Assessment of fluid responsiveness

Prof. Jean-Louis TEBOUL

Medical ICU
Bicetre hospital
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France
Conflicts of interest

Member of the Medical Advisory Board of Pulsion
# Predicting Fluid Responsiveness in ICU Patients

**A Critical Analysis of the Evidence**

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

*CHEST 2002, 121:2000-8*

<table>
<thead>
<tr>
<th>Source</th>
<th>Patients, No.</th>
<th>FC, No.</th>
<th>Fluid Infused</th>
<th>Volume Infused, mL</th>
<th>Speed of FC, min</th>
<th>Definition of Response</th>
<th>Rate of Response, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calvin et al²</td>
<td>28</td>
<td>28</td>
<td>5% Alb</td>
<td>250</td>
<td>20–30</td>
<td>ΔSV &gt; 0%</td>
<td>71</td>
</tr>
<tr>
<td>Schneider et al³</td>
<td>18</td>
<td>18</td>
<td>FFP</td>
<td>500</td>
<td>30</td>
<td>ΔSV &gt; 0%</td>
<td>72</td>
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<tr>
<td>Reuse et al⁴</td>
<td>41</td>
<td>41</td>
<td>4.5% Alb</td>
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<td>30</td>
<td>ΔCO &gt; 0%</td>
<td>63</td>
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<tr>
<td>Magder et al⁵</td>
<td>33</td>
<td>33</td>
<td>9% NaCl</td>
<td>100–950</td>
<td></td>
<td>ΔCO &gt; 250 mL/min</td>
<td>52</td>
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<tr>
<td>Diebel et al⁶</td>
<td>15</td>
<td>22</td>
<td>R. lactate</td>
<td>300–500</td>
<td></td>
<td>ΔCO &gt; 10%</td>
<td>59</td>
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<tr>
<td></td>
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<td>Colloids</td>
<td>500</td>
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<tr>
<td>Diebel et al⁷</td>
<td>32</td>
<td>65</td>
<td>R. lactate</td>
<td>300–500</td>
<td></td>
<td>ΔCO &gt; 20%</td>
<td>40</td>
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<tr>
<td>Wagner and Leatherman⁸</td>
<td>25</td>
<td>36</td>
<td>9% NaCl</td>
<td>938 ± 480</td>
<td>7–120</td>
<td>ΔSV &gt; 10%</td>
<td>56</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>5% Alb, FFP</td>
<td>574 ± 187</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Tavernier et al⁹</td>
<td>15</td>
<td>35</td>
<td>HES</td>
<td>500</td>
<td>30</td>
<td>ΔSV &gt; 15%</td>
<td>60</td>
</tr>
<tr>
<td>Magder and Lagonidis¹⁰</td>
<td>29</td>
<td>29</td>
<td>25% Alb</td>
<td>100</td>
<td>15</td>
<td>ΔCO &gt; 250 mL/min</td>
<td>45</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>9% NaCl</td>
<td>150–400</td>
<td></td>
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</tr>
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<td>Tousignant et al¹¹</td>
<td>40</td>
<td>40</td>
<td>HES</td>
<td>500</td>
<td>15</td>
<td>ΔSV &gt; 20%</td>
<td>40</td>
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<tr>
<td>Michard et al¹²</td>
<td>40</td>
<td>40</td>
<td>HES</td>
<td>500</td>
<td>30</td>
<td>ΔCO &gt; 15%</td>
<td>40</td>
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<tr>
<td>Feissel et al¹³</td>
<td>19</td>
<td>19</td>
<td>HES</td>
<td>8 mL/kg</td>
<td>30</td>
<td>ΔCO &gt; 15%</td>
<td>53</td>
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<td><strong>Total</strong></td>
<td><strong>334</strong></td>
<td><strong>406</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>52</strong></td>
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</tbody>
</table>
Fluid infusion will increase LV stroke volume only if both ventricles have preload reserve (or are preload responsive).

