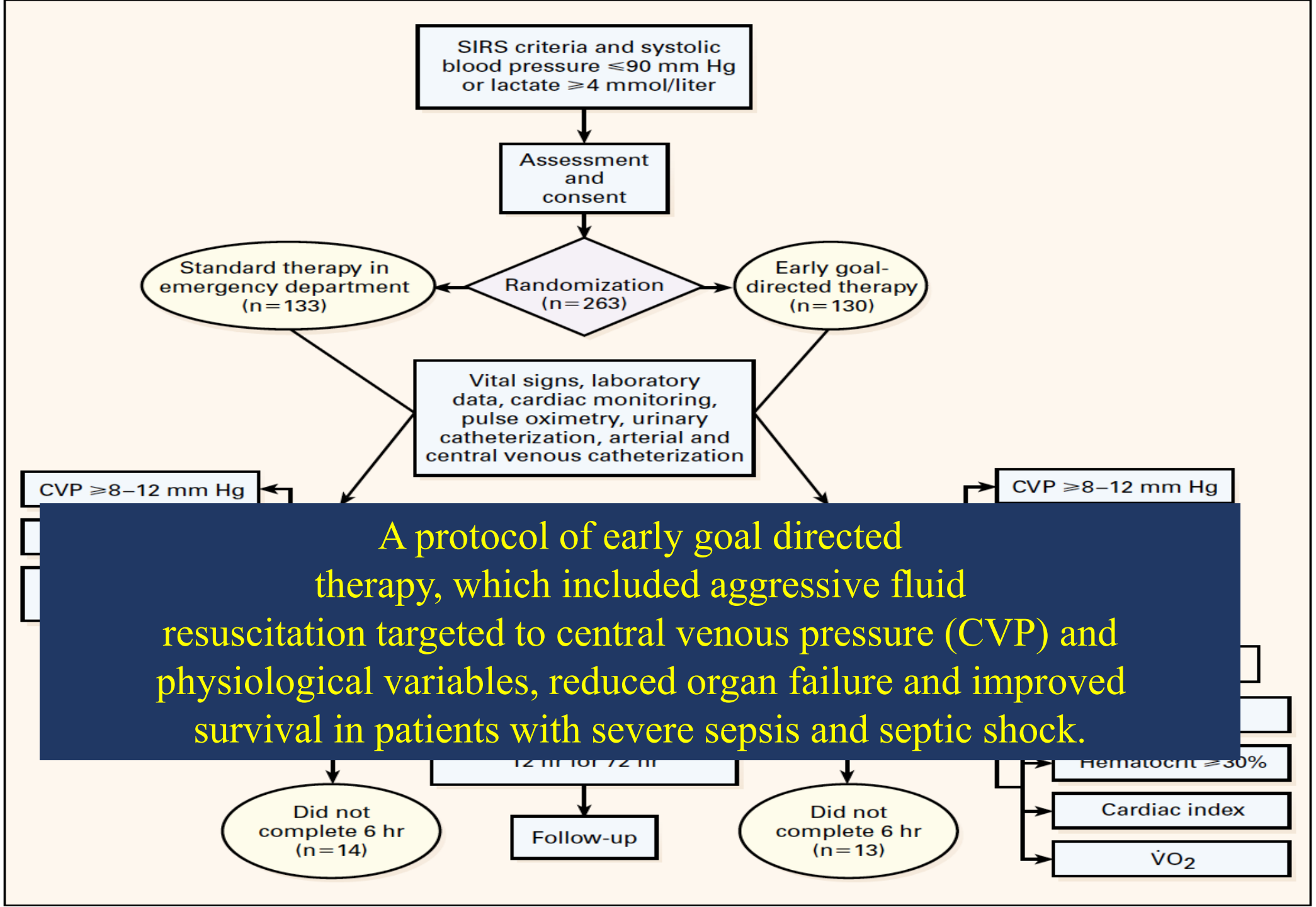
A more positive fluid balance both early in resuscitation and cumulatively over 4 days is associated with an increased risk of mortality in septic shock.

Central venous pressure may be used to gauge fluid balance <12 hrs into septic shock but becomes an unreliable marker of fluid balance thereafter.

The New England Journal of Medicine

EARLY GOAL-DIRECTED THERAPY IN THE TREATMENT OF SEVERE SEPSIS AND SEPTIC SHOCK

EMANUEL RIVERS, M.D., M.P.H., BRYANT NGUYEN, M.D., SUZANNE HAVSTAD, M.A., JULIE RESSLER, B.S., ALEXANDRIA MUZZIN, B.S., BERNHARD KNOBLICH, M.D., EDWARD PETERSON, PH.D., AND MICHAEL TOMLANOVICH, M.D., FOR THE EARLY GOAL-DIRECTED THERAPY COLLABORATIVE GROUP*



A protocol of early goal directed therapy, which included aggressive fluid resuscitation targeted to central venous pressure (CVP) and physiological variables, reduced organ failure and improved survival in patients with severe sepsis and septic shock.

An observational study fluid balance and patient outcomes in the randomized evaluation of normal vs. augmented level of replacement therapy trial*

The RENAL Replacement Therapy Study Investigators

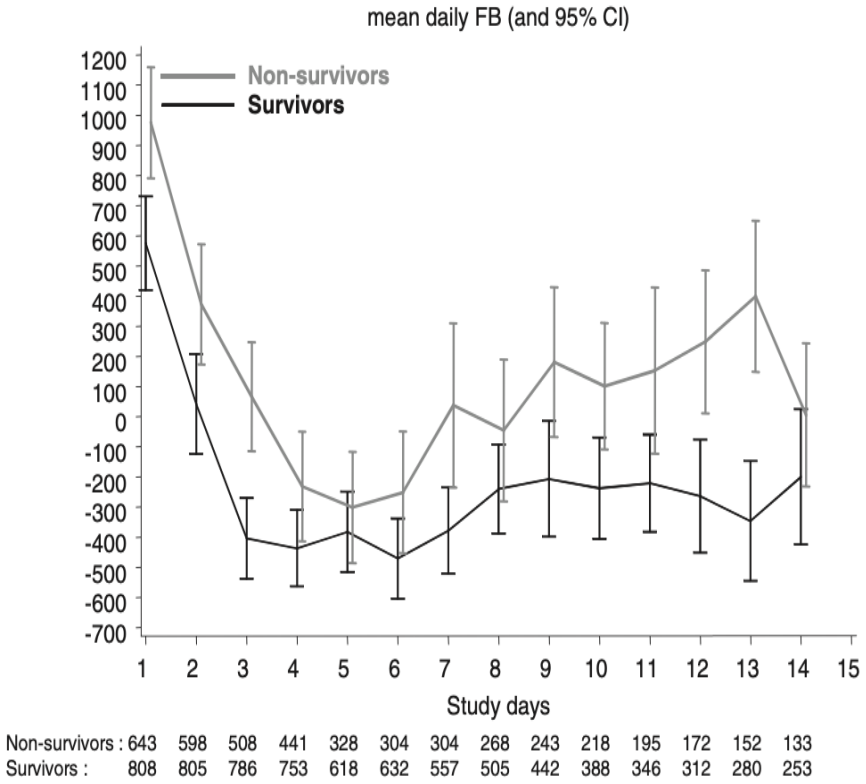


Figure 1. Graphic representation of mean daily fluid balance over the first 2 wks of observation after randomization according to survival status at 90 days (survivors = *continuous line*; nonsurvivors = *broken line*). The *y-axis* indicates mean daily fluid balance in mL/d. Mean daily FB during was significantly more positive in nonsurvivors. The *minus sign* indicates a negative fluid balance. For each study day on *x-axis*, the number of patients analyzed is also reported. The *vertical line* indicates the mean duration of renal replacement therapy at 6 days. *CI*, confidence interval.

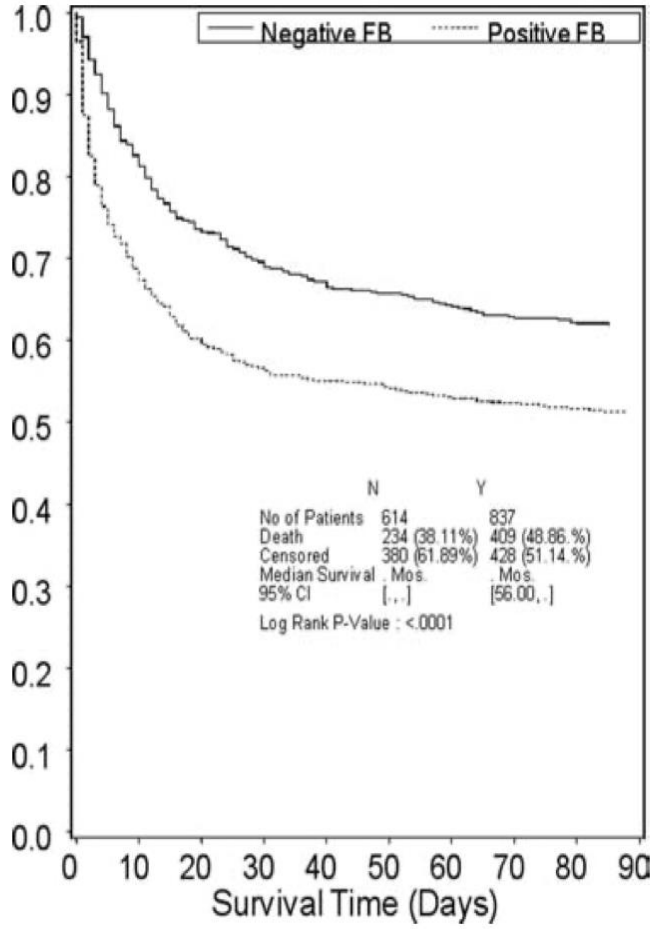


Figure 2. Kaplan Meier graph of survival plots from randomization to day 90 stratified by the presence or absence of a positive fluid balance (*FB*) from day 0 to day 2. The findings are similar to those seen when separating patients according to FB later during their time in intensive care unit. *CI*, confidence interval.

