# Assessment of fluid responsiveness in critically ill patients

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# Fluid Responsiveness

- Fluid responsiveness is defined as increase in cardiac output, increase in cardiac index , increase in stroke volume index, changes in stroke volume variation, changes in pulse pressure pressure variation when a bolus infusion (500ml) of fluid is given

Annals of intensive care. 2021 Dec;11(1):1-7

# Parameters and methodology to measure fluid responsiveness

- **Parameters**
- Cardiac output
- Cardiac index
- Stroke volume index
- Pulse pressure variation
- Stroke volume variation

- **Methodology**
- Pulmonary Thermodilution
- Pulse index continuous cardiac output (PiCCO)
- Lithium index continuous cardiac output (LiDCO)
- Flo trac
- Non invasive continuous cardiac output monitoring (NiCCOM)
- Echocardiography

Annals of intensive care. 2021 Dec;11(1):1-7

# Parameters and methodology to measure fluid responsiveness in RICU

- **Parameters**
- Cardiac output
- Cardiac index
- Stroke volume index
- Pulse pressure variation
- Stroke volume variation

- **Methodology**
- Flo trac
- Non invasive continuous cardiac output monitoring (NiCCOM) – Baxter(Cheetah)
- Pulse index continuous cardiac output (PiCCO)
- Echocardiography

# Fluids less or more? Optimize

- Uncorrected hypovolemia affects tissue oxygenation leading to multi organ dysfunction and death
- Excessive fluid administration is associated with increased complications, mortality and length of intensive care unit stay

Journal of intensive care medicine. 2009 Jan;24(1):35-46

# Early Restrictive or Liberal Fluid Management for Sepsis-Induced Hypotension

- Randomized controlled trial – multicentric
- 60 centers in USA - 1563 patients
- 782 patients in  restrictive fluid group and 781 in  liberal fluid group
- Death from any cause before discharge home by day 90 (the primary outcome) occurred in 109 patients (14.0%) in restrictive fluid group and in 116 patients (14.9%) in the liberal fluid group (estimated difference, −0.9% ; 95% CI, −4.4 to 2.6; P=0.61)

New England Journal of Medicine 2023 Jan 21

# Early Restrictive or Liberal Fluid Management for Sepsis-Induced Hypotension

- No difference in secondary outcomes - 28-day measures of the number of days free from ventilator use, days free from renal-replacement therapy, days free from vasopressor use, days out of the ICU, and days out of the hospital
- Restrictive fluid strategy did not result in lower mortality than liberal fluid strategy

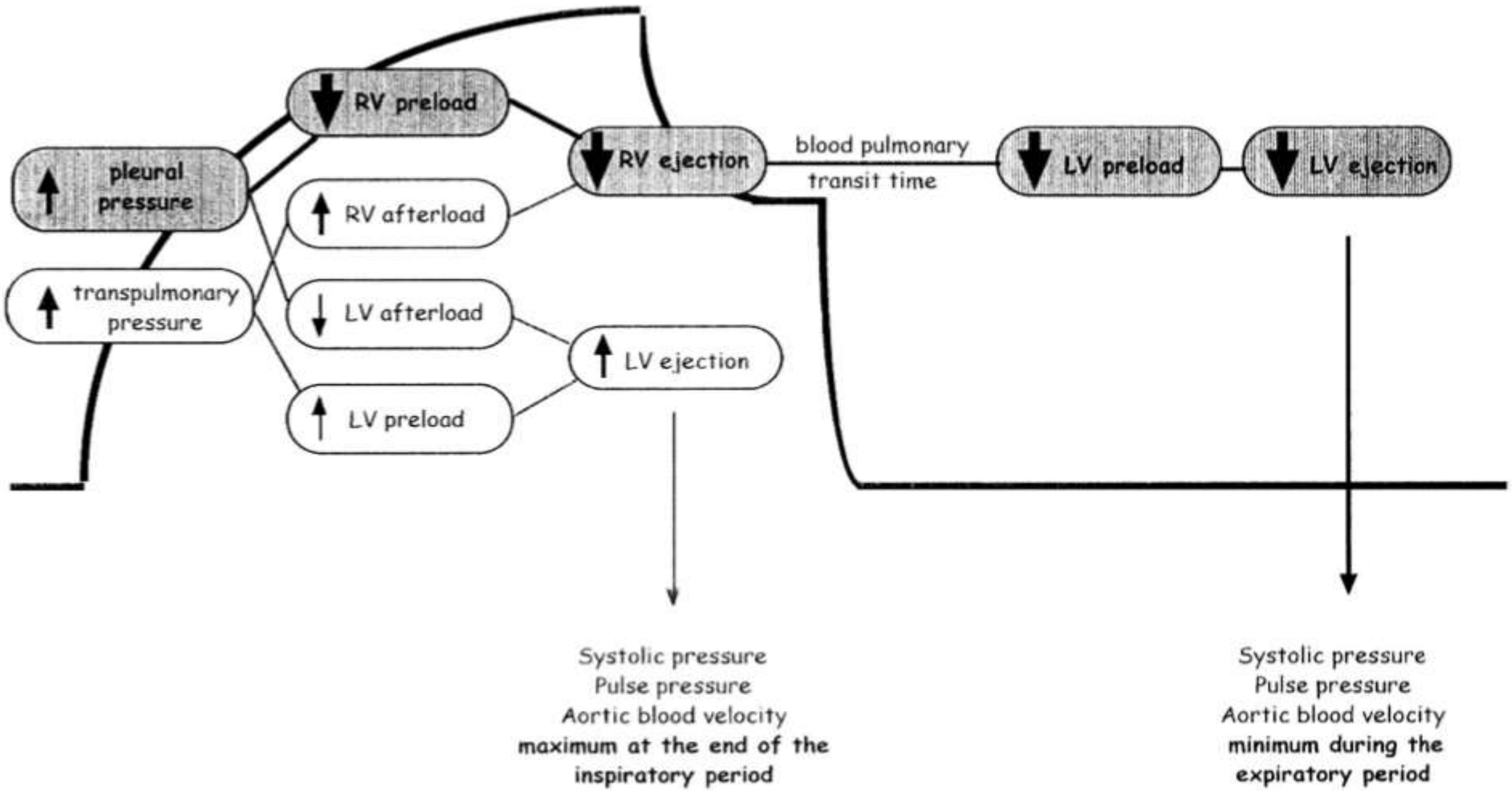
New England Journal of Medicine. 2023 Jan 21

# Assess fluid responsiveness

- Spontaneously breathing patients
- Mechanical ventilated patients

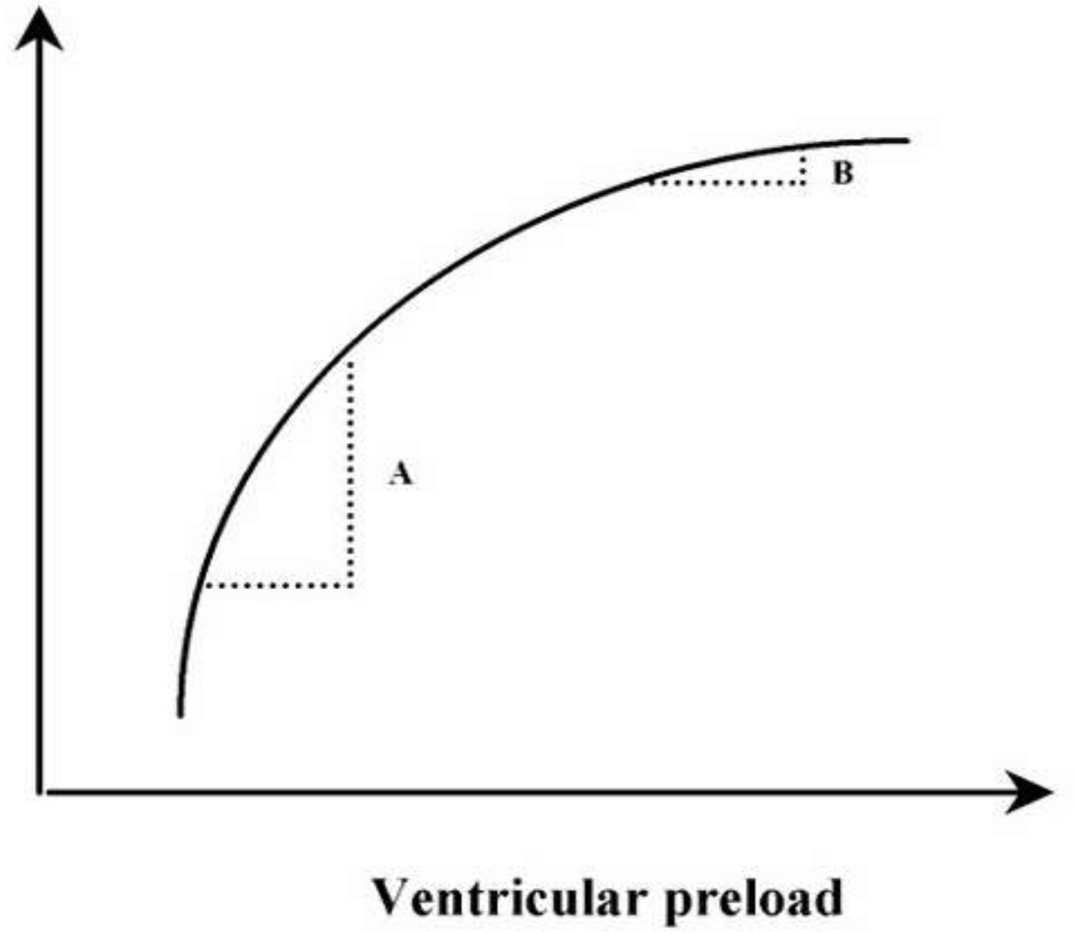
# How to assess fluid responsiveness Mechanically Ventilated Patients ?

# Heart-lung interaction during mechanical ventilation




Crit Care. 2000;4(5):282-9

# Frank starling's curve




Best Practice & Research Clinical Anaesthesiology. 2013 Jun 1;27(2):177-85

# Assessing fluid responsiveness - Mechanically Ventilated Patients

- **Static indicators**
- Central venous pressure
- Pulmonary artery occlusion pressure
- Left ventricular end diastolic area
- Right Ventricular end diastolic volume
- Inferior Vena Cava diameter
- Global end diastolic volume index

- **Dynamic indicators**
- Pulse pressure variation
- Stroke volume variation
- IVC collapsibility index
- Cardiac output/cardiac index

Best Practice & Research Clinical Anaesthesiology. 2013 Jun 1;27(2):177-85

# Central venous pressure

- 24 studies included 803 patients
- Baseline CVP was no different among responders and non responders
- Pooled correlation coefficient between CVP and measured blood volume was 0.16 (CI - 0.03 to 0.28)
- Pooled correlation between change in CVP and change in stroke index/cardiac index 0.11 (CI - 0.015 to 0.21)
- AUC 0.56 (95% CI, 0.51 to 0.6)

Chest. 2008 Jul 1;134(1):172-8

| Source | Setting | Type | Patients, No. | Methodology | AUC† | $r$, CVP/SI | $r$, ΔCVP/SI | CVP-R | CVP-NR |
|---|---|---|---|---|---|---|---|---|---|
| Calvin et al,[15] 1981 | ICU | Mixed ICU | 28 | PAC/Scint | | 0.16 | 0.26 | 4.7 | 4.8 |
| Reuse et al,[16] 1990 | ICU | ICU | 41 | PAC | | 0.21 | | 8.5 | 8.4 |
| Godje et al,[17] 1998 | ICU | CABG | 30 | PAC, COLD system‡ | | | 0.09 | | |
| Wagner and Leatherman,[18] 1998 | ICU | ICU | 25 | PAC | | 0.44 | | 7.4 | 10.1 |
| Wiesenack et al,[19] 2001 | OR | CABG | 18 | PAC, TPT | | | 0.09 | | |
| Berkenstad et al,[20] 2001 | OR | Neurosurgery | 15 | TPT | 0.49 | 0.05 | 0.08 | 9.3 | 9.3 |
| Michard et al,[21] 2000 | ICU | ICU | 40 | PAC | 0.51 | | | | |
| Reuter et al,[22] 2002 | ICU | CABG | 20 | TPT | 0.42 | | | | |
| Reuter et al,[23] 2003 | ICU | CABG | 26 | PAC, TEE | 0.71 | | | | |
| Barbier et al,[24] 2004 | ICU | Sepsis | 20 | TEE | 0.57 | | | 10 | 9 |
| Kramer et al,[25] 2004 | ICU | CABG | 21 | PAC | 0.49 | 0.13 | | 13.5 | 13.3 |
| Marx et al,[24] 2004 | ICU | Sepsis | 10 | PAC, TPT | | 0.41 | 0.28 | | |
| Preisman et al,[27] 2005 | OR | CABG | 18 | TPT, TEE | 0.61 | | | 8.7 | 10 |
| Perel et al,[28] 2005 | ICU | Vascular surgery | 14 | TEE | | 0.27 | | 9.6 | 12.2 |
| Hofer et al,[29] 2005 | OR | CABG | 40 | PAC, TEE | 0.54 | 0.02 | 0.2 | | |
| De Backer et al,[30] 2005 | ICU | ICU | 60 | PAC | 0.54 | | | 10 | 12 |
| Kumar et al,[31] 2004 | ICU | Healthy volunteers | 12 | PAC/Scint | | 0.32 | 0.22 | | |
| Osman et al,[32] 2007 | ICU | Septic | 96 | PAC | 0.58 | | | 8 | 9 |
| Magder and Bafaqeeh,[33] 2007 | ICU | CABG | 66 | PAC | | 0.36 | | 5.9 | 8.7 |
| Pooled | | | | | 0.56 | 0.18 | 0.11 | 8.7 | 9.7 |

*PAC = pulmonary artery catheter; TEE = transesophageal echocardiography; Scint = radionuclide scintography; TPT = transpulmonary thermodilution; CVP-R = baseline CVP of responders; CVP-NR = baseline CVP of nonresponders; SI = fluid responsiveness; see Table 1 for expansion of abbreviations.

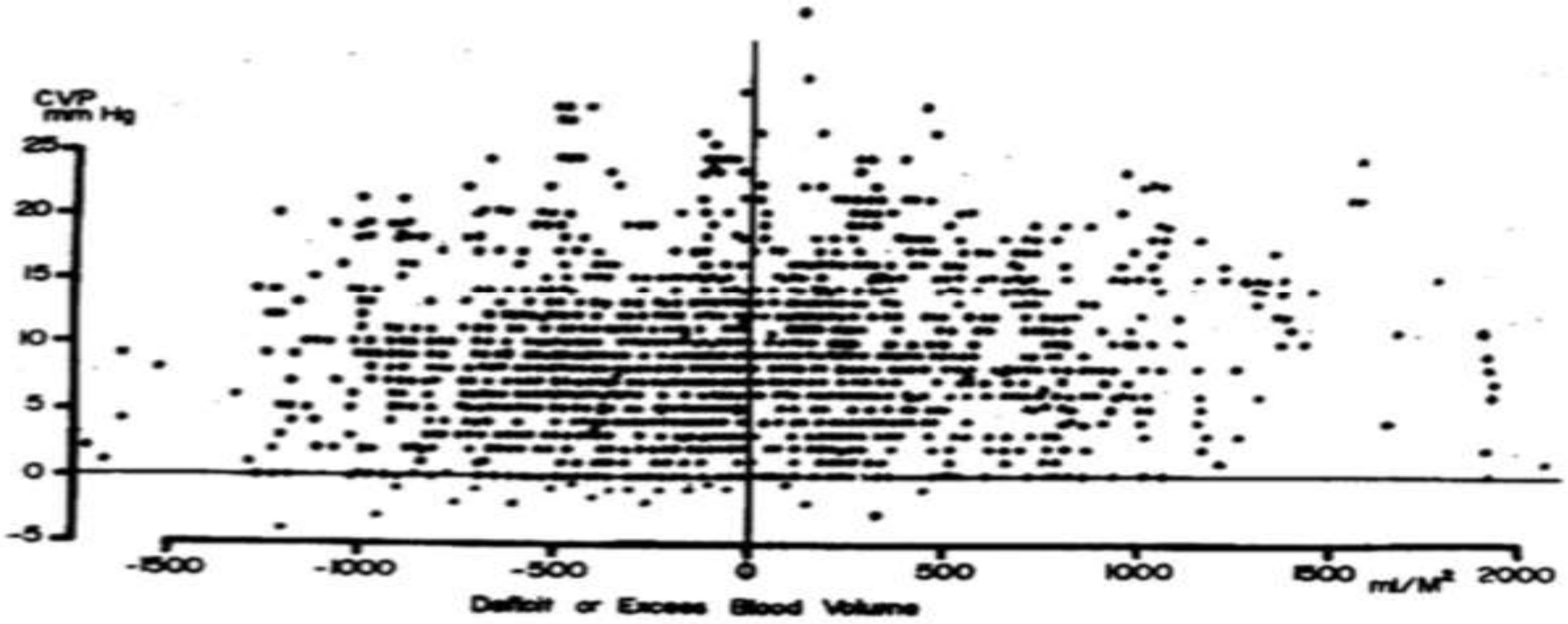
†Area under ROC curve of CVP and fluid responsiveness.