Fluid responsiveness equivalent to biventricular preload responsiveness.
normal heart

```
« static » measures of preload
cannot reliably predict
preload responsiveness
```

Ventricular preload

Stroke volume
neither baseline PAOP nor baseline CVP predicted volume responsiveness
Dynamic indices of preload responsiveness

Stroke volume

Ventricular preload

Preload responsiveness

Preload unresponsiveness

Failing heart
Dynamic indices of preload responsiveness

Respiratory variability of stroke volume
or its surrogates

Passive leg raising

End-expiratory occlusion test
Mechanical insufflation

RV filling

RV stroke volume
at inspiration

LV filling
2-3 heart beats later
(at expiration)

LV stroke volume
at expiration

* if RV preload responsive

** if LV preload responsive
MV induces **cyclic changes in SV** only in pts with **biventricular preload responsiveness**

**fluid responsiveness** occurs only in pts with **biventricular preload responsiveness**

Correlates with the magnitude of the induced by
How to assess LV stroke volume variability?

- arterial pressure variation (arterial catheter)
- pulse pressure variation (PPV)
Pulse Pressure Variation

\[
Pulse \ Pressure \ = \ k \cdot \ stroke \ volume \ arterial \ compliance
\]

The respiratory changes in arterial pulse pressure should reflect the respiratory changes in LV stroke volume.

Pulse pressure variation should predict fluid responsiveness.
Ventricular preload

Stroke volume

preload responsiveness

preload unresponsiveness

A

B

Ventricular preload
Clinical Use of Respiratory Changes in Arterial Pulse Pressure to Monitor the Hemodynamic Effects of PEEP
FRÉDÉRIC MICHAUD, DENIS CHEMLA, CHRISTIAN RICHARD, MARC WYSOCKI, MICHAEL R. PINsky, YVES LECARPENTIER, and JEAN-LOUIS TEBOUL
AM J RESPIR CRIT CARE MED 1999;159:935-939

Relation between Respiratory Changes in Arterial Pulse Pressure and Fluid Responsiveness in Septic Patients with Acute Circulatory Failure
FRÉDÉRIC MICHAUD, SANDRINE BOUSSAT, DENIS CHEMLA, NADIA ANGUEL, ALAIN MERCAT, YVES LECARPENTIER, CHRISTIAN RICHARD, MICHAEL R. PINSKY, and JEAN-LOUIS TEBOUL
Am J Respir Crit Care Med 2000; 162:134-8

PPV = \( \frac{PP_{\text{max}} - PP_{\text{min}}}{(PP_{\text{max}} + PP_{\text{min}})/2} \)
Relation between Respiratory Changes in Arterial Pulse Pressure and Fluid Responsiveness in Septic Patients with Acute Circulatory Failure

FRÉDÉRIC MICHAUD, SANDRINE BOUSSAT, DENIS CHEMLA, NADIA ANGUEL, ALAIN MERCAT, YVES LECARPENTIER, CHRISTIAN RICHARD, MICHAEL R. PINSKY, and JEAN-LOUIS TBOUL

Am J Respir Crit Care Med 2000; 162:134-8
Relation between Respiratory Changes in Arterial Pulse Pressure and Fluid Responsiveness in Septic Patients with Acute Circulatory Failure

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Am J Respir Crit Care Med 2000; 162:134-8
# Volume responsiveness

Xavier Monnet and Jean-Louis Teboul

*Current Opinion in Critical Care* 2007, 13:549–553

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## Table 1: Studies that have investigated the arterial pulse pressure variation (PPV) for predicting volume responsiveness and the respective threshold value for diagnosis