Conclusions: In the RENAL study, a negative mean daily fluid balance was consistently associated with improved clinical outcomes

In a European multicenter observational study of patients admitted to the intensive care unit (ICU), each 1 liter of positive fluid balance during the first 72 h of ICU stay was associated with a 10% increase in mortality after adjustments for other risk factors.

Vincent JL, Sakr Y, Sprung CL et al. Sepsis in European intensive care units: results of the SOAP study. Crit Care Med 2006; 34: 344–353.

In a landmark study of liberal versus conservative fluid management of patients with acute lung injury in the ICU, a more conservative fluid management strategy improved lung function and shortened the ICU stay, whereas there was no difference in the 60-day mortality between the two groups.

Wiedemann HP, Wheeler AP, Bernard GR et al. Comparison of two fluid management strategies in acute lung injury. N Engl J Med 2006; 354: 2564–2575.

to give or not to give????

Assessment of volume status and fluid responsiveness

Optimum fluid balance

Volume depletion
- Hypotension
- Shock
- Organ hypoperfusion
- Acute kidney injury

Volume overload
- Impaired oxygenation
- Edema
- Hypertension
- Organ congestion

Inadequate fluid therapy ⟷ Overaggressive fluid therapy

When dosing intravenous fluids, two key clinical questions are asked:

(1) what is the current state of the patient's intravascular volume?

(2) if the patient receives continued fluid resuscitation or a fluid bolus, will physiological variables such as blood pressure, tissue perfusion, and urine output improve?

Fundamentally, the only reason to give a patient a fluid challenge is to increase the stroke volume (SV; by at least 10–15%) and improve organ perfusion.

Table 1 | Commonly used clinical and laboratory parameters in the assessment of volume status

- Vital signs
  - Blood pressure (mean arterial pressure)
  - Pulse
  - Orthostatic changes in blood pressure and pulse
- Physical examination
  - Mentation
  - Capillary refill
  - Skin turgor/dryness
  - Skin perfusion (color/mottling, temperature)
  - Temperature of extremities
  - Urine output
- Laboratory parameters
  - Fractional excretion of sodium, urea
  - Blood lactate
  - Mixed venous oxygen saturation

Table 2 | Summary of volume assessment tools

Method	Invasive or noninvasive	Static or dynamic	Assess fluid responsiveness	Comments
Historical findings	Noninvasive	Static	No	Of limited value with poor correlation with invasive pressure measurements
Physical exam	Noninvasive	Static and dynamic	Yes	Of limited value but serial examinations may detect changes in organ perfusion
Chest radiograph	Noninvasive	Static	No	Requires use of standardized measures of vascular pedicle width and cardiothoracic ratio. Serial chest X-ray may be helpful in determining effects of fluid therapy
Central venous pressure	Invasive	Static	No	Poor correlation with fluid responsiveness
Pulmonary capillary wedge pressure	Invasive	Static	No	Poor correlation with fluid responsiveness
Echocardiogram	Noninvasive	Static	No	Single measures of cardiac chamber volume hard to assess. Serial measures may be helpful
Stroke volume or pulse pressure variation	Invasive (pulse oximeter method in noninvasive)	Dynamic	Yes	Requires sedated, mechanically ventilated patient
Esophageal doppler	Invasive	Dynamic	Yes	Not useful for continuous measurements
Vena cava diameter	Noninvasive	Dynamic	Yes	Body habitus dependent
Passive leg raising	Noninvasive (bioreactance, end-tidal CO_2) Invasive (FloTrac or PiCCO or LiDOO)	Dynamic	Yes	Unreliable with intra-abdominal hypertension
End-expiratory occlusion	Passive leg raising	Dynamic	Yes	Requires 15-s end-expiratory occlusion
Bioimpedance	Noninvasive	Static	No	Not able to assess intravascular volume

0090-3493/84/1207-0549$02.00/0
CRITICAL CARE MEDICINE

Vol. 12, No. 7
Printed in U.S.A.

Clinical evaluation compared to pulmonary artery catheterization in the hemodynamic assessment of critically ill patients

PAUL R. EISENBERG, MD; ALLAN S. JAFFE, MD; DANIEL P. SCHUSTER, MD

When clinicians were asked to predict hemodynamic parameters based only on history and physical examination, their performance was poor.
In this study, pulmonary artery wedge pressure was correctly predicted only 30% of the time. Cardiac output, systemic vascular resistance, and right atrial pressures were correctly predicted approximately 50% of the time.