Chest. 2008 Jul 1;134(1):172-8

Table 1—*Summary of Studies of Blood Volume**

| Source | Setting | Type | Patients, No. | Methodology | *r*, Blood Volume |
|---|---|---|---|---|---|
| Baek et al,[10] 1975 | ICU | General surgery | 69 | $^{125}$I-albumin | 0.19 |
| Shippy et al,[11] 1984 | ICU | ICU | 118 | $^{125}$I-albumin | 0.27 |
| Hoeft et al,[12] 1994 | OR/ICU | CABG | 11 | Indocyanine green | 0.12 |
| Oohashi et al,[13] 2005 | ICU | Esophagectomy | 16 | Indocyanine green | 0.17 |
| Kuntscher et al,[14] 2006 | ICU | Burns | 16 | COLD system† | 0.02 |
| Pooled value | | | | | 0.16 |

*OR = operating room; CABG = coronary artery bypass graft surgery.
†COLD Z-021 system (Pulsion Medical Systems; Munich, Germany).



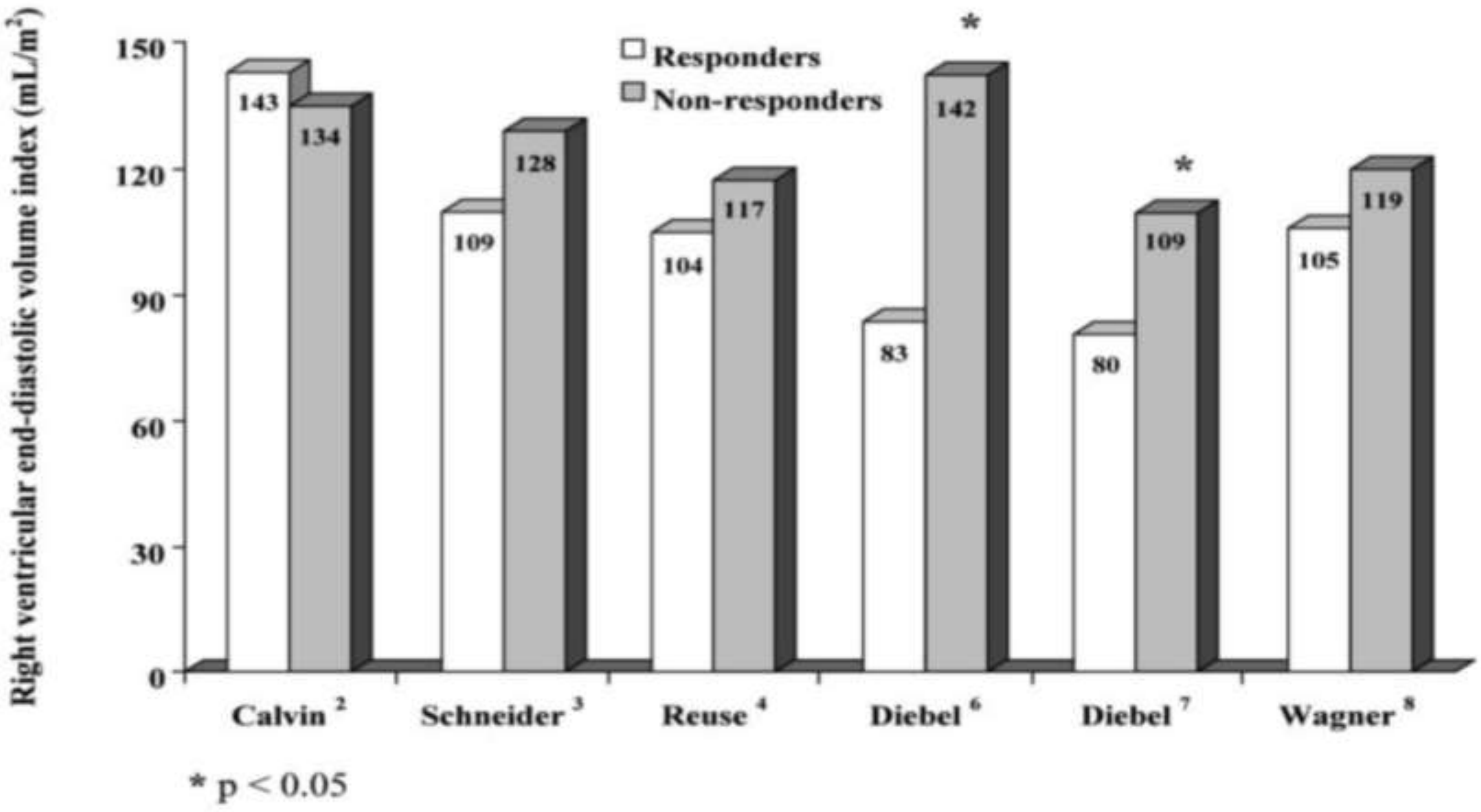

Chest. 2008 Jul 1;134(1):172-8

# Static indicator – Right ventricular end diastolic volume index

- 6 studies measured RVEDVI
- RVEDV index  not significantly lower in responders than in non responders
- Weak  corelation  between baseline RVEDV index and the increase in stroke volume in response to volume expansion ($r^2$ = 0.19)
- No threshold to  predict the hemodynamic response to volume expansion before fluid was administered

Chest. 2002 Jun 1;121(6):2000-8

# Static indicator – Right ventricular end diastolic volume index




Chest. 2002 Jun 1;121(6):2000-8

# Static indicator - Pulmonary artery occlusion pressure

- PAOP not significantly lower in responders when compared to non responders in 7 of 9 studies
- No threshold to predict the hemodynamic response to volume expansion before fluid was administered
- Weak relationship between the baseline PAOP and the increase in stroke volume in response to volume expansion ($r^2$ =0.33)

Chest. 2002 Jun 1;121(6):2000-8

# Static indicator- Left ventricular end diastolic area

- EDAI was  significantly different between the two groups (9.7 ± 3.7 vs 9.7 ± 2.4 $cm^2/m^2$)
- Baseline EDAI did not correlate significantly with the volume expansion-induced changes in cardiac index ($r^2$ = 0.11; p = 0.17)

Chest. 2001 Mar 1;119(3):867-73

# Static indicators

- Reflect preload and  are not accurate
- Apart from preload, stroke volume and cardiac output also depends on cardiac contractility

Best Practice & Research Clinical Anaesthesiology. 2013 Jun 1;27(2):177-85

Intensive Care Med (2014) 40:1795–1815
DOI 10.1007/s00134-014-3525-z

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# Consensus on circulatory shock and hemodynamic monitoring. Task force of the European Society of Intensive Care Medicine

GUIDELINES

# Surviving sepsis campaign: international guidelines for management of sepsis and septic shock 2021

Check for updates

**Recommends using dynamic variables over static measures to guide fluid resuscitation, whenever applicable**

Intensive Care Med (2014) 40:1795–1815
Intensive Care Med (2021) 47:1181–1247

# Dynamic variables assessing preload responsiveness based on heart–lung interactions

- Pulse pressure variability (PPV)
- Stroke volume variability (SVV)
- Plethysmography variable index (PVI)
- Vena cava distensibility

Annals of Intensive Care. 2022 Dec;12(1):1-6
Ann Transl Med 2018;6(18):352

# Dynamic variables assessing preload responsiveness by mimicking a classic fluid challenge

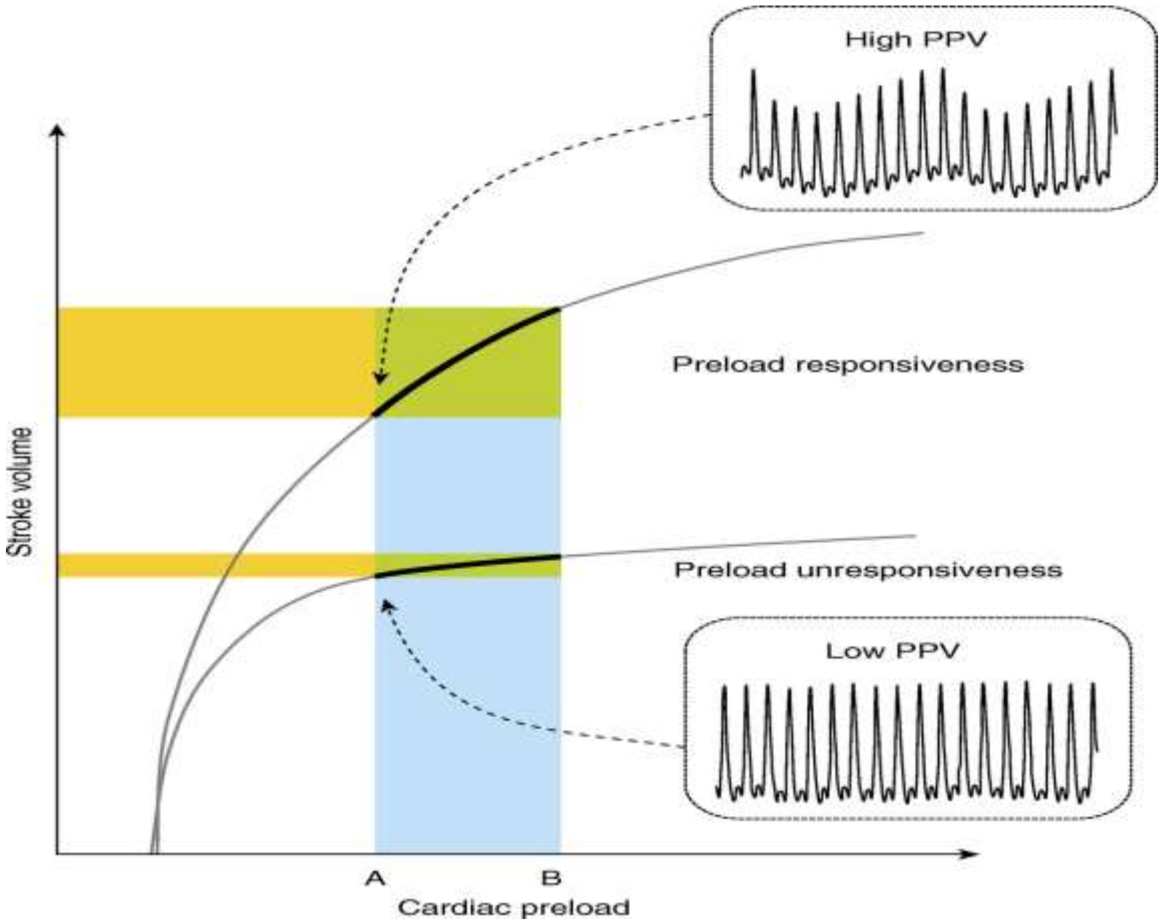
- End expiratory occlusion test (EEOT)
- End expiratory occlusion test (EEOT) + End inspiratory occlusion Test
- Tidal volume challenge test
- Passive leg raising
- Mini fluid Challenge
- Trendelenburg manoeuvre

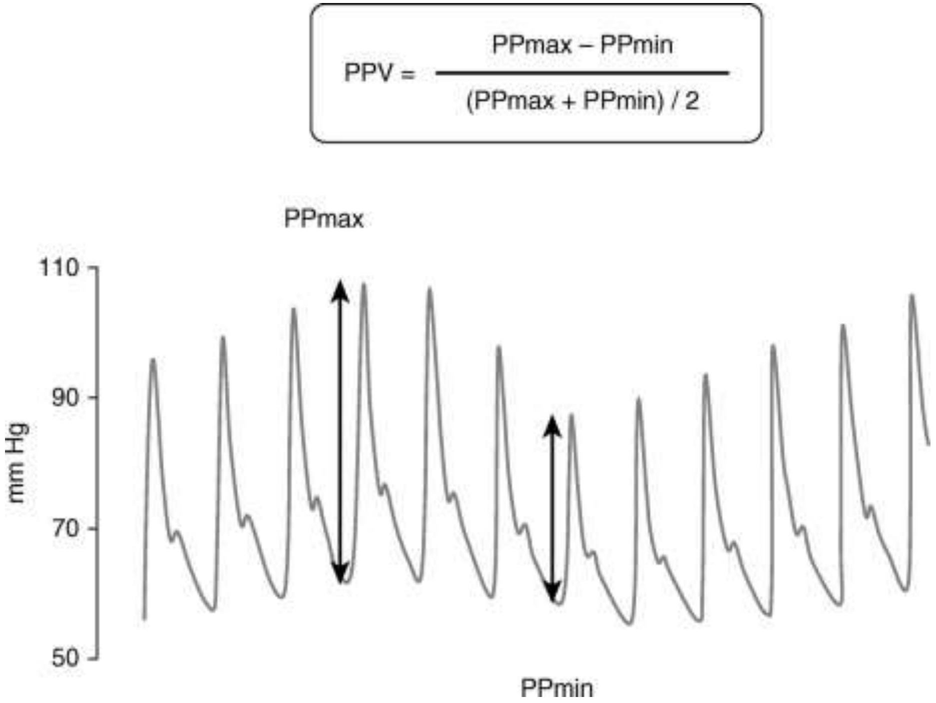
Annals of Intensive Care. 2022 Dec;12(1):1-6
Ann Transl Med 2018;6(18):352

# Pulse pressure variability

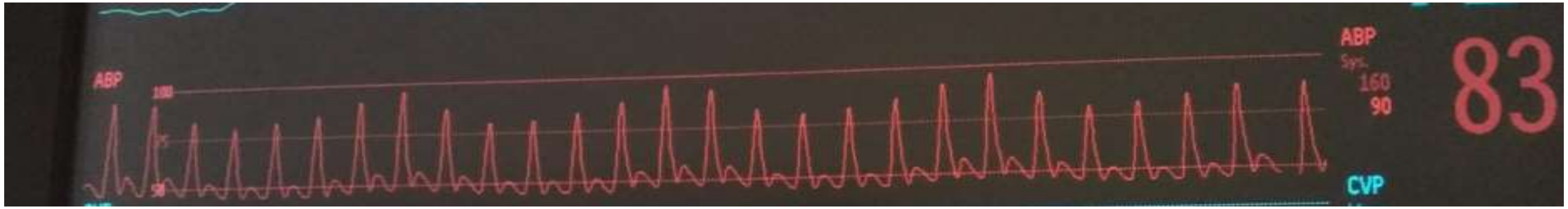
- Pulse pressure varies with respiration induced by positive pressure ventilation
- Indicator of a patient's position on the Frank-Starling Curve, a curve that denotes a patient response to preload (fluid responsiveness)
- $PPV = 100 \times (PP_{max} – PP_{min})/Pp_{mean}$
- PPV  of 12 to 15% is diagnostic threshold

Critical care. 2009 Sep 1;37(9):2642-7
Yang and Du Critical Care 2014, 18:650




AJRCCM 2019 Jan 1;199(1):22-31



ABP
ABP
Sys.
160
90
83
CVP

# Pulse pressure variability

- Meta-analysis of 22 studies and 807 patients,
- PPV predicted fluid responsiveness with an area under the receiving operating characteristic (AUROC) curve of 0.94 and a threshold of 12% PPV
- Sensitivity 0.88 (95% confidence interval (CI) 0.81 to 0.92) and pooled specificity 0.89 (95% CI 0.84 to 0.92)

Yang and Du Critical Care 2014, 18:650

# Limitations of pulse pressure variation

- Spontaneous breathing
- Cardiac arrhythmias
- Low tidal volume
- Low lung compliance
- Increased intraabdominal pressure
- Very high respiratory rate
- Right ventricular dysfunction

Critical care. 2009 Sep 1;37(9):2642-7
Yang and Du Critical Care 2014, 18:650
AJRCCM  2019 Jan 1;199(1):22-31

# Pulse pressure variability and low tidal volume

- 19 studies
- Total of 777 patients
- Sensitivity of PPV to predict fluid responsiveness during mechanical ventilation at Vt $\leqslant$8mL/kg 0.65 (95% confidence interval [CI]: 0.57-0.73), the specificity 0.79 (95% CI: 0.73-0.84), and the AUC was 0.75.

Circulatory, Respiratory and Pulmonary Medicine. 2020 Jan;14

# Stroke volume variation

- Meta analysis
- 266 patients and 12 studies
- Pooled corelation co efficient between baseline stroke volume variation and change in stroke volume index/cardiac index is 0.72
- Sensitivity 0.82 (0.75–0.98) and specificity 0.86 (0.77–0.92)
- Area under ROC is 0.84 (0.81–0.87)

Critical care medicine. 2009 Sep 1;37(9):2642-7

# Stroke volume variation and low tidal volume ventilation

- A total of 33 studies involving 1352 patients were included for analysis
- Areas under the curve (AUC) for predicting fluid responsiveness for SVV  is 0.90
- Sensitivity is 0.83 (0.75–0.88) and specificity is 0.85 (0.78–0.90)
- SVV threshold for fluid responsiveness is 12%

Annals of intensive care. 2021 Dec;11(1):1-7


48
SVI
mL/b/m²
PVPI
GEDI
ELWI
GEF
12
SVV
%
104
PR
bpm
5.0
CI
L/min/m²
844
SVRI
dyne-s-m²/cm⁵
CVP
mmHg
ScvO2
%
69
MAP
mmHg
71
mL/b
SV
12
%
SVV
48
mL/b/m²
SVI
7.4
L/min
CO
5:49:53 pm
20.12.2022
FloTrac
20


Male
Age: 62
Height: 152 cm
BSA: 1.57
02:21 PM
12/20/22
HR
bpm
126
SVI
mL/beat/m²
23
CI
L/min/m²
2.9
1930
Bolus
Dynamic Assessment was completed successfully.
OK
Δ SVI Trend
20.5%
Preload
Fluid Responsive
ΔSVI = 20.5%
Start PLR
Start BOLUS
Clinical Range
Waveforms
Dynamic Assessment
Numeric

# Plethysmography variability index

- Delta POP – (respiratory variation of pulse oximetry plethysmographic amplitude) (POP max – POP min/average POP) as percentage
- PVI is PI max - PI min/PI max as percentage
- PVI is a measures  dynamic changes in the Perfusion Index (PI) in  one or more complete respiratory cycles

Intensive care medicine. 2007 Jun;33(6):993-9.