<table>
<thead>
<tr>
<th>Reference</th>
<th>Year of publication</th>
<th>Clinical setting</th>
<th>PPV threshold value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Michard <em>et al.</em> [22]</td>
<td>2000</td>
<td>Medical ICU patients</td>
<td>13</td>
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<tr>
<td>Vieillard-Baron <em>et al.</em> [20]</td>
<td>2004</td>
<td>Medical ICU patients</td>
<td>12</td>
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<tr>
<td>Kramer <em>et al.</em> [23]</td>
<td>2004</td>
<td>Coronary artery bypass grafting</td>
<td>11</td>
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<tr>
<td>Preisman <em>et al.</em> [19]</td>
<td>2005</td>
<td>Coronary artery bypass grafting</td>
<td>9</td>
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<tr>
<td>Feissel <em>et al.</em> [24]</td>
<td>2005</td>
<td>Mix of surgical and medical ICU patients</td>
<td>17</td>
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<tr>
<td>Solus-Biguenet <em>et al.</em> [10*]</td>
<td>2006</td>
<td>Hepatic resection</td>
<td>14</td>
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<tr>
<td>Laffernière <em>et al.</em> [17*]</td>
<td>2006</td>
<td>Medical ICU patients</td>
<td>12</td>
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<tr>
<td>Monnet <em>et al.</em> [18**]</td>
<td>2006</td>
<td>Medical ICU patients</td>
<td>12</td>
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<tr>
<td>Charron <em>et al.</em> [26]</td>
<td>2006</td>
<td>Surgical ICU patients</td>
<td>10</td>
</tr>
<tr>
<td>Natalini <em>et al.</em> [27*]</td>
<td>2006</td>
<td>Mix of surgical and medical ICU patients</td>
<td>15</td>
</tr>
<tr>
<td>Feissel <em>et al.</em> [30*]</td>
<td>2007</td>
<td>Medical ICU patients</td>
<td>12</td>
</tr>
<tr>
<td>Cannesson <em>et al.</em> [31*]</td>
<td>2007</td>
<td>Coronary artery bypass grafting</td>
<td>11</td>
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</tbody>
</table>
Calculated automatically and displayed in real-time by new hemodynamic monitors
How to assess LV stroke volume variability?

- arterial pressure variation (arterial catheter)
- stroke volume variation using arterial pressure waveform analysis

Arterial pressure waveform analysis  ➔ Stroke volume
Calculated automatically and displayed in real-time by new hemodynamic monitors
Stroke Volume Variation as a Predictor of Fluid Responsiveness in Patients Undergoing Brain Surgery

Haim Berkenstadt, MD*, Nevo Margalit, MD†, Moshe Hadani, MD†, Zeev Friedman, MD*, Eran Segal, MD*, Yael Villa, PhD*, and Azriel Perel, MD*

Anesth Analg 2001;92:984–9

sensitivity = 79 %
specificity = 93 %
Assessment of stroke volume variation for prediction of fluid responsiveness using the modified FloTrac™ and PiCCOplus™ system

Christoph K Hofer¹, Alban Senn², Luc Weibel¹ and Andreas Zollinger¹

Critical Care 2008, 12:R82

Stroke Volume Variation in Morbidly Obese Patients Undergoing Laparoscopic Bariatric Surgery

Anil Kumar Jain • Amitabh Dutta


Stoke volume variations for assessment of cardiac responsiveness to volume loading in mechanically ventilated patients after cardiac surgery