Journal of Critical Care (2011) 26, 402–410

ELSEVIER

CXR

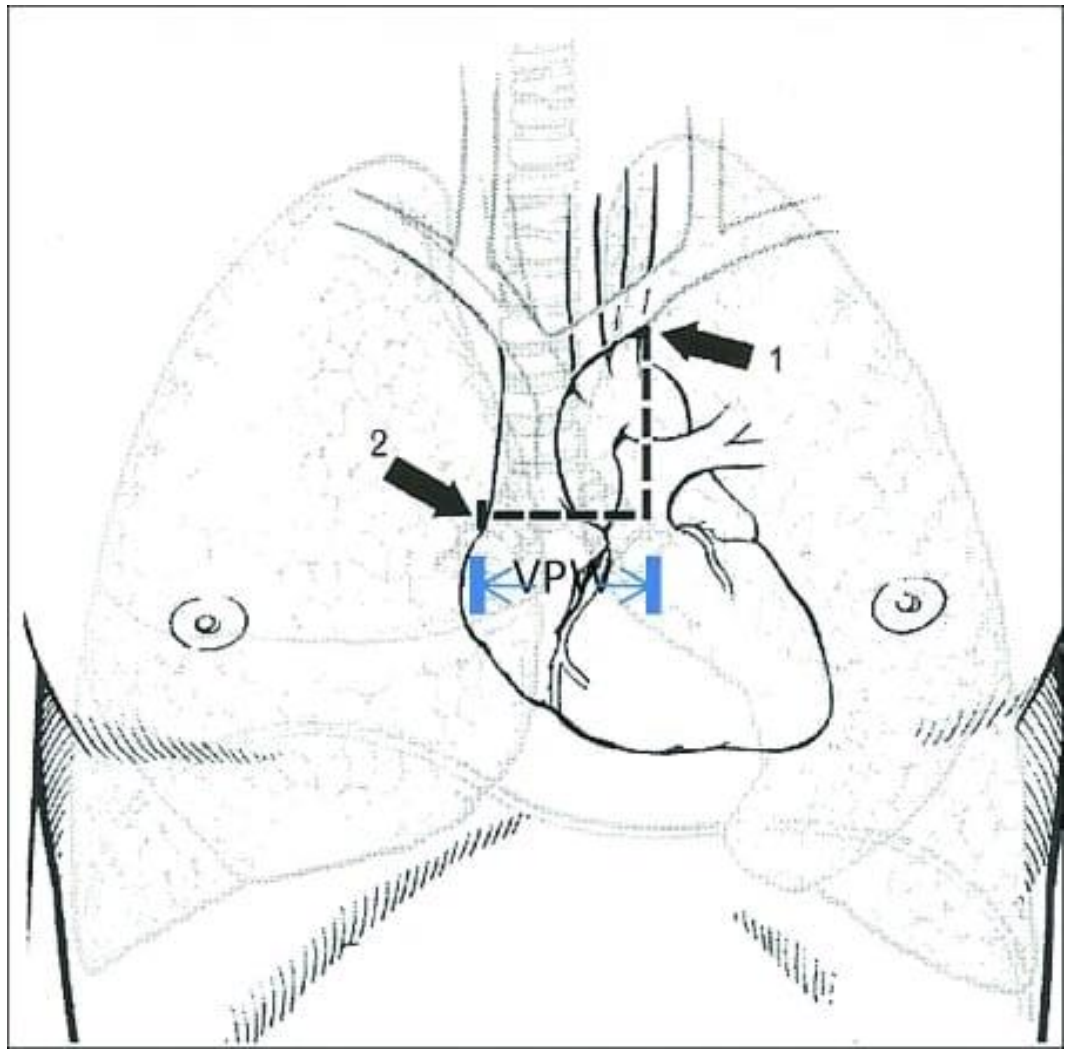
Journal of Critical Care

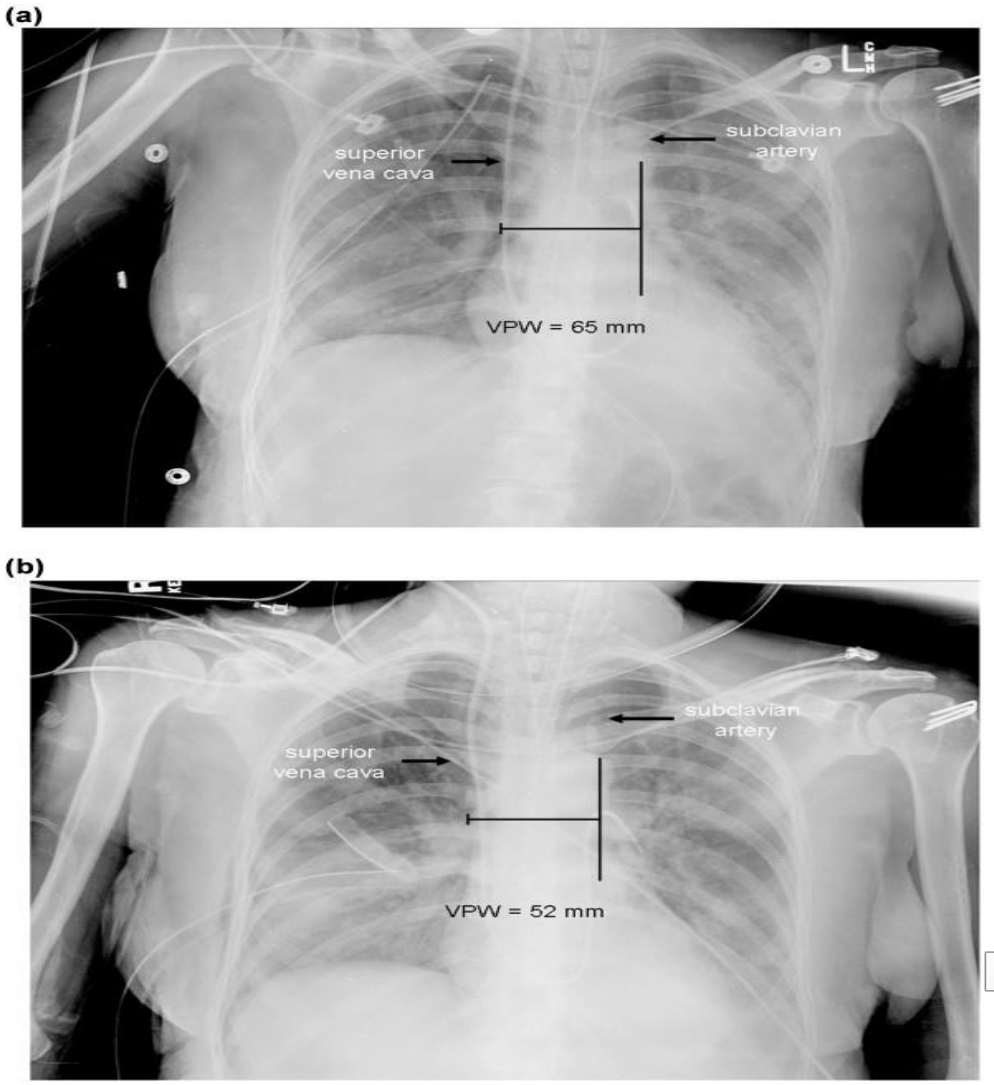
Physical examination, central venous pressure, and chest radiography for the prediction of transpulmonary thermodilution–derived hemodynamic parameters in critically ill patients: A prospective trial☆

Bernd Saugel MD[a,*], Stephan Ringmaier MD[a], Konstantin Holzapfel MD[b], Tibor Schuster PhD[c], Veit Phillip MD[a], Roland M Schmid MD[a], Wolfgang Huber MD[a]

Typical radiologic signs suggesting volume overload are highly variable and insensitive and that CXR findings cannot predict extravascular lung water

Using a VPW cutoff value of 70mm in addition to a cardiothoracic ratio greater than 0.55 significantly improved the accuracy of CXR in determining volume status.
The VPW is best utilized in a single patient on serial measurements, and changes in VPW show a high correlation with changes in volume status.





STATIC PRESSURE MEASUREMENTS

Most common of these parameters are

- CVP
- Pulmonary artery occlusion pressure, or PCWP
- Right ventricular end-diastolic volume

CVP

- Role of CVP More than 100 studies have been published to date that have demonstrated no relationship between the CVP and fluid responsiveness in various clinical settings.

The likelihood that CVP can accurately predict fluid responsiveness is only 56% (slightly better than flipping a coin)

Marik PE, Baram M, Vahid B: Does the central venous pressure predict fluid responsiveness?A systematic review of the literature and the tale of seven mares. Chest 2008, 134:172-178.Nolen-Walston RD, Norton JL, de Solis C, Underwood C, Boston R, Slack J, Dallap BL:The effects of hypohydration on central v[illegible]ous pressure and splenic volume in adulthorses. J Vet Intern Med 2010.

CVP is dependent on venous return (VR) to the heart, right ventricular compliance, peripheral venous tone, and posture, and the CVP is particularly unreliable in pulmonary vascular disease, right ventricular disease, patients with tense ascites, isolated left ventricular failure, and valvular heart disease.

In patients with an intact sympathetic response to hypovolemia, the CVP may actually fall in response to fluid, as compensatory venoconstriction is reduced. Thus, it is possible to have a low CVP and not be volume responsive, as well as have a high CVP and be volume responsive.

CHEST

Special Feature

Does Central Venous Pressure Predict Fluid Responsiveness?*

A Systematic Review of the Literature and the Tale of Seven Mares

Paul E. Marik, MD, FCCP; Michael Baram, MD, FCCP; and Bobbak Vahid, MD

Conclusions: **This systematic review demonstrated a very poor relationship between CVP and blood volume as well as the inability of CVP/ΔCVP to predict the hemodynamic response to a fluid challenge. CVP should not be used to make clinical decisions regarding fluid management.**

(CHEST 2008; 134:172–178)

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SAUNDERS

Crit Care Clin 23 (2007) 383–400

CRITICAL
CARE
CLINICS

Noninvasive Hemodynamic Monitoring in the Intensive Care Unit

Paul E. Marik, MD, FCCM, FCCP[a,*],
Michael Baram, MD[a,b]

[a]*Division of Pulmonary and Critical Care Medicine, Thomas Jefferson University, 834 Walnut Street, Suite 650, Philadelphia, PA 19107, USA*
[b]*Department of Emergency Medicine, Thomas Jefferson University, 834 Walnut Street, Suite 650, Philadelphia, PA 19107, USA*

Traditional
goals of resuscitation have included blood pressure, pulse rate, central venous pressure (CVP), and arterial oxygen saturation. These variables change minimally in early shock and are poor indicators of the adequacy of resuscitation

Multiple studies
have confirmed that both the CVP and PCWP in healthy controls and in patients with various disease states are unable to predict the hemodynamic response to a fluid challenge . It is therefore somewhat alarming that the CVP is still widely used as a guide to fluid resuscitation and is incorporated into protocols that are endorsed by professional societies

- Role of CVP in “Dynamic assessment ”As noted earlier, it is best NOT to use a single value of CVP to predict volume responsiveness

Sheldon Magder et al Curr Opin Crit Care 11:264—270

PCWP

The vast majority of studies have demonstrated a poor correlation between PCWP, volume status, and responsiveness to fluid resuscitation