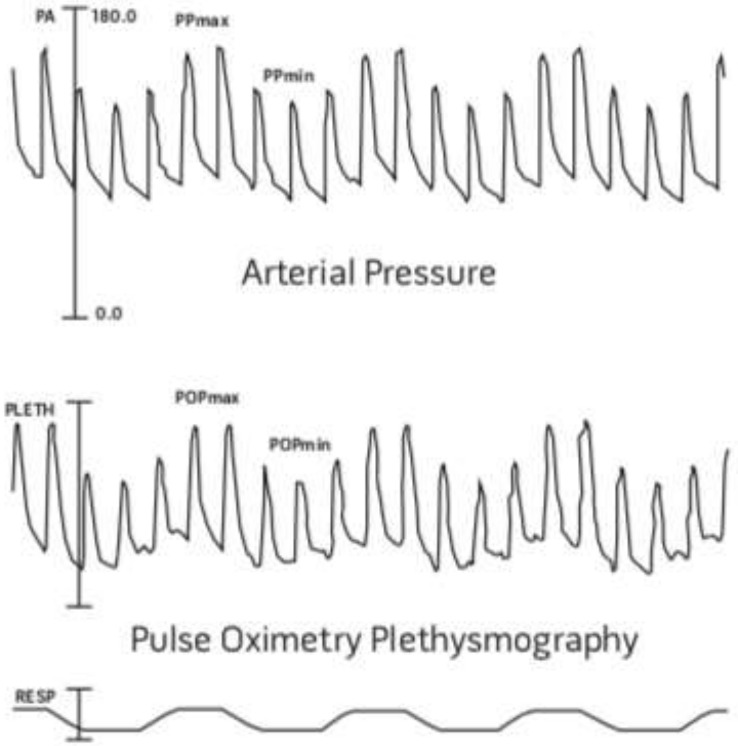



*Figure 1. Relation between respiratory variations in pulse oximetry plethysmographic waveform amplitude and arterial pulse pressure in ventilated patients. Adapted from Cannesson et al., 2005.*[10]

Cannesson et al Crit Care. 2005;9(5):562-8
Cannesson et al Anesthesia & Analgesia. 2008 Apr 1;106(4)

# Plethysmography variability index

- Meta analysis
- 25 studies  975 mechanically ventilated patients
- Threshold is 12 – 15%
- Area under  curve (AUC) of receiver operating characteristics (ROC) to predict preload responsiveness  0.82 (CI- 0.79–0.85)
- Sensitivity – 0.77 (95% CI 0.67–0.85)
- Specificity - 0.77 (95% CI 0.71–0.82)

Liu et al. BMC Anesthesiology (2019) 19:67

# Limitations of PVI

- Arrhythmias
- Right heart failure
- Spontaneous breathing activity
- low tidal volume (<8ml/kg)
- Patients treated with vasopressors

BMC anesthesiology. 2019 Dec;19(1):1-7.

# Tidal volume challenge

- Test consists of increasing the tidal volume from 6 to 8 mL/IBW for 1 minute
- Measure changes in Pulse Pressure Variation and stroke volume variation
- Change in PPV of 3.5% - diagnostic threshold
- Change in PPV– area under ROC - 0.99 (0.98–1.00)
- Change in PPV - Sensitivity – 94% and specificity – 100%

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Critical care medicine. 2017 Mar 1;45(3):415-21
Indian J Crit Care Med. 2021 Jun; 25(6): 685–690
Annals of intensive care. 2021 Dec;11(1):1-7

# Tidal volume challenge

- Change in stroke volume variation of 2.5% diagnostic threshold
- Change in SVV– area under ROC - 0.97(0.92–1.00)
- Change in SVV - Sensitivity – 88% and specificity – 100%

Critical care medicine. 2017 Mar 1;45(3):415-21
Anesthesia & Analgesia. 2020 Mar 1;130(3):752-61
British Journal of Anaesthesia. 2021 Oct 1;127(4):532-8


HR
53
SVI
36
CI
1.9
SVV
13
No Dynamic Assessment
Clinical Range
Waveforms
Dynamic Assessment


HR
52
SVI
39
CI
2.0
SVV
17
CO
2.8
No Dynamic Assessment
Clinical Range
Waveforms
Dynamic Assessment

# End Expiratory occlusion test

- Interrupting the ventilator at end-expiration for 15–30 s
- Assess change in Cardiac output
- EEOT abolishes increase in intrathoracic pressure and prevents drop in preload
- Increases venous return and acts like a fluid challenge

Critical care medicine. 2017 Mar1;45(3):415-21
Critical Care. 2019 Dec;23(1):1-3

# End expiration occlusion test

- 13 studies (9 in ICU care and 4 in operating room) included 530 Patients
- Pooled sensitivity - 0.85 [0.77–0.91]
- Pooled specificity - 0.88 [0.83–0.91].
- AUROC curve was 0.91 [0.86–0.94]
- Change in cardiac output threshold is 5%

Annals of intensive care. 2020Dec;10(1):1-0

# End Expiratory occlusion test

- 9  studies with tidal volume ≤7 mL/kg  the AUROC curve  0.96 [0.92–0.97]
- Sensitivity 0.89 [0.70–0.96] and specificity 0.92 [0.83–0.96]
- 3 studies test duration was >15 s  AUSROC - 0.93 [0.88–0.95]
- Sensitivity of 0.87 [0.72–0.95] and Specificity of  0.86 [0.74–0.93]

Annals of intensive care. 2020Dec;10(1):1-0

# End Expiratory occlusion test

- Among 8 studies peep < 7 the AUROC curve - 0.89 [0.83–0.95] ,
- Sensitivity of 0.86 [0.80–0.91] and Specificity of 0.86 [0.79–0.91]
- 5 studies PEEP level >7 cmH2O it AUROC 0.95 [0.92–0.97]
- Sensitivity 0.85 [0.62–0.95] and Specificity of 0.93 [0.85– 0.97]

Annals of intensive care. 2020Dec;10(1):1-0

# End Expiratory occlusion test

- Advantage
- Low tidal volume ventilated patients
- Cardiac arrhythmias

Annals of intensive care. 2020Dec;10(1):1-0


HR
95
SVI
21
CI
2.0
CO
2.8
No Dynamic Assessment
Clinical Range
Waveforms
Dynamic Assessment
Numeric


HR
88
CI
2.4
CO
3.3
HR
88
SVV
18
No Dynamic Assessment
Clinical Range
Waveforms
Dynamic Assessment
Numeric

# End Expiratory occlusion test + End inspiratory occlusion test

- 15-second end-inspiratory and end-expiratory occlusions
- Occlusions  separated by 1 minute to allow the cardiac index to return to its baseline value
- Cardiac output measured by picco and echo during the last 5 sec
- Increase in cardiac output by 13% is diagnostic threshold

Critical Care Medicine. 2017 Nov 1;45(11):e1131-8

# End Expiratory occlusion test + End inspiratory occlusion test

## 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]

| Variables | Receiver Operating Characteristics Curve Area | 95% CI | Threshold Value (%) | Sensitivity (%) (95% CI) | Specificity (%) (95% CI) | Youden Index | $p^a$ | $p^b$ |
|---|---|---|---|---|---|---|---|---|
| Continuous pulse contour cardiac index | | | | | | | | |
| Effect of the end-expiratory occlusion | 0.982 | 0.853–1.000 | 4 | 93 (68–100) | 100 (78–100) | 0.93 | < 0.0001 | – |
| Effect of the end-inspiratory occlusion | 0.760 | 0.570–0.896 | −10 | 60 (32–84) | 93 (68–100) | 0.53 | 0.006 | 0.02 |
| Added effects of both occlusions | 0.924 | 0.767–0.989 | 11 | 93 (68–100) | 80 (52–96) | 0.73 | < 0.0001 | 0.26 |
| Velocity time integral of the left ventricular outflow tract | | | | | | | | |
| Effect of the end-expiratory occlusion | 0.938 | 0.785–0.993 | 5 | 93 (68–100) | 100 (78–100) | 0.93 | < 0.0001 | – |
| Effect of the end-inspiratory occlusion | 0.904 | 0.740–0.981 | −8 | 80 (52–96) | 87 (59–98) | 0.67 | < 0.0001 | 0.58 |
| Added effects of both occlusions | 0.973 | 0.838–1.000 | 13 | 93 (68–100) | 93 (68–100) | 0.86 | < 0.0001 | 0.44 |

Critical Care Medicine. 2017 Nov 1;45(11):e1131-8

# IVC assessment

- Meta analysis
- 20 studies – 1107 patients  IVC collapsibility/distensibility
- Sensitivity 0.71 (95% CI: 0.62-0.80)
- Specificity 0.75 (95% CI: 0.64-0.85)
- Change in collapsibility index with  of 12 to 18 percent has been associated with fluid responsiveness in mechanically ventilated patients
- Used in patients with Vt>8m/PBW and also in cardiac arrthymias

# Limitations of IVC assessment

- Ventilator settings - High peep and/or  low tidal volume
- Patients inspiratory efforts – Assisted ventilation mode/non invasive ventilation/CPAP
- Lung hyperinflation **-** Asthma/COPD exacerbation
- Cardiac conditions impeding venous return - Chronic RV dysfunction, severe Tricuspid Regurgitation and Cardiac tamponade


Intensive care medicine. 2004 Sep;30(9):1740-6.
European Journal of Ultrasound. 2012 Apr;33(02):152-9.
Journal of the American College of Cardiology. 2002 Sep 40(5):841-53
Journal of intensive care medicine. 2020 Apr;35(4):354-63

# Limitations of IVC assessment

- Increased abdominal pressure – increased abdominal hypertension
- Local mechanical factors - Venous return hindrance, IVC dilatation (stenosis, thrombosis) , IVC compression(mass), Hindrance to IVC size change (ECMO cannulae, cava filters)
- Patients with pronounced IVC inspiratory lateral displacement - Migration of IVC imaging plane, false inspiratory size reduction


Critical care medicine. 2011 Feb 1;39(2):344-8

Critical Ultrasound Journal. 2012 Dec;4(1):1-5

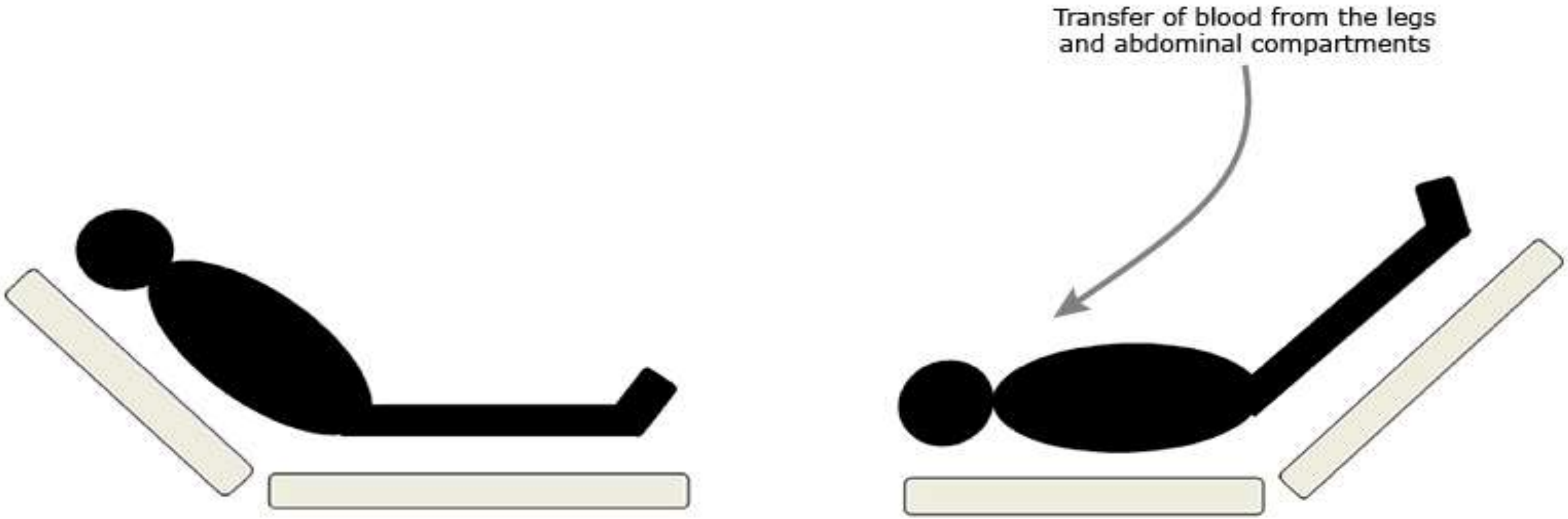
Trends in Anaesthesia and Critical Care. 2015 Jun 1;5(2-3):70-5

# Passive Leg Raising

- Provides a bolus of the patient's own intravascular blood from the capacitance veins of the lower extremities into the thorax
- No fluid infused, rapidly reversible test
- Can be used in spontaneously breathing patients, low tidal volume, low lung compliance, in patients with arrhythmia
- Begin procedure in semi recumbent position (blood from splanchnic circulation also adds to the infused volume)
- Measures cardiac output

Annals of intensive care. 2021 Dec;11(1):1-7.

## Passive leg raising maneuver for fluid responsiveness




Passive leg raising maneuver. After starting with the head elevated to 45 degrees, rapidly repositioning the patient with legs elevated to 30 to 45 degrees allows autotransfusion of blood from the legs into the thorax. An increase in cardiac output suggests that the patient might be fluid responsive.

Annals of intensive care. 2011 Dec;1(1):1-9

# Passive Leg Raising

- Responders defined as increase in CO by 12-15%
- Reference standards – CO, cardiac index, stroke volume and aortic flow measurements after fluid challenge
- The pooled sensitivity and specificity of PLR-cCO were 89.4% (84.1–93.4%) and 91.4% (85.9–95.2%) respectively and pooled area under the receiver operating characteristics curve (AUC) was 0.95 (0.92–0.97)

Intensive care medicine. 2010 Sep;36(9):1475-83.