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; Ayni Hirani, MD

Crit Care Med 2009; 37:2642–2647

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>n</th>
<th>Patient</th>
<th>SPV</th>
<th>PPV</th>
<th>SVV</th>
<th>Fluid Challenge</th>
<th>TV (mL/kg)</th>
<th>Device</th>
<th>Cardiac End Point</th>
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<td>Tavernier (31)</td>
<td>1998</td>
<td>15</td>
<td>ICU-sepsis</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>500 mL HES</td>
<td>8–11</td>
<td>PAC</td>
<td>SVI</td>
</tr>
<tr>
<td>Michard (32)</td>
<td>1999</td>
<td>14</td>
<td>ICU-ARDS</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>10 PEEPc</td>
<td>7–12</td>
<td>PAC</td>
<td>CI</td>
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<td>Michard (33)</td>
<td>2000</td>
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<td>ICU-sepsis</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>500 mL HES</td>
<td>8–12</td>
<td>PAC</td>
<td>CI</td>
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<td>Berkenstadt (34)</td>
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<td>15</td>
<td>Neurosurg⁷</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>100 mL HES⁶</td>
<td>—</td>
<td>PiCCO®</td>
<td>SVI</td>
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<td>Reuter (35)</td>
<td>2002</td>
<td>20</td>
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<td>N</td>
<td>Y</td>
<td>20 mL × BMI gelatin</td>
<td>—</td>
<td>PiCCO</td>
<td>SVI</td>
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<td>Reuter (36)</td>
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<td>N</td>
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<td>Y</td>
<td>20 mL × BMI gelatin</td>
<td>13–15</td>
<td>PiCCO</td>
<td>CI</td>
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<td>Reuter (37)</td>
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<td>N</td>
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<td>Y</td>
<td>10 mL × BMI HES⁶</td>
<td>10</td>
<td>PiCCO</td>
<td>SVI</td>
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<td>Bendjellid (38)</td>
<td>2004</td>
<td>16</td>
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<td>Y</td>
<td>N</td>
<td>10 PEEPc</td>
<td>8–10</td>
<td>PAC</td>
<td>SVI</td>
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<td>Y</td>
<td>N</td>
<td>N</td>
<td>Trendelenburg</td>
<td>8</td>
<td>PiCCO</td>
<td>SVI</td>
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<td>Kramer (40)</td>
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<td>Y</td>
<td>N</td>
<td>500 mL blood</td>
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<td>PAC</td>
<td>CO</td>
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<td>500 mL HES</td>
<td>8–10</td>
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<td>Y</td>
<td>10 mL/kg HES</td>
<td>10</td>
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<td>SVI</td>
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<td>Preissman (43)</td>
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<td>Y</td>
<td>Y</td>
<td>PCV</td>
<td>—</td>
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<td>SVI</td>
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<td>Y</td>
<td>N</td>
<td>8–10</td>
<td>PAC</td>
<td>CI</td>
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<td>7</td>
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<td>TTE</td>
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<td>Solus-Biguenet (47)</td>
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<td>SV</td>
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<td>500 mL HES</td>
<td>8</td>
<td>PAC</td>
<td>CI</td>
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<td>Wyfels (50)</td>
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<td>32</td>
<td>Post C.Surg</td>
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<td>Y</td>
<td>N</td>
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<td>8–10</td>
<td>PAC</td>
<td>CI</td>
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<td>Feissel (51)</td>
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<td>23</td>
<td>ICU-sepsis</td>
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<td>Y</td>
<td>N</td>
<td>8 mL/kg HES</td>
<td>8–10</td>
<td>TEE</td>
<td>CI</td>
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<td>Lee (52)</td>
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<td>8–10</td>
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<td>25</td>
<td>C.Surg⁷</td>
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<td>Y</td>
<td>N</td>
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<td>8–10</td>
<td>PAC</td>
<td>CI</td>
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<td>Cannesson (54)</td>
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<td>25</td>
<td>C.Surg⁷</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>500 mL HES</td>
<td>8–10</td>
<td>PAC</td>
<td>CI</td>
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<td>Atler (55)</td>
<td>2008</td>
<td>59</td>
<td>Post C.Surg</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>20 mL/kg LR</td>
<td>8</td>
<td>PAC</td>
<td>CO</td>
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<td>Belloni (56)</td>
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<td>19</td>
<td>C.Surg⁷</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>7 mL/kg HES</td>
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<td>LiDCO®/PAC</td>
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<td>Cannesson (57)</td>
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<td>25</td>
<td>C.Surg⁷</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>500 mL HES</td>
<td>8–10</td>
<td>PAC</td>
<td>CI</td>
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<tr>
<td>Hofer (58)</td>
<td>2008</td>
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<td>Post CABG</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Trendelenburg</td>
<td>8–10</td>
<td>FloTrac®/PiCCO</td>
<td>SV</td>
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<td>Biasi (59)</td>
<td>2008</td>
<td>35</td>
<td>Liver transplant</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Albumin 20 mL × BMI</td>
<td>8–10</td>
<td>FloTrac/TEE</td>
<td>CO</td>
</tr>
</tbody>
</table>

Note: SPV, PPV, and SVV stand for systolic pressure variability, pulse pressure variability, and systolic volume variability, respectively. TV (mL/kg) refers to the tidal volume in milliliters per kilogram.
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; Tajander Vasu, MD; Amyn Hirani, MD

Crit Care Med 2009; 37:2642–2647

AUC

PPV

0.94 (0.93–0.95)

Average cut-off: 12.5%
How to assess LV stroke volume variability?