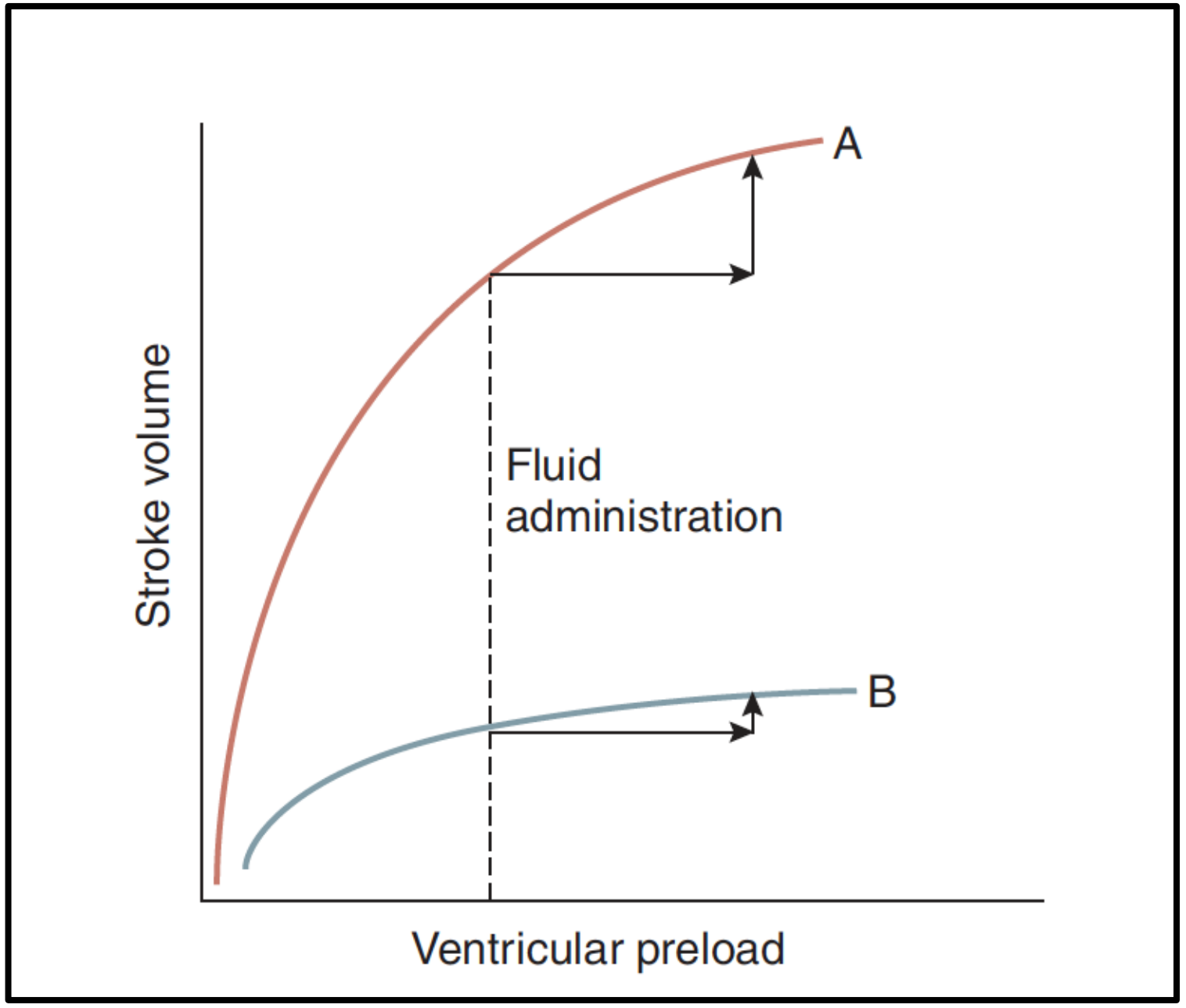
Cardiac filling pressures are not appropriate to predict hemodynamic response to volume challenge*

Crit Care Med 2007 Vol. 35, No. 1

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

Conclusion: Our study demonstrates that cardiac filling pressures are poor predictors of fluid responsiveness in septic patients. Therefore, their use as targets for volume resuscitation must be discouraged, at least after the early phase of sepsis has concluded. (Crit Care Med 2007; 35:64–68)

In addition, in a study of 100 ICU patients, it was determined that a baseline PCWP cutoff value of < 11mmHg was poor at determining fluid responsiveness, defined as an increase of the cardiac index of >15%.
The sensitivity of this cutoff value was 77%, with a specificity of 51%.
They further examined a combination of CVP<8mmHg and PCWP<12mmHg in predicting response to fluid challenge. This combination performed poorly as well, with a sensitivity of 35% and specificity of 71%.



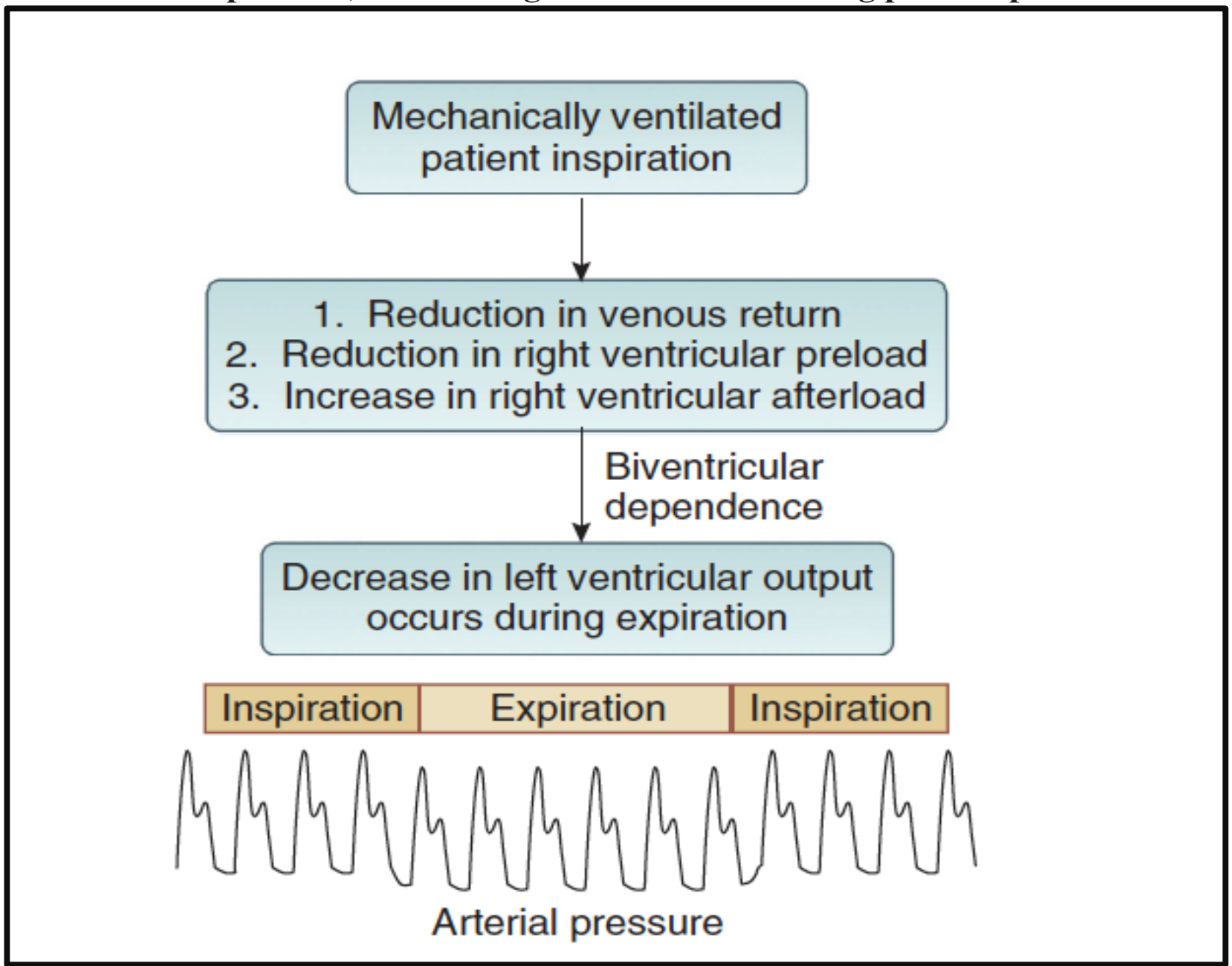
Preload does not predict volume responsiveness

ECHOCARDIOGRAPHIC ASSESSMENT OF VOLUME STATUS

DYNAMIC VARIABLES

The degree of variation in parameters such as SV (SV variation, SVV), pulse pressure (pulse pressure variation, PPV), changes in aortic flow velocity, and the diameter of inferior vena cava (IVC) or SVC as a result of changes in intrathoracic pressure induced by spontaneous respiration or by positive pressure ventilation are among the tools to assess volume responsiveness.

Although in the normal breathing cycle the VR and right heart preload increase during inspiration and decrease at the end of inspiration, these changes are reversed during positive pressure ventilation



Hypovolemic patients frequently demonstrated systolic pressure variation (SPV)>10mmHg, whereas this was unusual in normovolemic or hypervolemic patients. SPV decreases with increasing blood volume and increases with volume depletion

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

Service de Réanimation Médicale et Service de Physiologie Cardio-Respiratoire, Centre Hospitalo-Universitaire de Bicêtre, Assistance Publique-Hopitaux de Paris, Le Kremlin Bicêtre, Université Paris XI, Paris, France; INSERM U451-LOA-ENSTA-Ecole Polytechnique, Palaiseau, France; and Division of Critical Care Medicine, University of Pittsburgh, Pittsburgh, Pennsylvania

The responders demonstrated a reduction in PPV after volume expansion. A cutoff value of 13% for PPV had a sensitivity of 94% and specificity of 96% to discriminate between fluid responders and non responders.
Variability in PP was superior in discriminating fluid responders