# Predicting Fluid Responsiveness by Passive Leg Raising: A Systematic Review and Meta-Analysis of 23 Clinical Trials*

Thomas G. V. Cherpanath, MD[1]; Alexander Hirsch, MD, PhD[2]; Bart F. Geerts, MD, PhD[3];
Wim K. Lagrand, MD, PhD[1]; Mariska M. Leeflang, PhD[4]; Marcus J. Schultz, MD, PhD[5];
A. B. Johan Groeneveld, MD, PhD[6]

**TABLE 3. Overview of Measurement Techniques and Outcome Variables**

| Author | Method 1 | Outcome 1 | Cutoff (%) | % Fluid Responders | Method 2 | Outcome 2 | Method 3 | Outcome 3 |
|---|---|---|---|---|---|---|---|---|
| Monnet (28) | Esophageal Doppler | ABF | 15 | 52 | ABP transducer | PP | | |
| Lafanechère (29) | Esophageal Doppler | ABF | 15 | 45 | | | | |
| Lamia (30) | Echocardiography | SVI | 15 | 54 | | | | |
| Maizel (31) | Echocardiography | CO | 12 | 50 | Echocardiography | SV | | |
| Monnet (32) | Pulse contour | CI | 15 | 68 | ABP transducer | PP | | |
| Thiel (33) | Echocardiography | SV | 15 | 46 | | | | |
| Biais (34) | Echocardiography | SV | 15 | 67 | Pulse contour[a] | SV | | |
| Préau (35) | Echocardiography | SV | 15 | 41 | ABP transducer | PP | Femoral Doppler | Femoral blood flow |
| Lakhal (36) | Pulse contour | CO | 10 | 42 | ABP transducer | PP | | |
| Benomar (37) | Bioreactance | CO | 9 | 49 | | | | |
| Monnet (38) | Pulse contour | CI | 15 | 88 | | | | |
| Guinot (39) | Echocardiography | SV | 15 | 52 | Echocardiography | CO | | |
| Monnet (40) | Pulse contour | CI | 15 | 56 | | | | |
| Dong (41) | Pulse contour | SVI | 15 | 69 | Central venous catheter | Central venous pressure | | |
| Monge García (42) | Esophageal Doppler | CO | 15 | 57 | ABP transducer | PP | Gas analyzer tube | Partial end-tidal carbon dioxide |
| Monnet (43) | Pulse contour | CI | 15 | 44 | | | | |
| Fellahi (44) | Pulse contour | CI | 15 | 56 | Endotracheal bioimpedance | CI | | |
| Marik (45) | Bioreactance | SVI | 10 | 53 | Carotid Doppler | Carotid blood flow | | |
| Monnet (46) | Pulse contour | CI | 15 | 53 | ABP transducer | PP | Capnography | End-tidal carbon dioxide |
| Saugel (47) | Pulse contour | CI | 15 | 29 | ABP transducer | Mean arterial pressure | Pulse contour | Cardiac power index |
| Brun (48) | Echocardiography | SVI | 15 | 52 | Brachial cuff | PP | | |
| Kupersztych (49) | Pulse contour | CI | 15 | 40 | Bioreactance | CI | | |
| Duus (50) | Bioreactance | SV | 10 | 64 | | | | |

Critical care medicine. 2016 May 1;44(5):981-91

TABLE 4. **Comparison of the Primary Measurement Techniques Measuring Flow Variables**

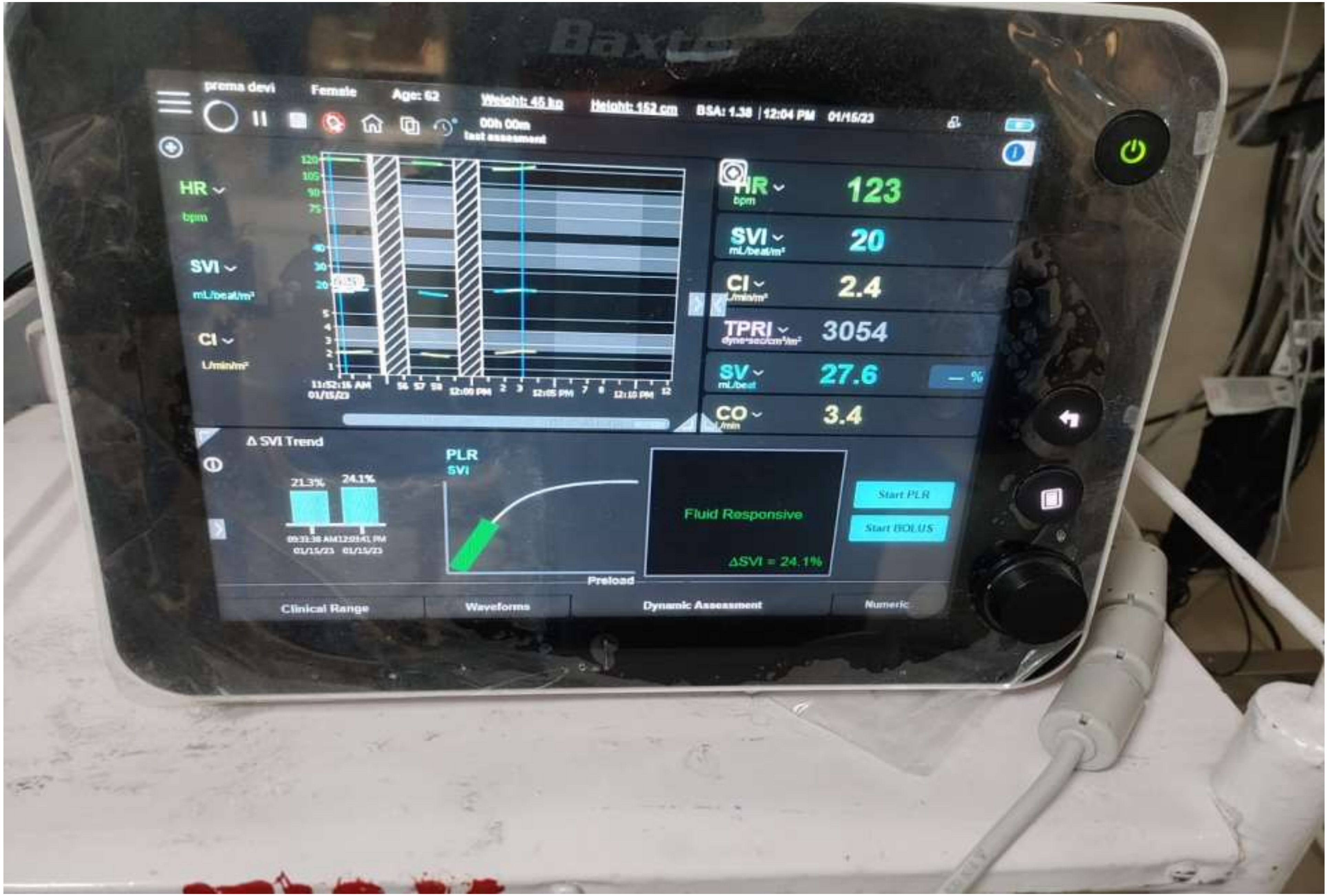
| Technique | No. of Studies | No. of Fluid Challenges in Combination With Passive Leg Raise | Sensitivity | Specificity | Area Under the Receiver Operating Characteristic Curve |
|---|---|---|---|---|---|
| Esophageal Doppler | 3 | 130 | 96 (84–99) | 92 (77–97) | 0.96 |
| Transthoracic echocardiography | 7 | 272 | 79 (68–87) | 91 (86–95) | 0.88 |
| Pulse contour analysis | 10 | 423 | 84 (77–89) | 92 (87–95) | 0.92 |
| Bioreactance | 3 | 209 | 84 (67–93) | 86 (68–94) | 0.89 |

Critical care medicine. 2016 May 1;44(5):981-91

# Passive leg raising

- **Advantages**
- Spontaneous breathing activity
- Cardiac rhythm
- Low Vt volume
- Lung compliance

- **Limitations**
- False negatives in case of intra-abdominal hypertension and use of venous compression stockings



prema devi
Female
Age: 62
Weight: 45 kg
Height: 152 cm
BSA: 1.38
12:04 PM
01/15/23
00h 00m
last assessment
HR
bpm
SVI
mL/beat/m²
CI
L/min/m²
11:52:16 AM
01/15/23
12:00 PM
12:05 PM
12:10 PM
HR
bpm
123
SVI
mL/beat/m²
20
CI
L/min/m²
2.4
TPRI
3054
SV
mL/beat
27.6
-- %
CO
L/min
3.4
Δ SVI Trend
21.3%
24.1%
01/15/23
01/15/23
PLR
SVI
Preload
Fluid Responsive
ΔSVI = 24.1%
Start PLR
Start BOLUS
Clinical Range
Waveforms
Dynamic Assessment
Numeric

# Mini fluid Challenge Test

- Infusing 100 to 150 mL of crystalloid or colloid over 1 min
- Index measured  is :
- Change in  cardiac output – 5%

British journal of anaesthesia. 2015 Sep 1;115(3):449-56

# Mini fluid Challenge Test

- Advantages
- Spontaneous  breathing activity,
- Cardiac rhythm
- Low  Vt volume
- Lung compliance
- Intraabdominal hypertension

British journal of anaesthesia. 2015 Sep 1;115(3):449-56

# Trendelenburg manoeuvre

Yonis et al. Critical Care (2017) 21:295
DOI 10.1186/s13054-017-1881-0
Critical Care

RESEARCH Open Access

Change in cardiac output during Trendelenburg maneuver is a reliable predictor of fluid responsiveness in patients with acute respiratory distress syndrome in the prone position under protective ventilation

- 33 patients - Single centre prospective study
- ARDS patient with failure  in prone position
- Keep the Patient in Trendelenburg position for 1 min
- Increase in cardiac index ≥ 8% with sensitivity of 87% (95% CI, 67–100), and specificity of 89% (95% CI, 72–100)
- ROC for trendelenburg manoeuvre 0.90 (95% CI, 0.80–1.00)

Yonis et al. Critical Care (2017) 21:295

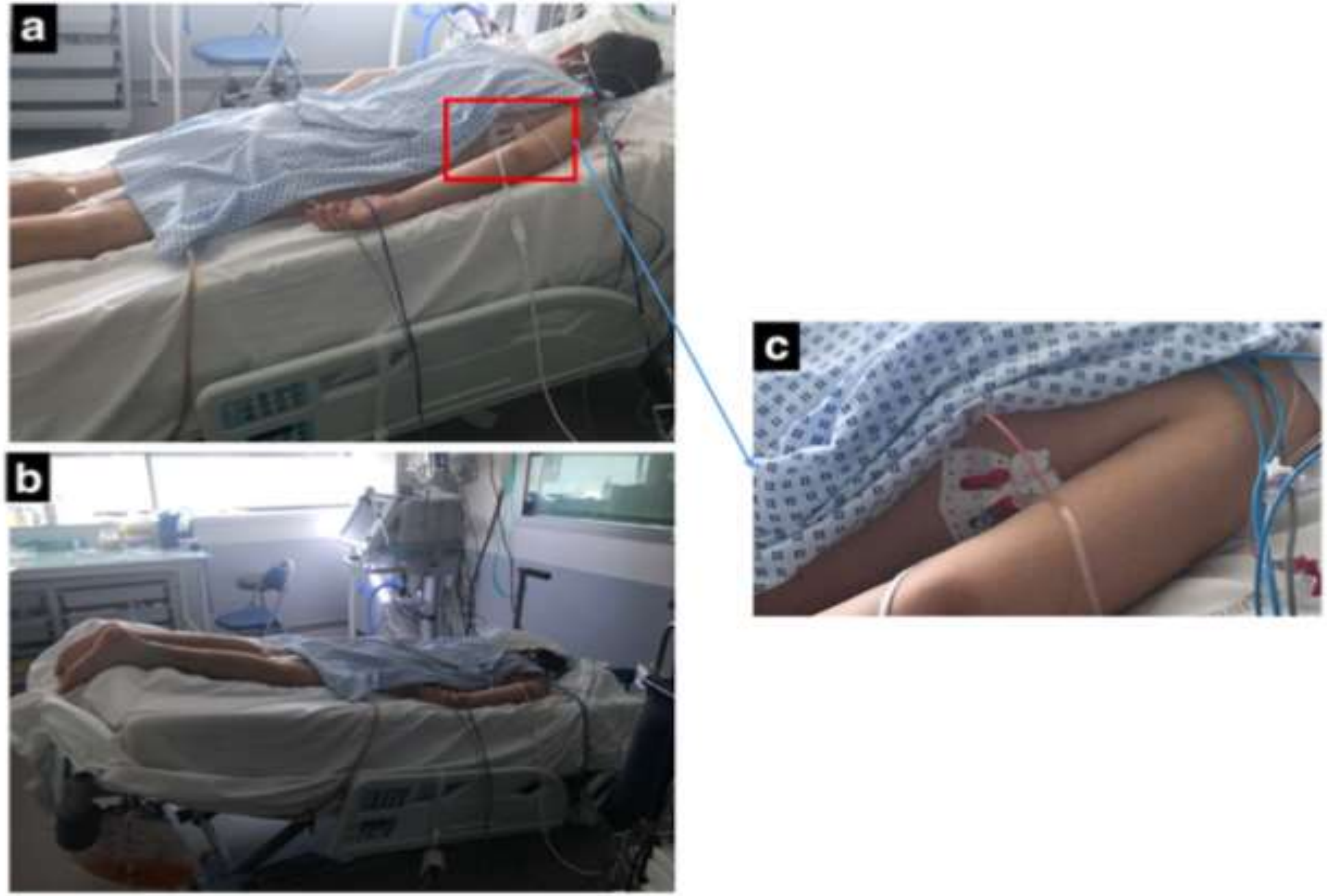



**Fig. 1** Trendelenburg maneuver. **a** Starting position of the Trendelenburg maneuver with bed angulation +13°. **b** Trendelenburg position with a −13° downward bed angulation. **c** Pressure transducers taped on the thorax at the phlebostatic reference point

Yonis et al. Critical Care (2017) 21:295

# Trendelenburg manoeuvre

- Advantage
- Possible even in prone position (ARDS patients)
- On operating table or under ECMO
- Works regardless of breathing activity
- Cardiac rhythm
- Low tidal volume

- Limitation
- Possible gastric reflux

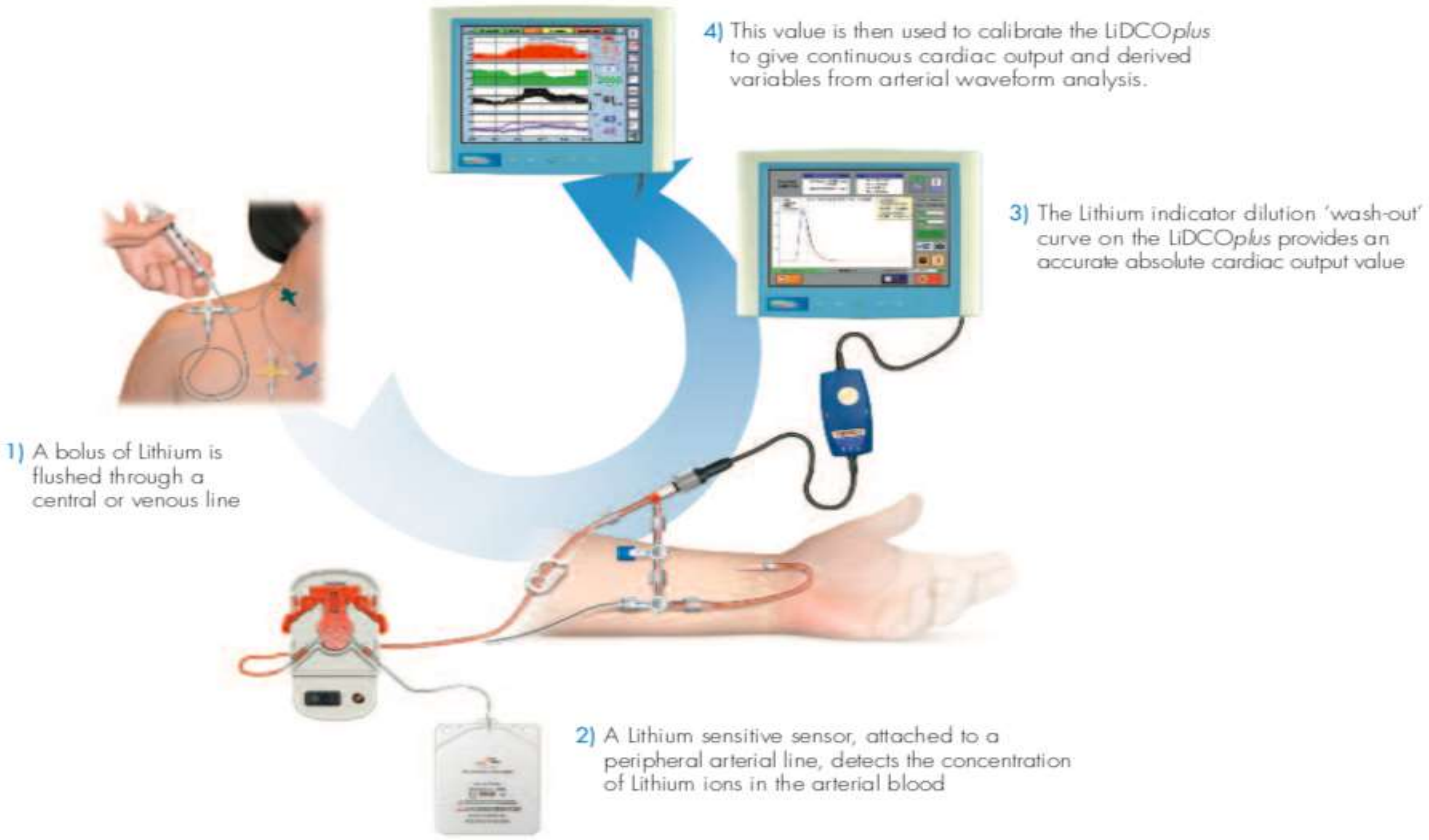
Yonis et al. Critical Care (2017) 21:295
Luo et al. Ann. Intensive Care (2021) 11:16
Annals of intensive care. 2021 Dec;11(1):1-0