- arterial pressure variation (arterial catheter)
- stroke volume variation using arterial pressure waveform analysis
- aortic blood velocity variation
- conventional echocardiography
Respiratory Changes in Aortic Blood Velocity as an Indicator of Fluid Responsiveness in Ventilated Patients With Septic Shock*

Marc Feissel, MD; Frédéric Michard, MD; Isabelle Mangin, MD; Olivier Buye, MD; Jean-Pierre Faller, MD; and Jean-Louis Teboul, MD, PhD

CHEST 2001; 119:867–873

\[ \Delta V_{\text{peak}} = \frac{V_{\text{peak max}} - V_{\text{peak min}}}{(V_{\text{peak max}} + V_{\text{peak min}}) / 2} \]
How to assess LV stroke volume variability?

- arterial pressure variation (arterial catheter)
- stroke volume variation using arterial pressure waveform analysis
- aortic blood velocity variation
- conventional echocardiography
- esophageal doppler monitoring device
Esophageal Doppler monitoring predicts fluid responsiveness in critically ill ventilated patients

\[ \Delta \text{ABF} \% = \frac{\text{ABF}_{\text{max}} - \text{ABF}_{\text{min}}}{(\text{ABF}_{\text{max}} + \text{ABF}_{\text{min}})/2} \]
How to assess LV stroke volume variability?

- arterial pressure variation (arterial catheter)
- stroke volume variation using arterial pressure waveform analysis
- aortic blood velocity variation
  - conventional echocardiography
  - esophageal doppler monitoring device
- vena cava diameter variation
The respiratory variation in inferior vena cava diameter as a guide to fluid therapy

\[ \Delta \text{dIVC} \% = \frac{\text{dIVC}_{\text{max}} - \text{dIVC}_{\text{min}}}{(\text{dIVC}_{\text{max}} + \text{dIVC}_{\text{min}})/2} \]
How to assess LV stroke volume variability?

- arterial pressure variation (arterial catheter)
- stroke volume variation using arterial pressure waveform analysis
- aortic blood velocity variation
  - conventional echocardiography
  - esophageal doppler monitoring device
- vena cava diameter variation
- pulse oxymetry wave variation
Arterial Versus Plethysmographic Dynamic Indices to Test Responsiveness for Testing Fluid Administration in Hypotensive Patients: A Clinical Trial

Giusepoe Natalini, Antonio Rosano, Maria Taranto, Barbara Faggian, Elena Vittorielli, Achille Bernardini.

Anesth Anaalg 2006;103:1478–84

Cut-off values:

- PPV: 15 %
- $\Delta P_{pleth}$: 15 %
Plethysmographic dynamic indices predict fluid responsiveness in septic ventilated patients
Pleth variability index to monitor the respiratory variations in the pulse oximeter plethysmographic waveform amplitude and predict fluid responsiveness in the operating theatre

M. Cannesson¹, O. Desebbe¹, P. Rosamel¹, B. Delannoy¹, J. Robin², O. Bastien¹ and J.-J. Lehot¹

<table>
<thead>
<tr>
<th>Area under the curve</th>
<th>Cutoff</th>
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<tbody>
<tr>
<td>ΔPP</td>
<td>0.938</td>
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<tr>
<td>ΔPOP</td>
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<tr>
<td>PPV</td>
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<tr>
<td>PVI</td>
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<td>CVP</td>
<td>0.417</td>
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<td>PCWP</td>
<td>0.396</td>
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</table>
Do patients benefit from the use of these respiratory variability indices?
Goal-directed fluid management based on pulse pressure variation monitoring during high-risk surgery: a pilot randomized controlled trial
Marcel R Lopes¹, Marcos A Oliveira¹, Vanessa Oliveira S Pereira¹, Ivaneide Paula B Lemos¹, Jose Otavio C Auler Jr² and Frédéric Michard³

Critical Care 2007, 11:R100

Fluid administration

Institution’s standard of care

1,694 ± 705 mL

Fluid administration

Goal:

PPV <10%
Goal-directed fluid management based on pulse pressure variation monitoring during high-risk surgery: a pilot randomized controlled trial

Marcel R Lopes¹, Marcos A Oliveira¹, Vanessa Oliveira S Pereira¹, Ivaneide Paula B Lemos¹, Jose Otavio C Auler Jr² and Frédéric Michard³

Critical Care 2007, 11:R100
Volume responsiveness is a physiological phenomenon related to a normal preload reserve.