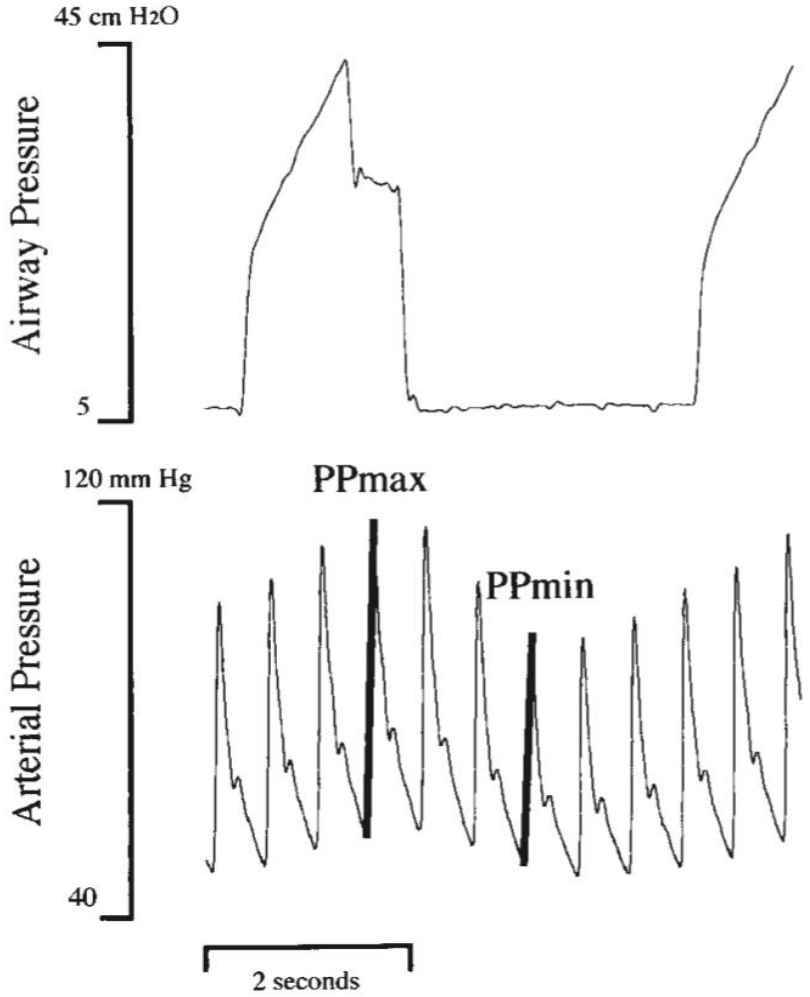


Figure 1. Simultaneous recording of systemic arterial and airway pressure curves in one illustrative patient with large Ps and Pp variations. Systolic and diastolic pressure were measured on a beat-to-beat basis and Pp was calculated as the difference between systolic and diastolic pressure. Pp_{max} and Pp_{min} were determined over a single respiratory cycle. The respiratory changes in pulse pressure (ΔPp) were calculated as the difference between Pp_{max} and Pp_{min} divided by the mean of t[illegible]wo values, and were expressed as a percentage. The respiratory chan[illegible]s in systolic pressure (ΔPs) were evaluated using a similar formula.

Dynamic changes in arterial waveform derived variables and fluid responsiveness in mechanically ventilated patients: A systematic review of the literature*

Paul E. Marik, MD, FCCM; Rodrigo Cavallazzi, MD; Tajender Vasu, MD; Amyn Hirani, MD

Conclusions: Dynamic changes of arterial waveform-derived variables during mechanical ventilation are highly accurate in predicting volume responsiveness in critically ill patients with an accuracy greater than that of traditional static indices of volume responsiveness. This technique, however, is limited to patients who receive controlled ventilation and who are not breathing spontaneously. (Crit Care Med 2009;37:2642-2647)

Assessing the Diagnostic Accuracy of Pulse Pressure Variations for the Prediction of Fluid Responsiveness

A "Gray Zone" Approach

Maxime Cannesson, M.D., Ph.D.,* Yannick Le Manach, M.D., Ph.D.,† Christoph K. Hofer, M.D.,‡ Jean Pierre Goarin, M.D.,§ Jean-Jacques Lehot, M.D., Ph.D.,‖ Benoît Vallet, M.D., Ph.D.,# Benoît Tavernier, M.D., Ph.D.#

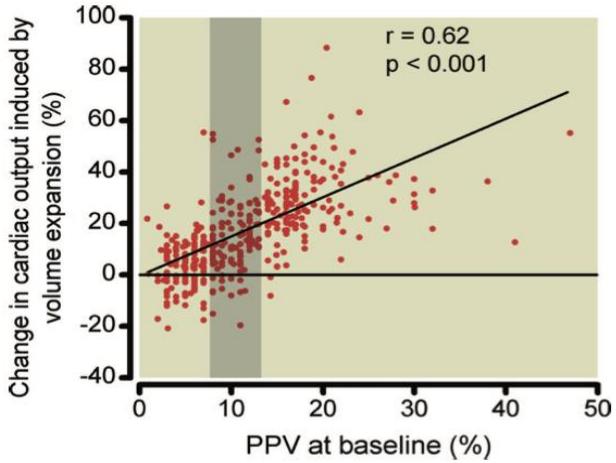
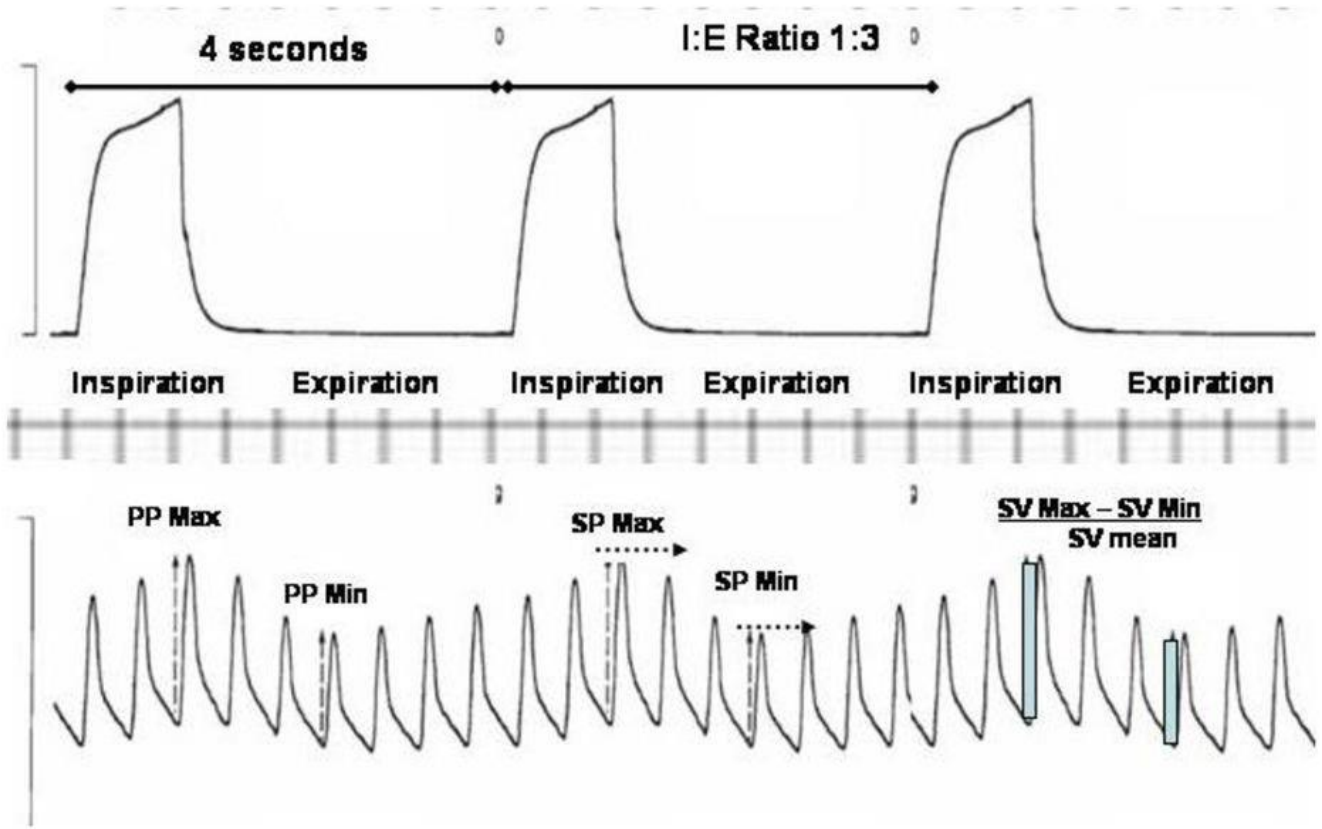


Fig. 1. Relationship between pulse pressure variation (PPV) measured before volume expansion and percent change in cardiac output (CO) induced by volume expansion (n = 413). A significant relationship between PPV at baseline and percent change in CO induced by volume expansion was seen. The gray zone shows upper and lower limits of the uncertainty zone.