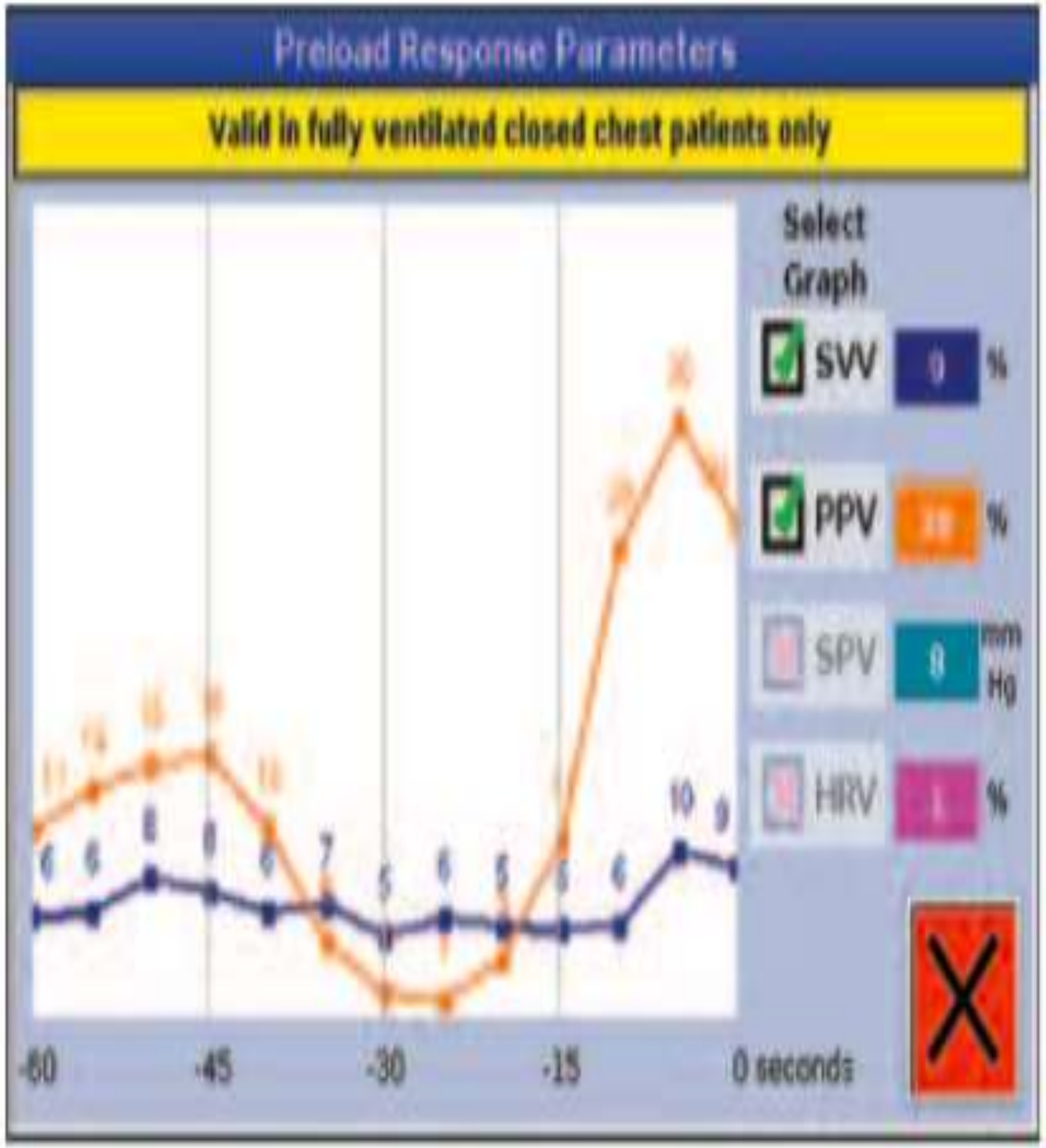
# Cardiac output

- Lithium dilution based device(LiDCO),
- Thermal dilution based device (PiCCO)
- Arterial waveform-based devices - FloTrac sensor and Vigileo monitoring system
- Thoracic electrical bioimpedance (TEB)
- Thoracic bioreactance
- Aortic doppler
- Point of care Echocardiography

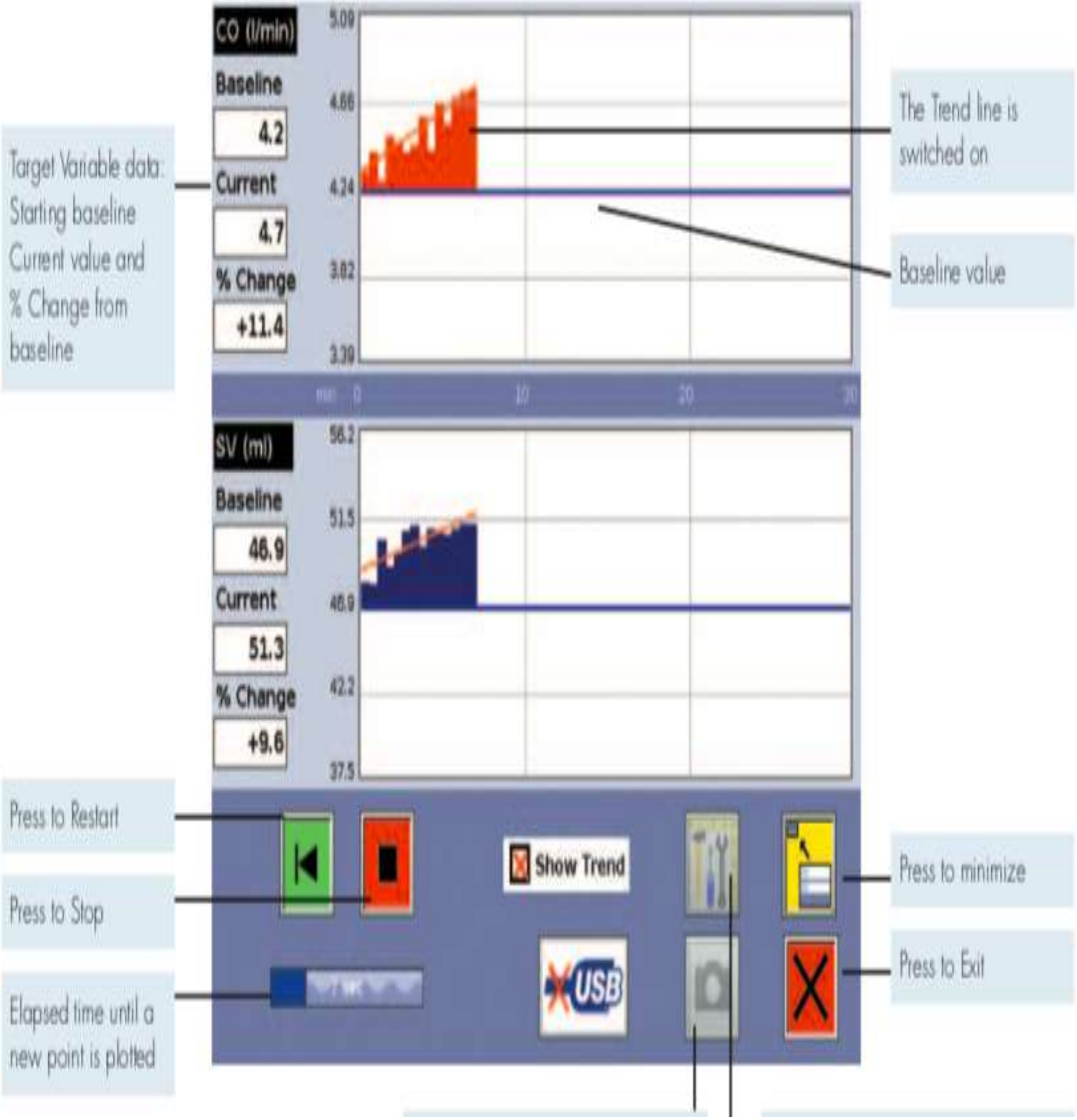
# LiDCO Plus System

- A small dose of lithium injected (central or peripheral line)
- Lithium concentration measured by lithium sensitive electrode in arterial line
- From the concentration-time curve cardiac output is calculated (Cardiac Output = (Lithium Dose x 60)/(Area x (1-PCV))
- This measurement is  used to calibrate pulse contour analysis software.
- After calibration continuous cardiac output monitoring is possible by analysing arterial pressure waveform

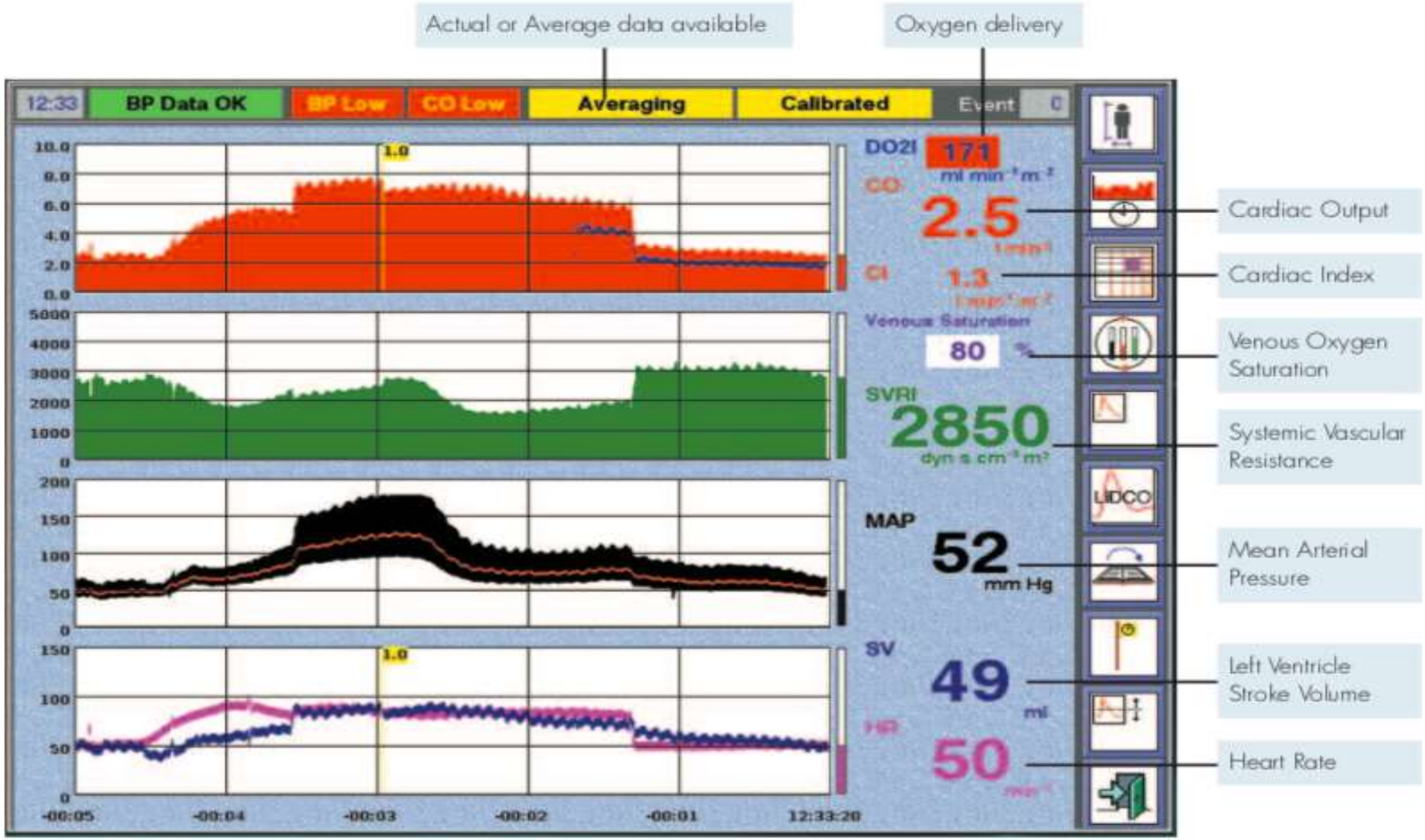

4) This value is then used to calibrate the LiDCO*plus* to give continuous cardiac output and derived variables from arterial waveform analysis.
3) The Lithium indicator dilution 'wash-out' curve on the LiDCO*plus* provides an accurate absolute cardiac output value
1) A bolus of Lithium is flushed through a central or venous line
2) A Lithium sensitive sensor, attached to a peripheral arterial line, detects the concentration of Lithium ions in the arterial blood



Preload Response Parameters
Valid in fully ventilated closed chest patients only
Select Graph
SVV
%
PPV
%
SPV
mm Hg
HRV
%
-60
-45
-30
-15
0 seconds

CO (l/min)
Baseline
4.2
Current
4.7
% Change
+11.4
SV (ml)
Baseline
46.9
Current
51.3
% Change
+9.6
Show Trend
Target Variable data: Starting baseline Current value and % Change from baseline
The Trend line is switched on
Baseline value
Press to Restart
Press to Stop
Elapsed time until a new point is plotted
Press to minimize
Press to Exit


Actual or Average data available
Oxygen delivery
12:33
BP Data OK
BP Low
CO Low
Averaging
Calibrated
Event
DO2I
171
CO
2.5
CI
1.3
Venous Saturation
80
%
SVRI
2850
MAP
52
mm Hg
SV
49
ml
HR
50
Cardiac Output
Cardiac Index
Venous Oxygen Saturation
Systemic Vascular Resistance
Mean Arterial Pressure
Left Ventricle Stroke Volume
Heart Rate
-00:05
-00:04
-00:03
-00:02
-00:01
12:33:20

# LiDCO

- Prospective study where intermittent LiDCO (single injection of 0.3 mmol Lithium) compared to two calibrated (equalized to first LiDCO) continuous cardiac output algorithms over 24 hours
- Range of cardiac outputs was 3.45 to 10.47 litres per minute
- Correlation with Pulse CO (LiDCO LTD) ($r^2 = 0.89$: $p <= 0.05$)
- Correlation with PiCCO ($r^2 = 0.88$ : $p <= 0.05$)

Critical Care Medicine. 2005 Dec 1;33(12):A56

# LiDCO

- Measures absolute cardiac output value by  proven indicator dilution technique
- Requires no additional invasive catheters to insert into the patient
- Safe – using non-toxic bolus dosages
- Simple and quick to set up
- Not temperature dependent
- less invasive monitoring

European Journal of Anaesthesiology| EJA. 2004 Jun 1;21:22-3

# PICCO (Pulse index Continuous Cardiac Output)

**Transpulmonary thermodilution**

- Thermodilution cardiac output
- Volumetric preload (GEDV - Global End-Diastolic Volume)
- Contractility (CFI - Cardiac Function Index)
- Lung water (EVLW - Extravascular Lung Water)

**Pulse contour analysis**

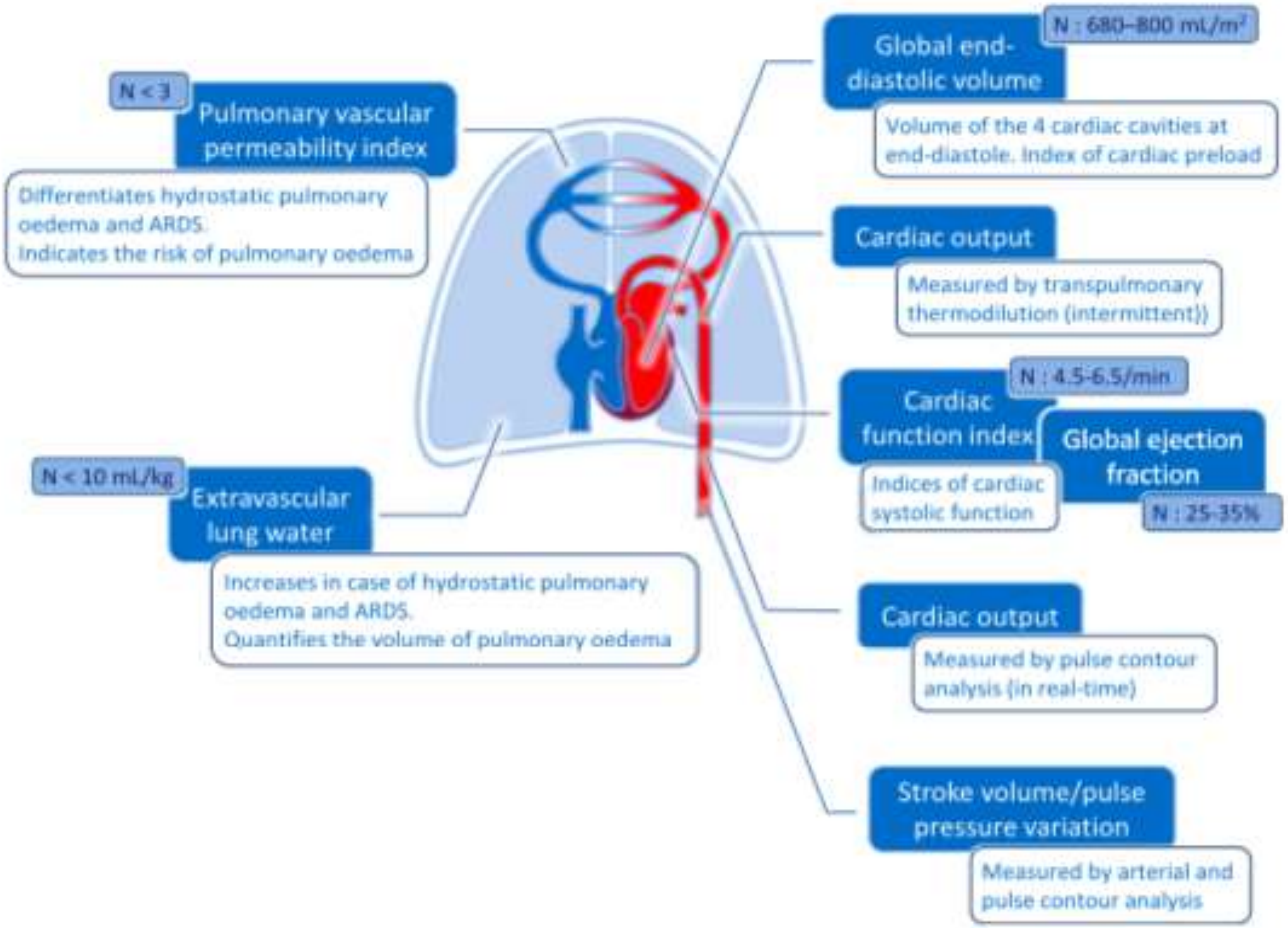
- Continuous cardiac output
- Afterload (SVR - Systemic Vascular Resistance)
- Stroke Volume (SV - Stroke Volume)
- Volume responsiveness (SVV , PPV)