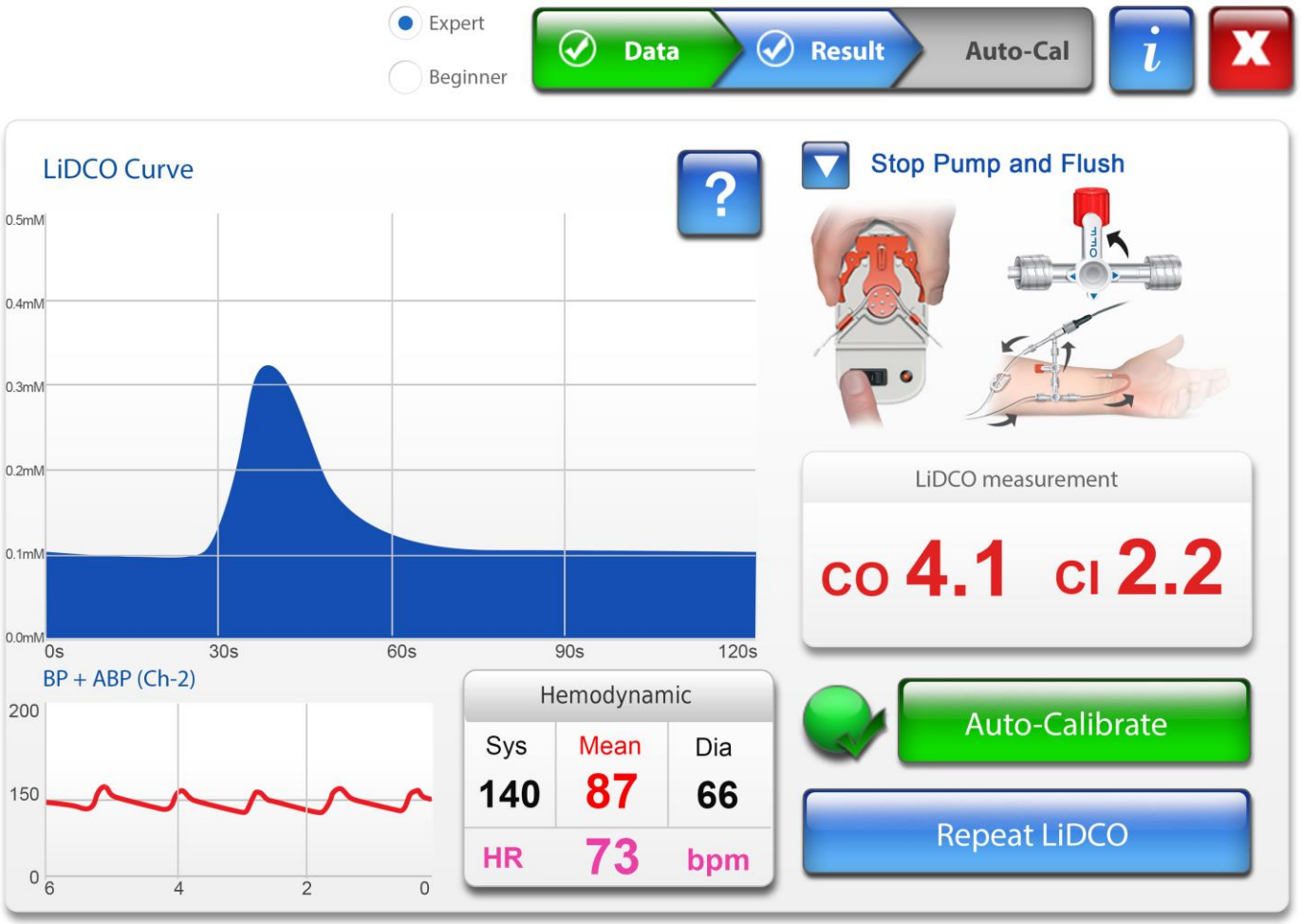
Results: 209 responders (51%) and 204 non responders (49%). The area under receiver operating characteristic curve was 0.89 (95% CI: 0.86– 0.92) for PPV, compared with 0.57 (95% CI: 0.54 – 0.59) for central venous pressure .The gray zone approach identified a range of PPV values (between 9% and 13%) for which fluid responsiveness could not be predicted reliably. These PPV values were seen in 98 (24%) patients.

Conclusion: Despite a strong predictive value, PPV may be inconclusive (between 9% and 13%) in approximately 25% of patients during general anesthesia.

SPV, PPV, SVV Dynamic Parameters

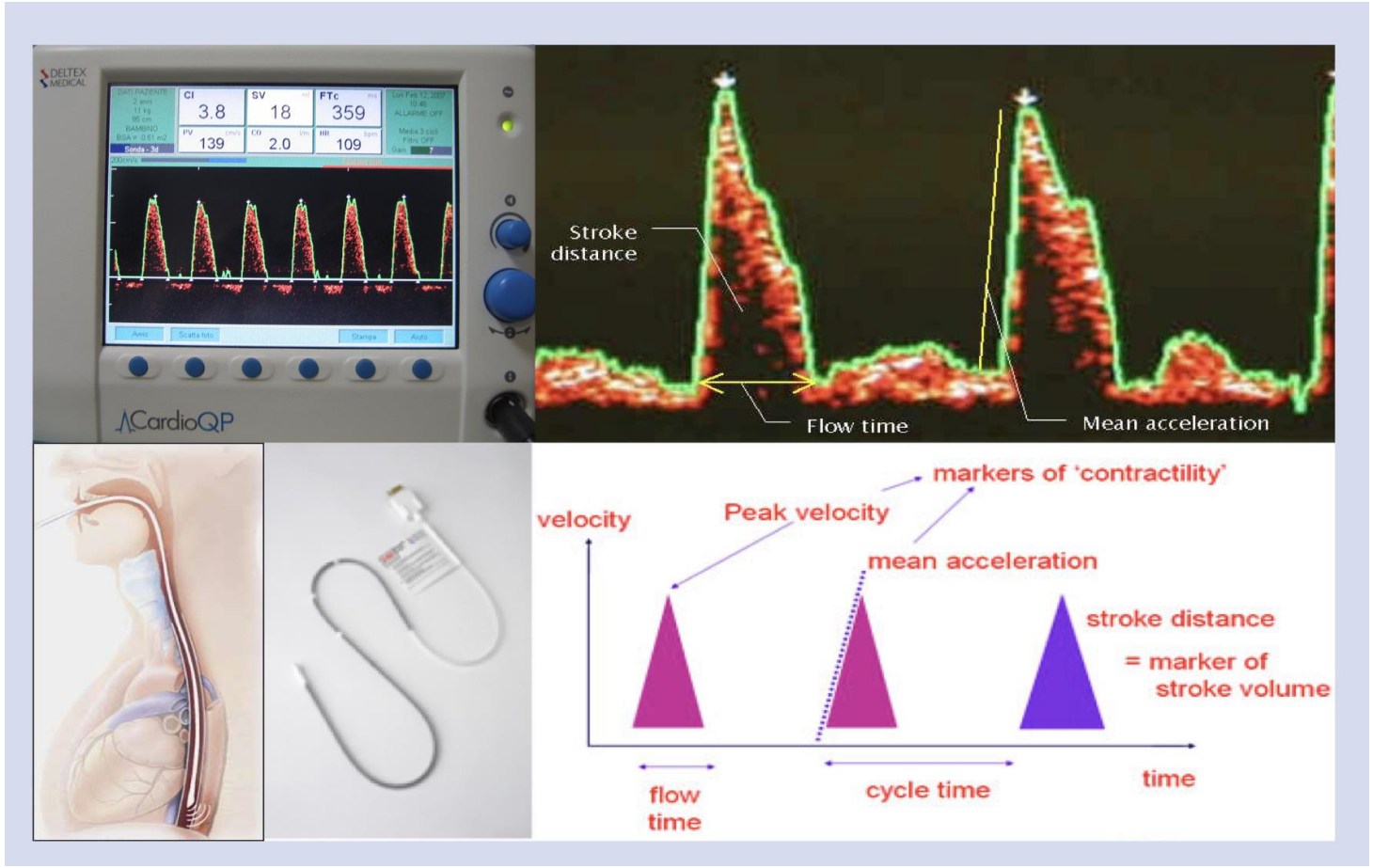


These dynamic changes in the
pulse oximeter wave form have shown significant correlation
with PPV and accurately predicted fluid responsiveness.



A Pleth Variability Index > 14% before volume expansion is predictive that a patient will respond to fluid administration with a sensitivity of 81%.

Esophageal Doppler monitoring



Cardiac output was determined by thermodilution (gold standard) and esophageal Doppler and changes in cardiac output after an IV fluid bolus were assessed as well using both techniques. Changes in cardiac output as determined by Doppler agreed 86% of the time with thermodilution methods and suggests that esophageal Doppler may be useful in this regard.

Respiratory variation in vena cava diameter

The Journal of **TRAUMA**® *Injury, Infection, and Critical Care*

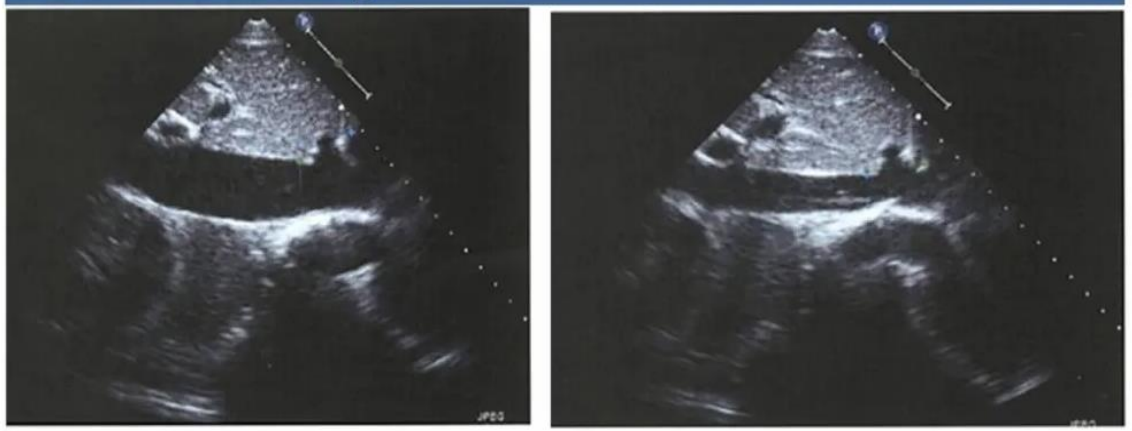
Hypovolemic Shock Evaluated by Sonographic Measurement of the Inferior Vena Cava During Resuscitation in Trauma Patients

Youichi Yanagawa, MD, PhD, Toshihisa Sakamoto, MD, PhD, and Yoshiaki Okada, MD, PhD

The intrathoracic changes in pressure during the respirator cycle affect VR and thus the diameter of the central veins such as the IVC. Ultrasound-measured absolute diameter of the IVC or the extent of change in its diameter with the respiratory cycle has been used to assess volume status.

Conclusion: **In trauma patients, inadequate dilatation of the IVC by fluid resuscitation, might indicate insufficient circulating blood volume despite normalization of blood pressure. IVC diameter appeared a better predictor of recurrence of shock than blood pressure, heart rate, or arterial base excess.**

A dilated IVC with less than 50 % collapse indicating a RAP of 10-15 mmg



Those who responded to volume expansion (defined as >15% increase in CO) as compared with those who did not respond, had greater collapsability index at baseline (25 vs. 6%).

How to estimate RA pressure without a doppler probe ?

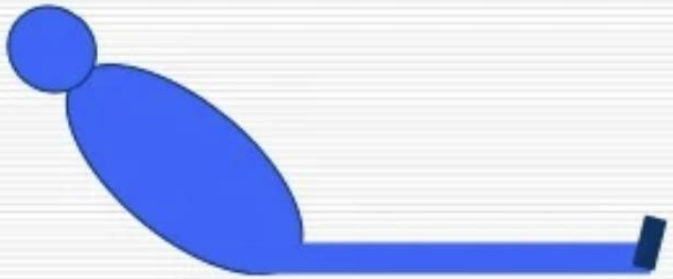
Size of IVC	IVC size On Inspiration	Right atrial pressure(mmhg)
Small < 1.5cm	Near total collapse	0 - 5
Normal (1.5-2.5cm)	Decrease > 50%	5 - 10
Normal	Decrease < 50%	10 - 15
Dilated > 2.5cms	Decrease < 50%	15 - 20
Both IVC & Hepatic veins dilated	No change	> 20

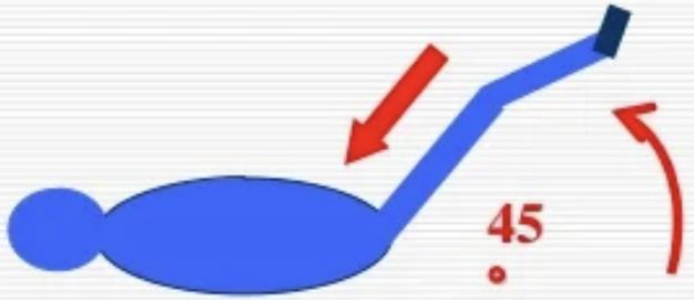
Modified from Otto C. M .Text book of clinical echocardiography W.B.Saunders ,2000

Assessment of PRELOAD DEPENDENCE
PREDICTION OF PRELOAD DEPENDENCE

PASSIVE LEG RAISING

Venous blood shift (Rutlen et al. 1981, Reich et al. 1989)



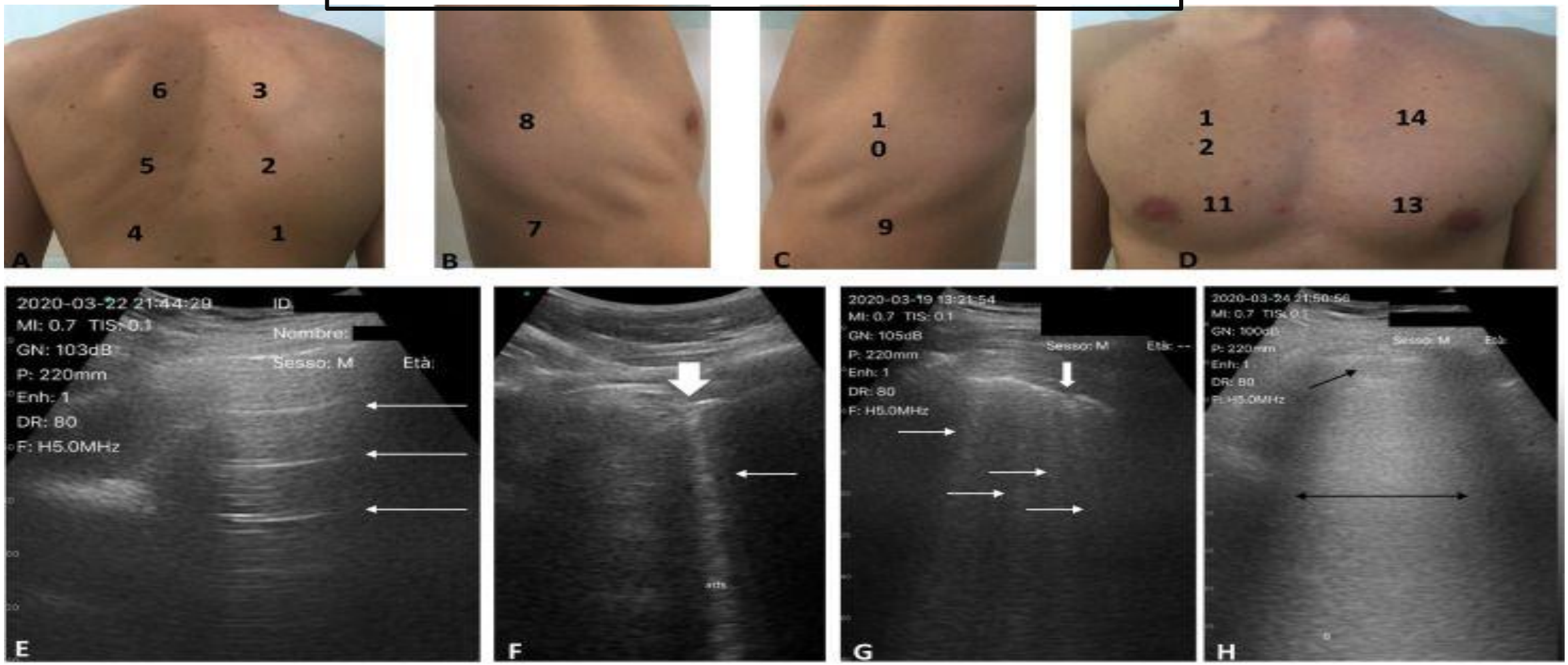


Transient and reversible effect

A 10% or greater increase in cardiac output in response to PLR predicts fluid responsiveness

A recent meta-analysis determined that the area under the curve or PLR for determining fluid responsiveness was 0.95 and was not affected by spontaneous breathing or cardiac dysrhythmias.