Monnet and Teboul Critical Care (2017) 21:147

# PICCO Thermodilution

- The cold indicator passes through the right heart, lungs and left heart
- The indicator is detected in a central artery
- Precise cardiac output measurement based on Stewart-Hamilton algorithm
- Breathing cycle independent
- Passage through the heart and lungs allows determination of preload volumes and lung water

Monnet and Teboul Critical Care (2017) 21:147


N < 3
Pulmonary vascular permeability index
Differentiates hydrostatic pulmonary oedema and ARDS.
Indicates the risk of pulmonary oedema
N < 10 mL/kg
Extravascular lung water
Increases in case of hydrostatic pulmonary oedema and ARDS.
Quantifies the volume of pulmonary oedema
N : 680–800 mL/m²
Global end-diastolic volume
Volume of the 4 cardiac cavities at end-diastole. Index of cardiac preload
Cardiac output
Measured by transpulmonary thermodilution (intermittent))
N : 4.5-6.5/min
Cardiac function index
Global ejection fraction
N : 25-35%
Indices of cardiac systolic function
Cardiac output
Measured by pulse contour analysis (in real-time)
Stroke volume/pulse pressure variation
Measured by arterial and pulse contour analysis

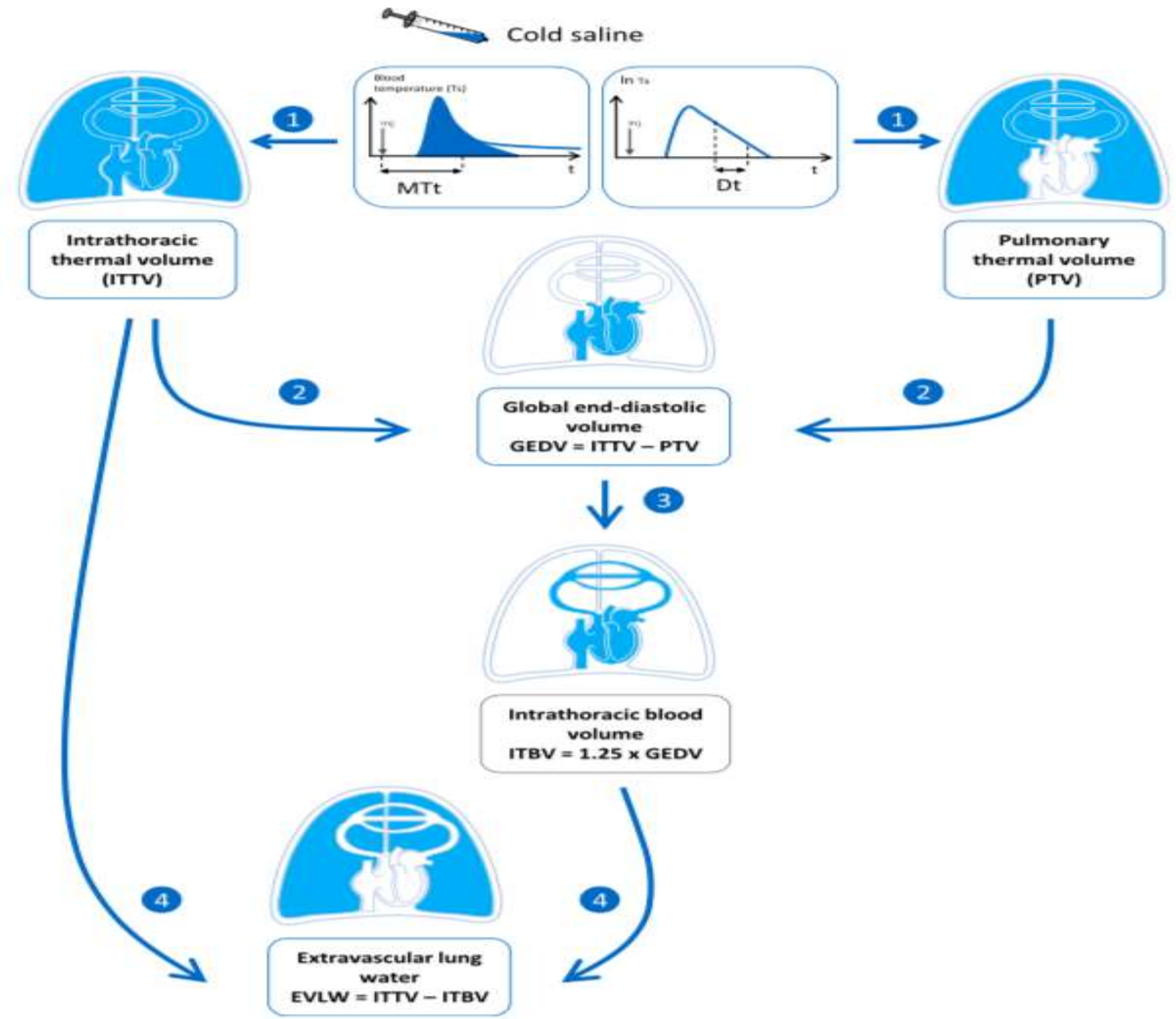



**Fig. 2** Assessment of intrathoracic volume by the PiCCO device. With the VolumeView device, the geometrical analysis of the thermodilution curve directly estimates the global end-diastolic volume. *Dt* downslope time, *MTt* mean transit time. For explanation, see the text

Monnet and Teboul Critical Care (2017) 21:147

# PICCO - GEDV

- Assessment of cardiac preload: global end-diastolic volume
- 36 patients with septic shock in medical ICU
- Changes in GEDV index were correlated (*r* - 0.72, p < 0.001) with changes in SVI

Chest. 2003 Nov 1;124(5):1900-8

# PICCO -GEDV

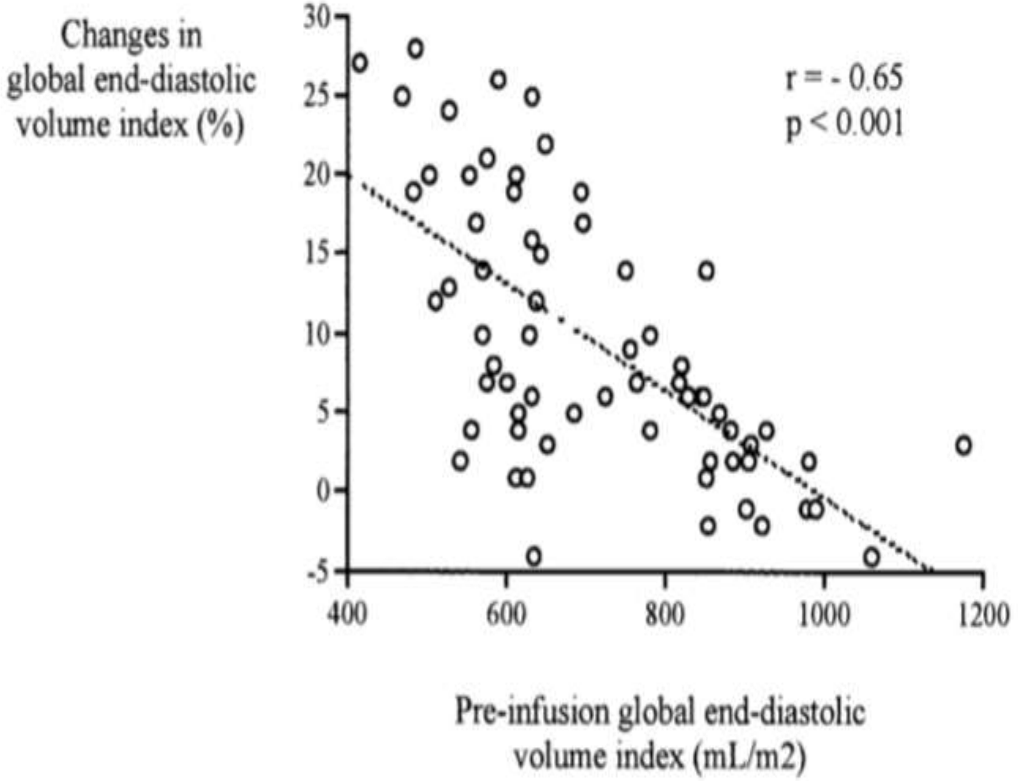



FIGURE 2. Relationship between the preinfusion GEDV index and volume loading-induced changes in GEDV index.

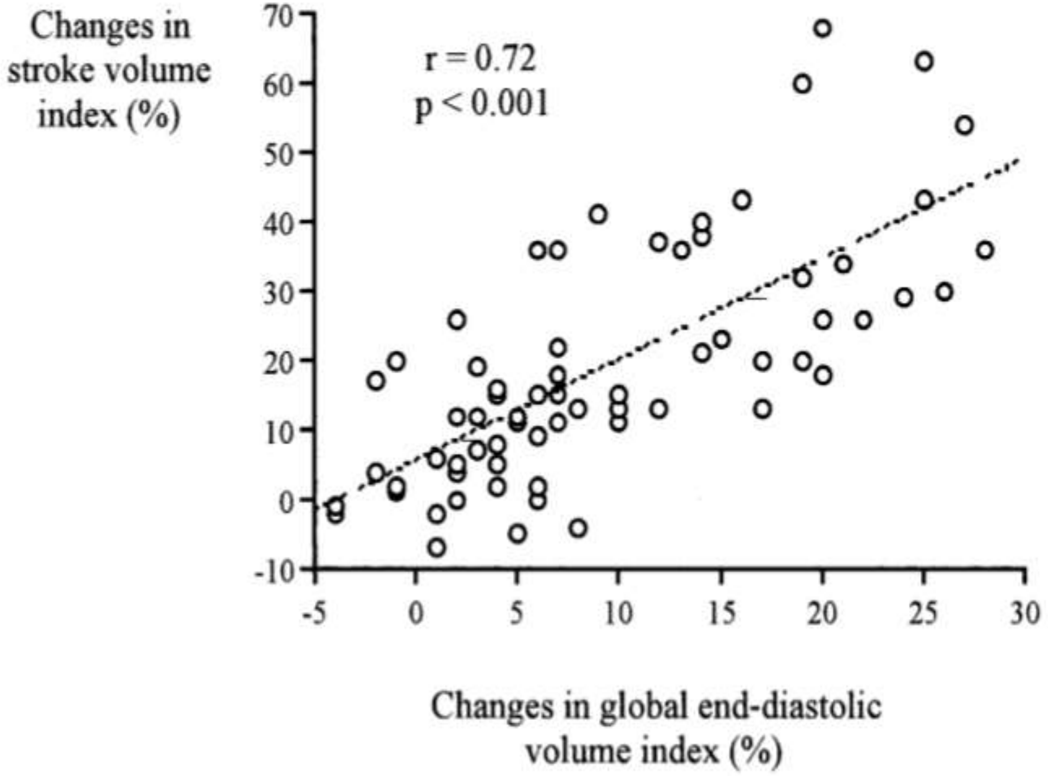



FIGURE 3. Relationship between volume loading-induced changes in GEDV index and changes in SVI.

Chest. 2003 Nov 1;124(5):1900-8

# PICCO -EVLWI

- 11 studies with 670 patients
- EVLWI significantly higher in non survivors than in survivors, with a mean difference of 5.06 mL/kg (95% confidence interval, −7.53 to −2.58)
- Independent predictor of ICU mortality in ARDS

Journal of Critical Care (2012) 27, 420.e1–420.e8
Critical Care. 2013 Feb;17(1):1-3
Critical care medicine. 2010 Jan 1;38(1):114-20

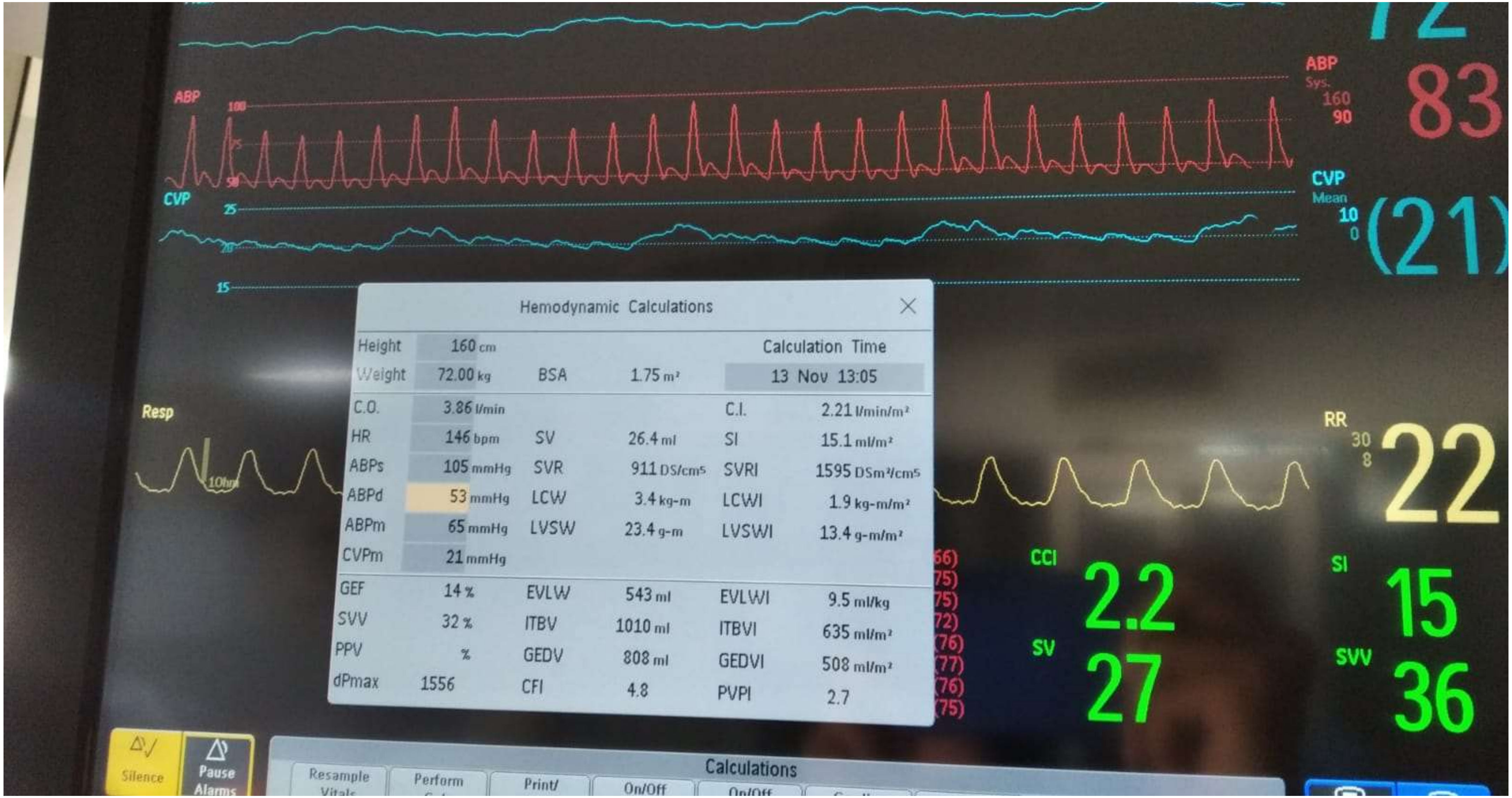
# Cardiac Function Index

- Ratio of cardiac output (measured by TPTD) and GEDV
- To follow its trends following ionotropic infusion along with global ejection fraction
- Unreliable in Right ventricular dilatation

Biomed Res Int. 2014;2014:598029

| Abbreviation | Range | Unit |
| --- | --- | --- |
| CI | 3.0 – 5.0 | $l/min/m^2$ |
| SVI | 40 – 60 | $ml/m^2$ |
| GEDI | 680 – 800 | $ml/m^2$ |
| ITBI | 850 – 1000 | $ml/m^2$ |
| SVV | < 10 | % |
| PPV | < 10 | % |
| SVRI | 1970 - 2390 | $dyn*s*cm^{-5}*m^2$ |
| CFI | 4.5 – 6.5 | 1/min |
| MAP | 70 – 90 | mmHg |
| ELWI | < 10 | ml/kg |

Monnet and Teboul Critical Care (2017) 21:147


ABP
83
CVP
(21)
Resp
RR
22
Hemodynamic Calculations
Height 160 cm
Weight 72.00 kg
BSA 1.75 m²
Calculation Time
13 Nov 13:05
C.O. 3.86 l/min
C.I. 2.21 l/min/m²
HR 146 bpm
SV 26.4 ml
SI 15.1 ml/m²
ABPs 105 mmHg
SVR 911 DS/cm5
SVRI 1595 DSm²/cm5
ABPd 53 mmHg
LCW 3.4 kg-m
LCWI 1.9 kg-m/m²
ABPm 65 mmHg
LVSW 23.4 g-m
LVSWI 13.4 g-m/m²
CVPm 21 mmHg
GEF 14 %
EVLW 543 ml
EVLWI 9.5 ml/kg
SVV 32 %
ITBV 1010 ml
ITBVI 635 ml/m²
PPV %
GEDV 808 ml
GEDVI 508 ml/m²
dPmax 1556
CFI 4.8
PVPI 2.7
CCI
2.2
SV
27
SI
15
SVV
36
Silence
Pause Alarms
Calculations
Resample Vitals
Perform
Print/
On/Off
On/Off

# Arterial wave form analysis

- Invasive method of determining cardiac output
- Cardiac output and stroke volume estimated from arterial lines
- FloTrac sensor and Vigileo monitoring system
- Arterial waveform sampled every 20 s at 100 Hz, resulting in 2000 data points
- Stroke volume = Standard deviation of these data points × conversion factor

Montenij et al. Curr Opin Anesthesiol 24:651–656

# Arterial waveform based devices

- Flo Trac sensor attaches existing arterial line and monitors advanced hemodynamic parameters
- Stroke Volume (SV)
- Stroke Volume Variation (SVV)
- Mean Arterial Pressure (MAP)
- Cardiac Output (CO)
- Systemic Vascular Resistance (SVR)

American Journal of the Medical Sciences. 2015 Apr 1;349(4):352-6

**Changes in stroke volume induced by passive leg raising in spontaneously breathing patients: comparison between echocardiography and Vigileo™/FloTrac™ device**

Matthieu Biais, Lionel Vidil, Philippe Sarrabay, Vincent Cottenceau, Philippe Revel and François Sztark

- Thirty-four patients with spontaneous breathing activity
- Measurements of stroke volume done with transthoracic echocardiography (SV-TTE) and with the VigileoTM (SV-Flotrac) in a semi-recumbent position, during Passive leg raising and after volume expansion (500 ml saline).
- Increase in SV-TTE ≥ 13% during PLR was predictive of response to volume expansion with a sensitivity of 100% and a specificity of 80%.

Critical Care. 2009 Dec;13(6):1-8.

# Flo Trac sensor and Vigileo monitoring system

- Increase in SV - Flotrac ≥ 16% during PLR was predictive of response to volume expansion with a sensitivity of 85% and a specificity of 90%
- Volume expansion-induced changes in SV-TTE correlated with volume expansion-induced changes in SV-Flotrac ($r^2 = 0.77$, $P < 0.0001$).

Critical Care. 2009 Dec;13(6):1-8.

# Aortic doppler

- Aortic Doppler - blood flow velocity in the aorta by means of a Doppler probe(esophagus (esophageal Doppler) or placed on the anterior chest wall (ie, transcutaneous Doppler)
- The CO is calculated based on the diameter of the aorta, the distribution of the CO to the descending aorta, and the measured flow velocity of blood in the aorta
- Doppler waveform is highly dependent on correct positioning, as it must be well aligned with the direction of blood flow.
- Poor positioning tends to underestimate true CO.

Critical Care Medicine. 2007 Feb 1;35(2):477-82

# Aortic doppler

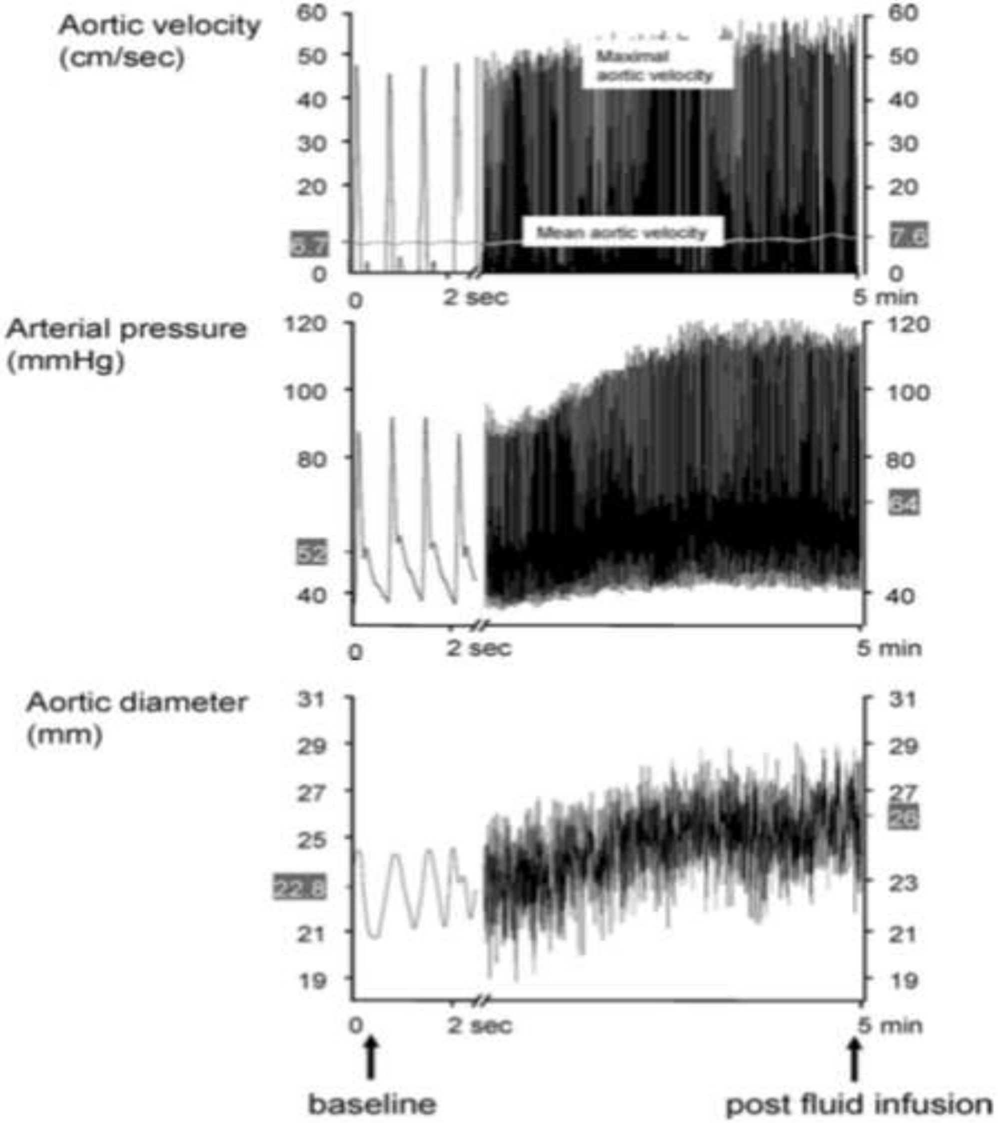
- 76 patients with acute circulatory failure
- Rapid volume expansion (500 mL of NaCl 0.9%)
- Aortic Blood Flow calculated from the values of aortic velocity and aortic diameter.
- ABF before, aortic blood flow obtained from aortic velocity and diameter measured before fluid expansion
- Estimated ABF after, aortic blood flow estimated from aortic velocity measured after fluid expansion and aortic diameter measured before fluid expansion

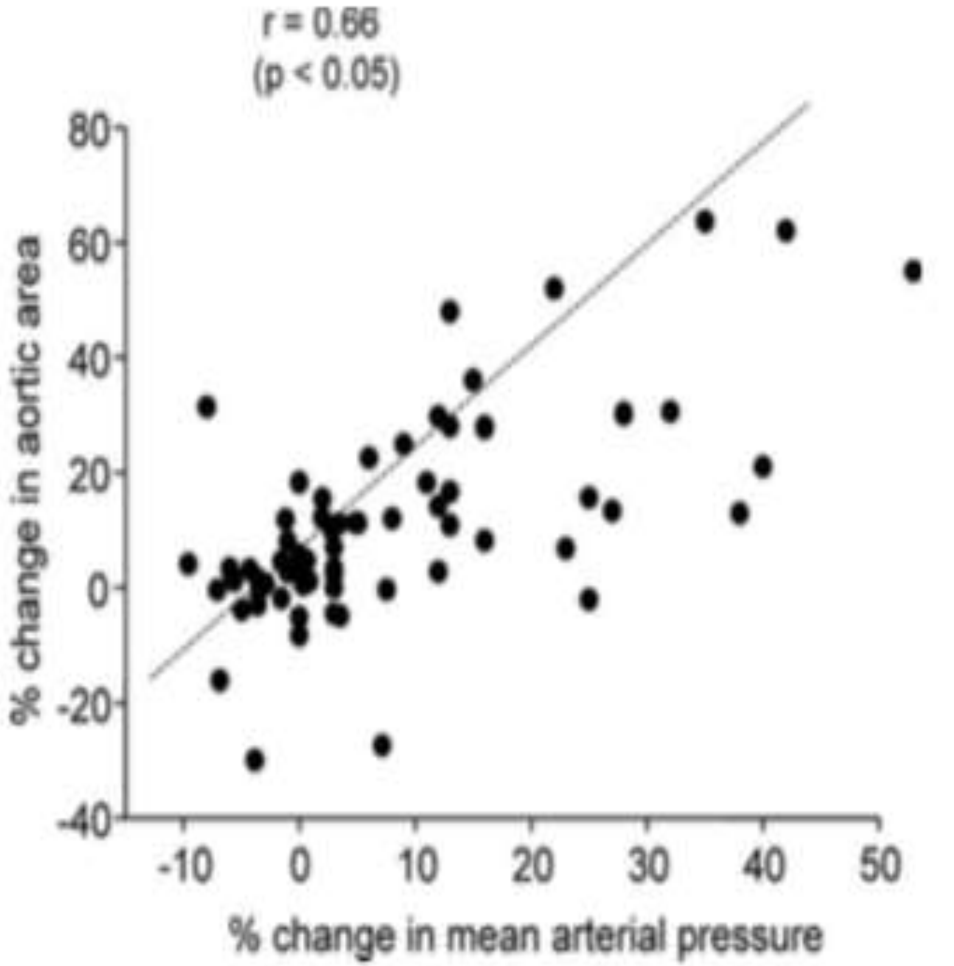
Critical Care Medicine. 2007 Feb 1;35(2):477-82

# Aortic doppler

- Measured ABF after, aortic blood flow obtained using the aortic velocity and the aortic diameter measured after fluid expansion
- Measured ABF after was used for assessing fluid response, it increased above 15% compared with ABF at baseline in 41 patients (responders)
- Estimated ABF after increased above 15% from ABF at baseline in 27 patients only

Critical Care Medicine. 2007 Feb 1;35(2):477-82



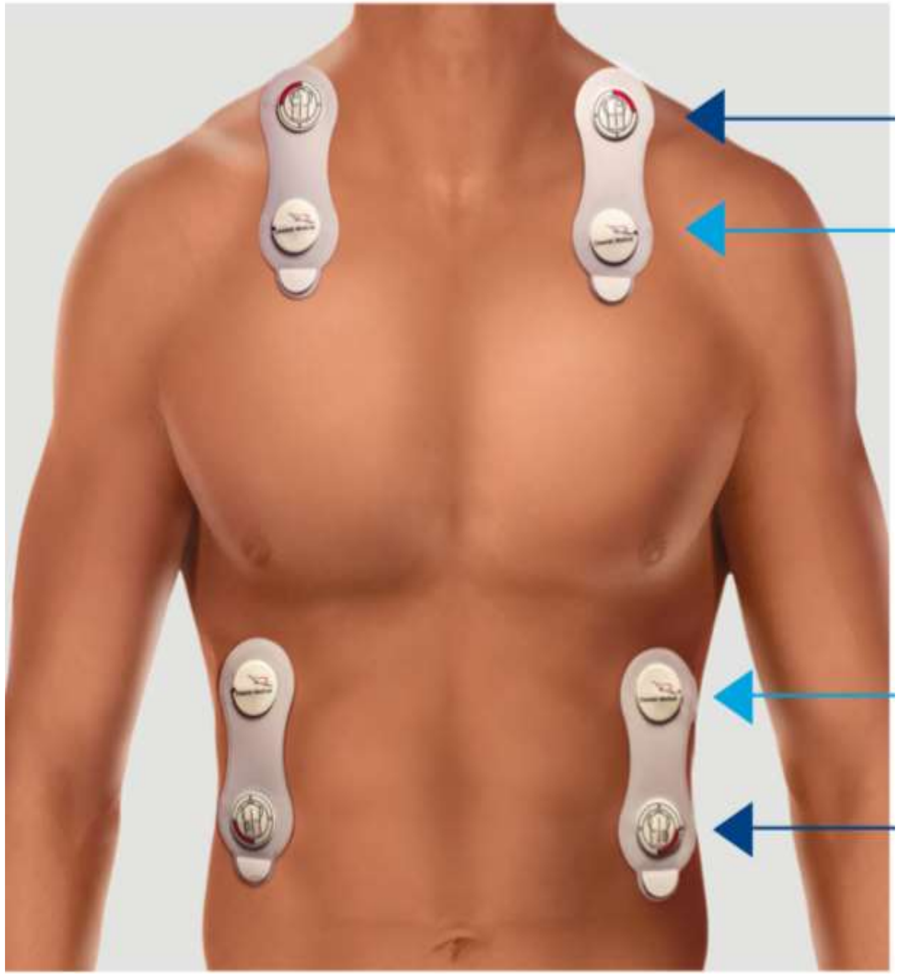

Critical Care Medicine. 2007 Feb 1;35(2):477-82

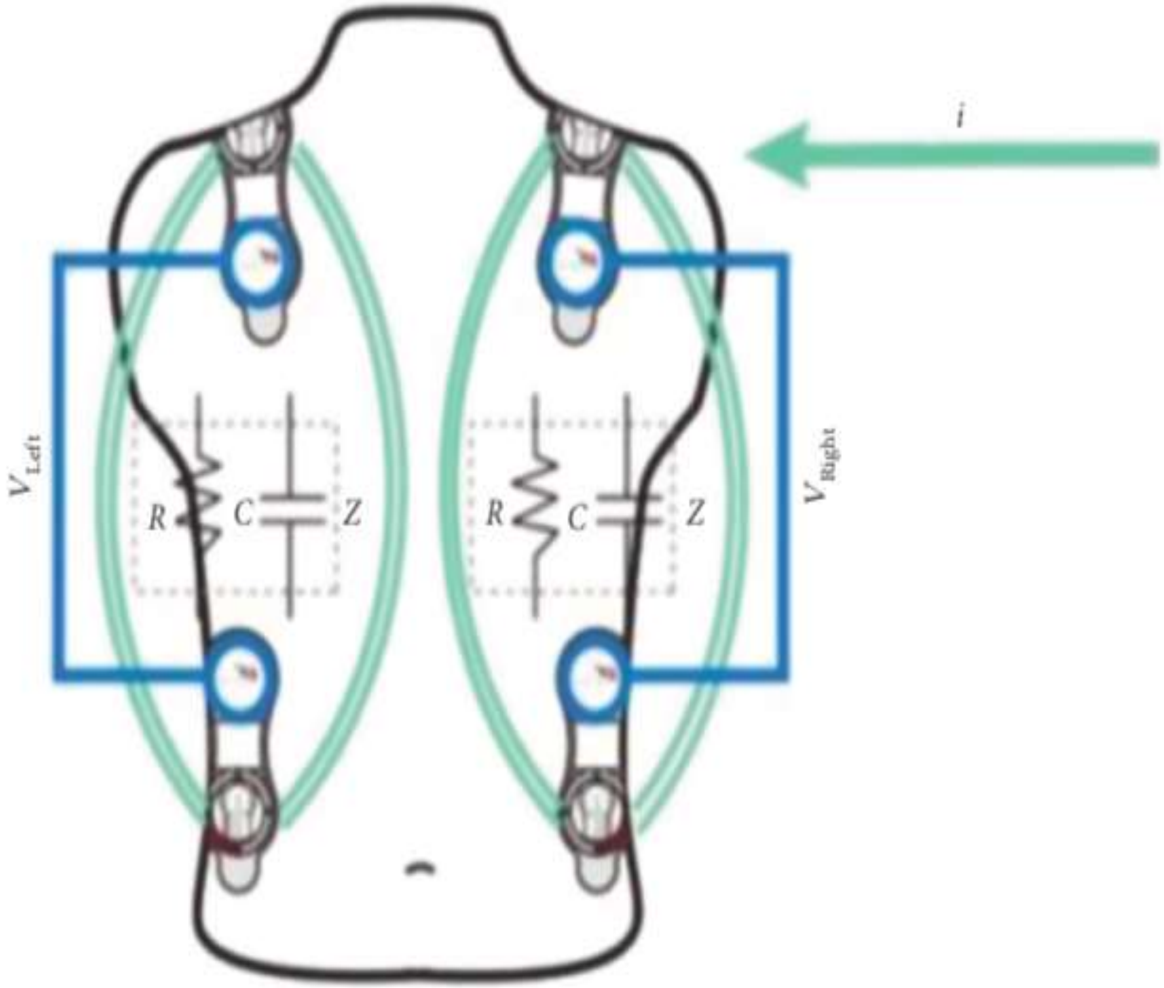
# NICCOM - Bioreactance – Baxter Cheetah

- Four non-invasive sensor pads are applied to the thorax, creating a “box” around the heart
- A small electric current is applied across the thorax between the outer pair of sensors
- A voltage signal is recorded between the inner pair of sensors
- The flow of blood in the thorax introduces a time delay or phase shift in the signal
- The monitor uses this phase shift as a baseline for stroke volume measurements