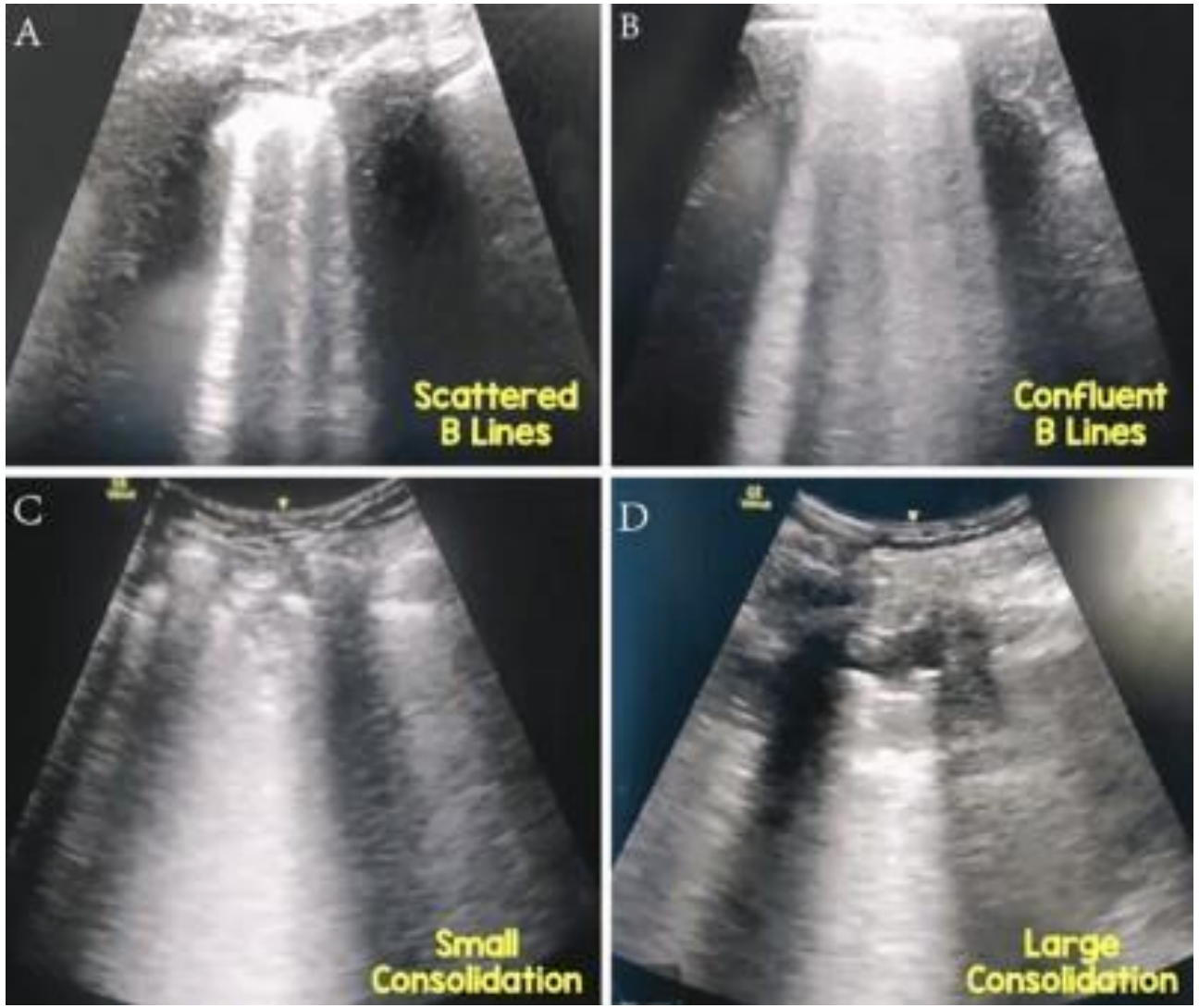
Point-of-care ultrasound

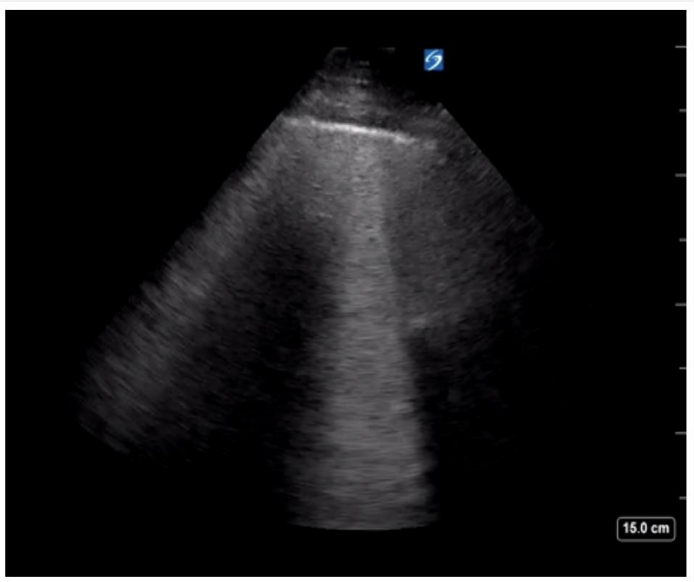


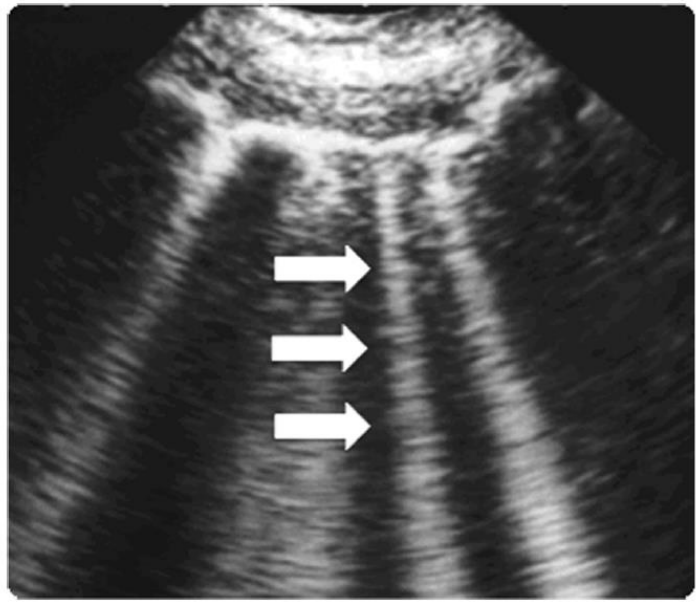
Lung POCUS

In one meta-analysis, the sensitivity and specificity of LUS in acute cardiogenic pulmonary edema were around 92% and 94%, respectively . The European guidelines stated that “bedside thoracic ultrasound for signs of interstitial edema and pleural effusion may be useful in detecting acute HF if the expertise is available”

Pulmonary Oedema – B Lines







BIOIMPEDANCE VECTOR ANALYSIS

Diagnosis and Management of Fluid Overload in Heart Failure and Cardio-Renal Syndrome: The "5B" Approach

Claudio Ronco, MD, Manish Kaushik, MD,* Roberto Valle, MD,† Nadia Aspromonte, MD,‡ and W. Frank Peacock IV, MD§*

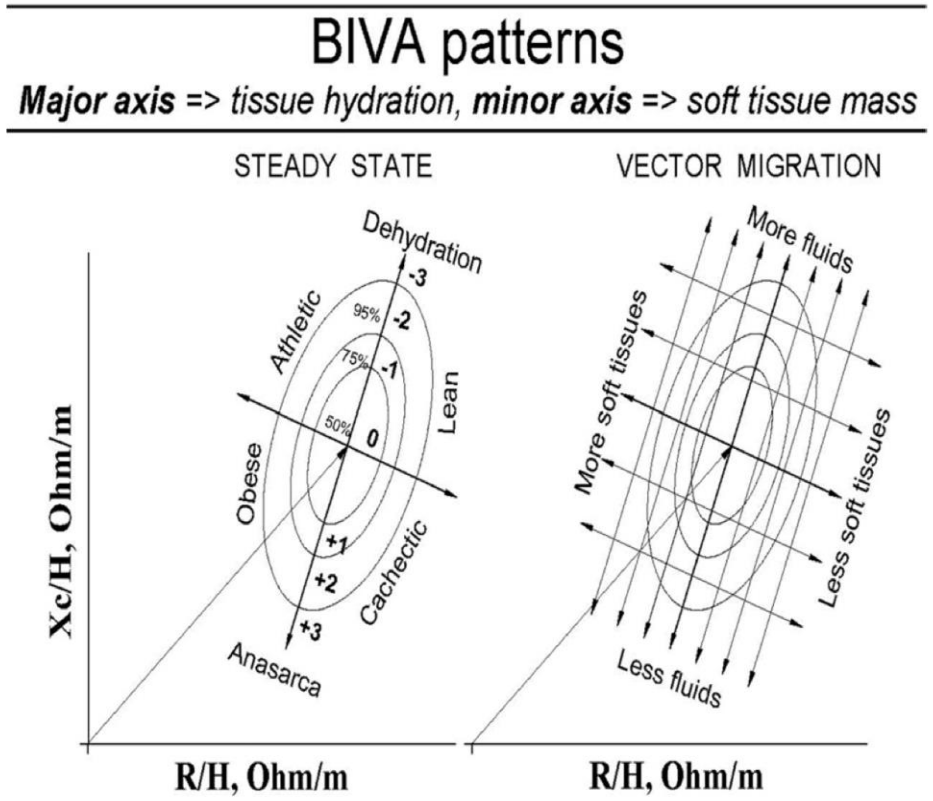


Figure 7. BIVA. The ellipsis describes the hydration and nutrition status domain. Optimal status is at the center of the domain and vector migration toward different directions represents an alteration of the nutritional/hydration status of the patient. Subsequent examinations are useful to establish a trend.

Consideration of the "5B" approach. This stands for balance of fluids (reflected by body weight), blood pressure, biomarkers, bioimpedance vector analysis, and blood volume. Addressing these parameters ensures that the most important issues affecting symptoms and outcomes are addressed. Furthermore, the patient is receiving the best possible care while avoiding unwanted side effects of the treatment.

Thanks for Your Attention