Journal of anesthesia. 2015 Jun;29(3):416-20

# Bioreactance – Baxter Cheetah



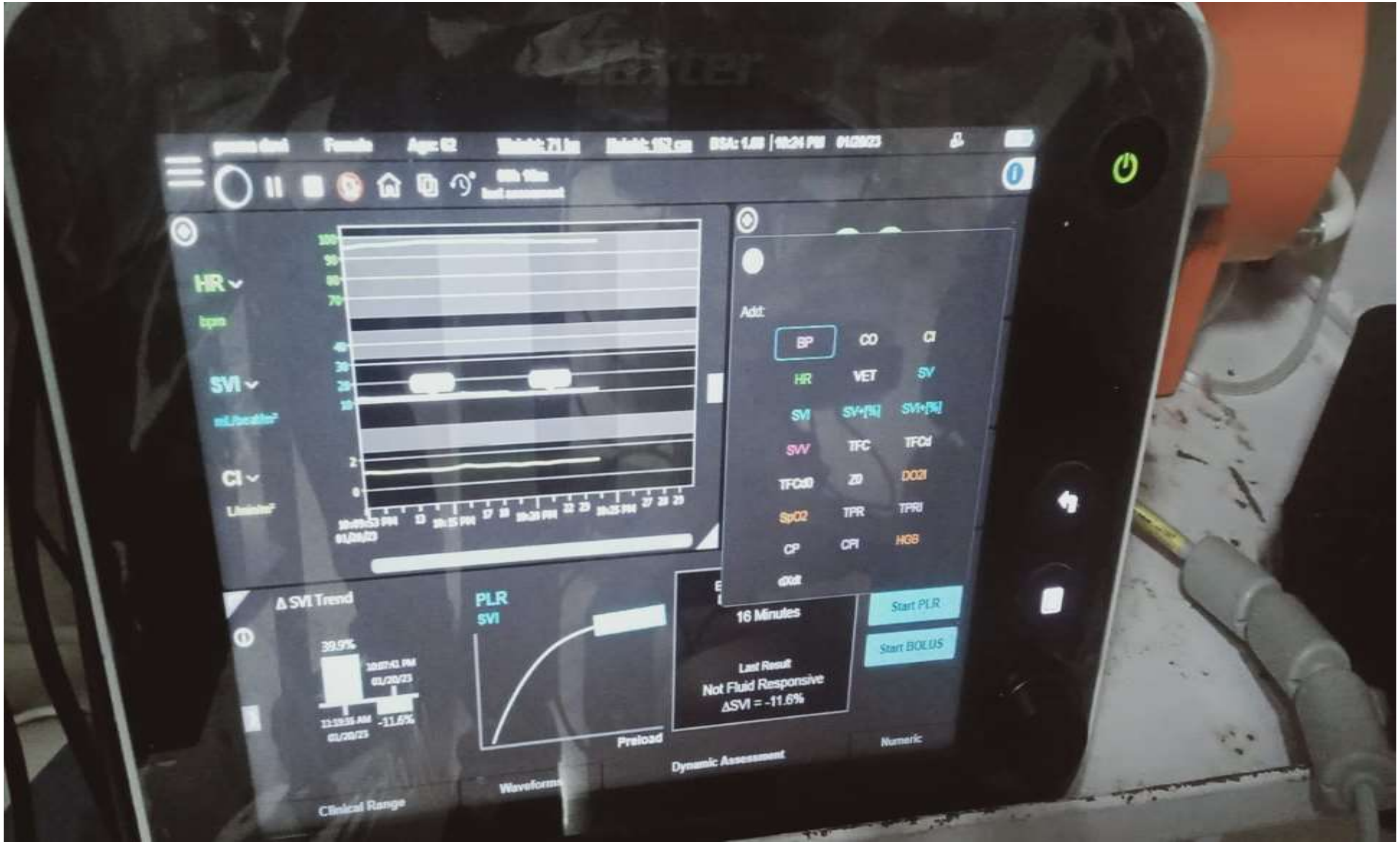



Critical Care Research and Practice. 2020 Sep 15;2020

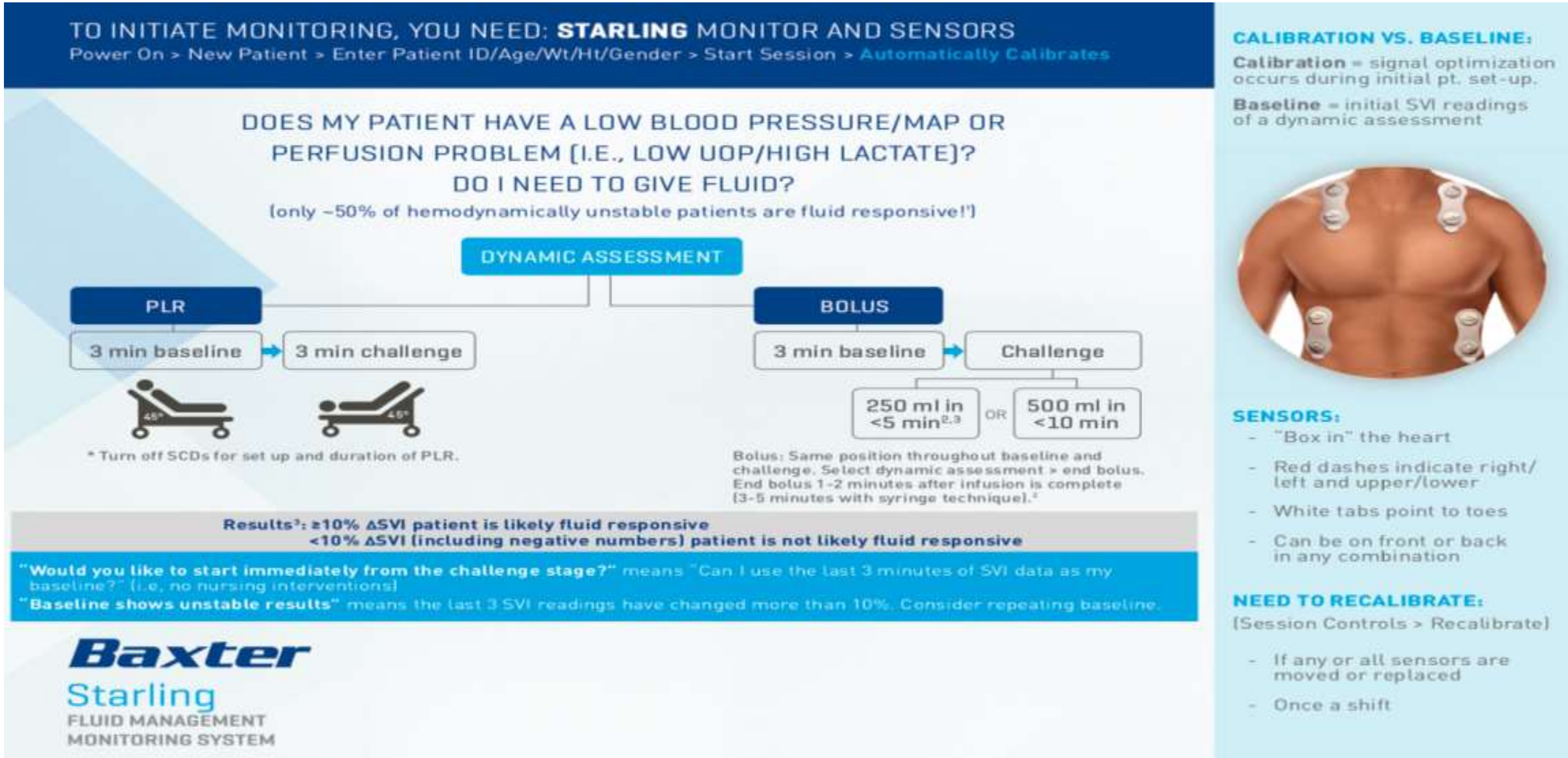
# NICCOM

- Single centre observational study
- 50 patients
- Correlation co efficient  between PCO and NCO ($r = 0.77$, $p < 0.001$)

Journal of anesthesia. 2015 Jun;29(3):416-20


Female
HR
bpm
SVI
CI
Add:
BP
CO
CI
HR
VET
SV
SVI
SVV
TFC
DO2I
SpO2
TPR
TPRI
CP
CPI
HGB
Δ SVI Trend
39.9%
-11.6%
PLR
SVI
Preload
16 Minutes
Last Result
Not Fluid Responsive
ΔSVI = -11.6%
Start PLR
Start BOLUS
Clinical Range
Waveforms
Dynamic Assessment
Numeric

# RICU - NICCOM

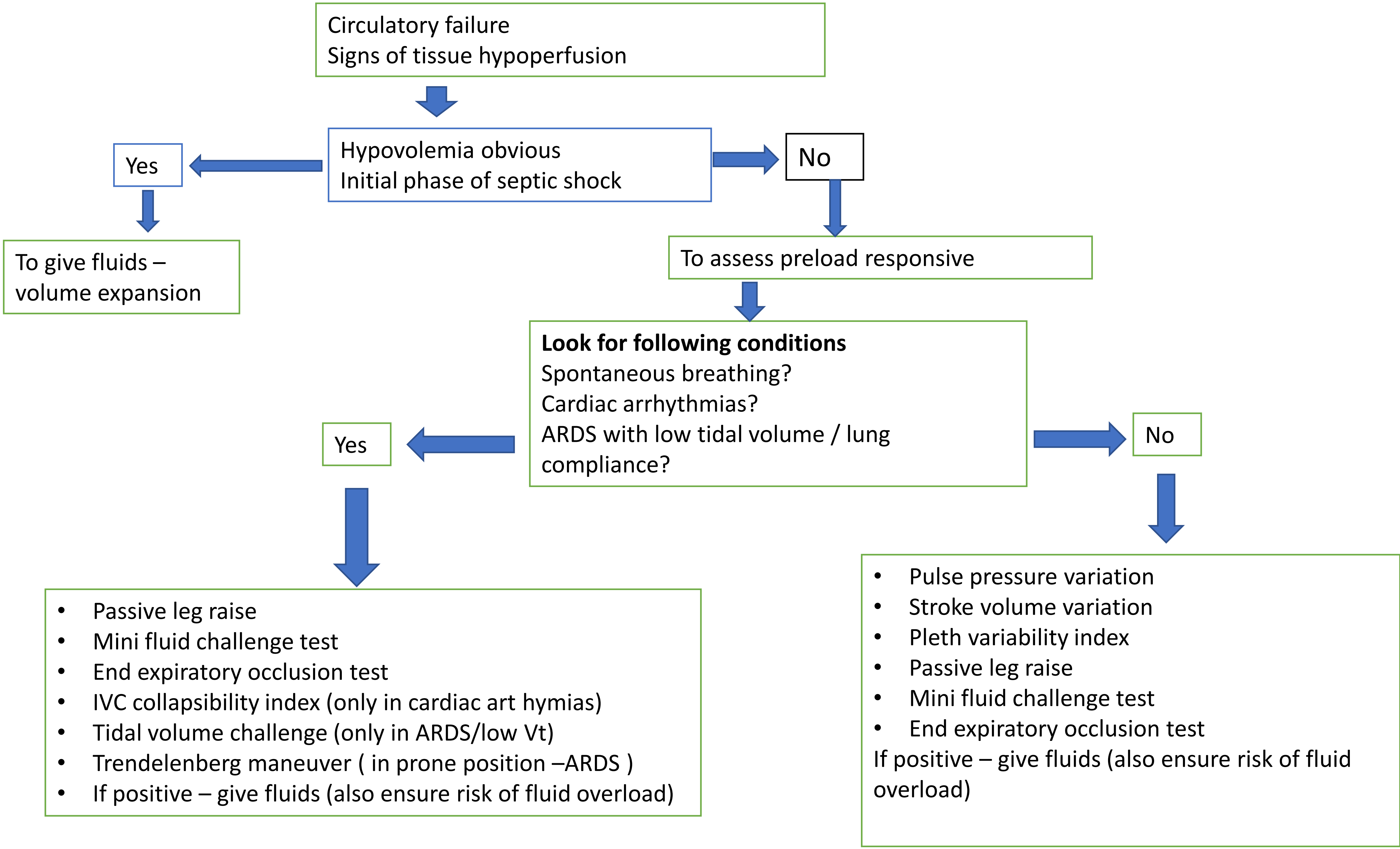


TO INITIATE MONITORING, YOU NEED: STARLING MONITOR AND SENSORS
Power On > New Patient > Enter Patient ID/Age/Wt/Ht/Gender > Start Session > Automatically Calibrates
DOES MY PATIENT HAVE A LOW BLOOD PRESSURE/MAP OR PERFUSION PROBLEM (I.E., LOW UOP/HIGH LACTATE)?
DO I NEED TO GIVE FLUID?
(only ~50% of hemodynamically unstable patients are fluid responsive!¹)
DYNAMIC ASSESSMENT
PLR
3 min baseline
3 min challenge
45°
45°
* Turn off SCDs for set up and duration of PLR.
BOLUS
3 min baseline
Challenge
250 ml in <5 min²·³
OR
500 ml in <10 min
Bolus: Same position throughout baseline and challenge. Select dynamic assessment > end bolus. End bolus 1-2 minutes after infusion is complete (3-5 minutes with syringe technique).²
Results³: ≥10% ΔSVI patient is likely fluid responsive
<10% ΔSVI (including negative numbers) patient is not likely fluid responsive
"Would you like to start immediately from the challenge stage?" means "Can I use the last 3 minutes of SVI data as my baseline?" (i.e, no nursing interventions)
"Baseline shows unstable results" means the last 3 SVI readings have changed more than 10%. Consider repeating baseline.
Baxter
Starling
FLUID MANAGEMENT MONITORING SYSTEM
CALIBRATION VS. BASELINE:
Calibration = signal optimization occurs during initial pt. set-up.
Baseline = initial SVI readings of a dynamic assessment
SENSORS:
- "Box in" the heart
- Red dashes indicate right/left and upper/lower
- White tabs point to toes
- Can be on front or back in any combination
NEED TO RECALIBRATE:
(Session Controls > Recalibrate)
- If any or all sensors are moved or replaced
- Once a shift

# RICU - NICCOM

| Parameters | Normal Adult Range[13] | Cardiogenic Shock | Septic Shock | Hypovolemic Shock |
|---|---|---|---|---|
| BP (MAP) | > 65 | ↓ | ↓ | ↓ |
| Heart Rate (HR) | 60-100 | ↑ | ↑ | ↑ |
| Cardiac Index (CI) | 2.5–4.0 L/min/$m^2$ | ↓ | early late ↑↓ | early late ↑↓ |
| Total Peripheral Resistance Index (TPRI) | 1970–2390 dynes • sec/$cm^5$/$m^2$ | ↑ | ↓ | ↓ |
| Common Stroke Volume Response (ΔSVI) to Dynamic Assessment | | ΔSVI <10% | ΔSVI ≥10% | ΔSVI ≥10% |
| ΔSVI ≥10% Predictive of 15% increase in CO with 500cc[14] | | | | |
| **Dynamic Assessments Directly Challenge the Heart with Volume to Measure its Response:** Passive Leg Raise (PLR) Maneuver — Translocation of 250-300cc of blood from lower extremities into the heart[3] • Fluid Bolus Challenge (FB) — Rapid Infusion of 250cc of fluid over 3-5 minutes[3] | | | | |

| Parameters | Equation | Normal adult range |
|---|---|---|
| Stroke Volume (SV) | CO/HR x 1000 | 60 – 100 mL/beat |
| Stroke Volume Index (SVI) | SV/BSA | 33 – 47 mL/beat/$m^2$ |
| Δ Stroke Volume Index (ΔSVI) | Change in SV after Dynamic Assessment | ≥10% Likely to be Fluid Responsive[3]<br><10% Unlikely to be Fluid Responsive[3] |
| Cardiac Output (CO) | HR x SV/1000 | 4.0 – 8.0 L/min |
| Cardiac Index (CI) | CO/BSA | 2.5 – 4.0 L/min/$m^2$ |
| Mean Arterial Pressure (MAP) | (SBP + (2 x DBP))/3 | 70 – 105 mmHg |
| Total Peripheral Resistance (TPR) | 80 x (MAP)/CO | 800 – 1200 dynes • sec/$cm^5$ |
| Total Peripheral Resistance Index (TPRI) | 80 x (MAP)/CI | 1970 – 2390 dynes • sec/$cm^5$/$m^2$ |
| ΔSVI ≥10% Predictive of 15% increase in CO with 500cc[14] | | |
| **Dynamic Assessments Directly Challenge the Heart with Volume to Measure its Response:** Passive Leg Raise (PLR) Maneuver — Translocation of 250-300cc of blood from lower extremities into the heart[3] • Fluid Bolus Challenge (FB) — Rapid Infusion of 250cc of fluid over 3-5 minutes[2] | | |


Circulatory failure
Signs of tissue hypoperfusion
Hypovolemia obvious
Initial phase of septic shock
Yes
No
To give fluids – volume expansion
To assess preload responsive
Look for following conditions
Spontaneous breathing?
Cardiac arrhythmias?
ARDS with low tidal volume / lung compliance?
Yes
No
• Passive leg raise
• Mini fluid challenge test
• End expiratory occlusion test
• IVC collapsibility index (only in cardiac art hymias)
• Tidal volume challenge (only in ARDS/low Vt)
• Trendelenberg maneuver ( in prone position –ARDS )
• If positive – give fluids (also ensure risk of fluid overload)
• Pulse pressure variation
• Stroke volume variation
• Pleth variability index
• Passive leg raise
• Mini fluid challenge test
• End expiratory occlusion test
If positive – give fluids (also ensure risk of fluid overload)