Therefore, detecting volume responsiveness must not lead to infuse fluid systematically.

The decision of fluid infusion must be based on the presence of criteria of peripheral hypoperfusion.
Limitations of respiratory variability indices

- impossible to interpret in pts with spontaneous breathing activity
- impossible to interpret in patients with arrhythmias

In all these situations and in case of any doubt about interpretation, other reliable dynamic tests are required... and are now available

- difficult to interpret in case of severe RV failure
Dynamic indices of preload responsiveness

Respiratory variability of stroke volume
or its surrogates

Passive leg raising

End-expiratory occlusion test
passive ... not active!!
PLR mimics fluid challenge

Unlike fluid challenge, no fluid is infused, and, the effects are reversible and transient.
Ventricular preload

Stroke Volume

Preload unresponsiveness

PLR Preload responsiveness

Passive leg raising
Real-time CO response to PLR

The hemodynamic response to PLR can predict the hemodynamic response to fluid infusion.

Passive leg raising predicts fluid responsiveness in the critically ill*
Xavier Monnet, MD, PhD; Mario Rienzo, MD; David Osman, MD; Nadia Anguel, MD; Christian Richard, MD; Michael R. Pinsky, MD, Dr hc; Jean-Louis Téboul, MD, PhD
Crit Care Med 2006; 34:1402–1407

Changes in aortic blood flow induced by passive leg raising predict fluid responsiveness in critically ill patients
A Lafanechère, F Pène, C Goulenok, A Delahaye, V Mallet, G Choukroun, JD Chiche, JP Mira and A Cariou
Critical Care 2006, 10:R132
Passive leg raising predicts fluid responsiveness in the critically ill™

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

Crit Care Med 2006; 34:1402–1407
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Crit Care Med 2006; 34:1402–1407

PLR-induced change in **aortic blood flow**

**good prediction**

of **volume responsiveness**

- sensitivity: 97%
- specificity: 94%
The hemodynamic response to PLR can predict the hemodynamic response to fluid infusion.

Real-time CO response to PLR
Echocardiographic prediction of volume responsiveness in critically ill patients with spontaneously breathing activity
Echocardiographic prediction of volume responsiveness in critically ill patients with spontaneously breathing activity

PLR-induced change in Velocity-Time Integral

- good prediction of volume responsiveness

24 pts with circulatory failure and SB TTE before and after 500 mL saline PLR-induced change in Velocity-Time Integral

VTI

12%
The hemodynamic response to PLR can predict the hemodynamic response to fluid infusion.

Real-time CO response to PLR

Non-invasive stroke volume measurement and passive leg raising predict volume responsiveness in medical ICU patients: an observational cohort study
Steven W Thiel, Marin H Kollef and Warren Isakow

Critical Care 2009, 13:R111
The hemodynamic response to PLR can predict the hemodynamic response to fluid infusion.

Real-time CO response to PLR

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

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

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

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The hemodynamic response to **PLR** can predict the hemodynamic response to **fluid infusion**.

**Real-time CO response to PLR**

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

Matthieu Blais, Lionel Vidi, Philippe Sarrabay, Vincent Cottenceau, Philippe Revel and François Sztark

*Critical Care* 2009, 13:R195
<table>
<thead>
<tr>
<th>Study name</th>
<th>sample size</th>
<th>AUC</th>
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<tbody>
<tr>
<td>Monnet CCM 2006</td>
<td>71</td>
<td>0.96</td>
</tr>
<tr>
<td>Lafanéchère CC 2006</td>
<td>22</td>
<td>0.95</td>
</tr>
<tr>
<td>Lamia ICM 2007</td>
<td>24</td>
<td>0.96</td>
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<td>Maizel ICM 2007</td>
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<td>0.89</td>
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<tr>
<td>Monnet CCM 2009</td>
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<td>Thiel CC 2009</td>
<td>102</td>
<td>0.89</td>
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<tr>
<td>Biais CC 2009</td>
<td>30</td>
<td>0.96</td>
</tr>
<tr>
<td>Preau CCM 2010</td>
<td>34</td>
<td>0.94</td>
</tr>
</tbody>
</table>

**PLR-induced changes in CO**

**Figure:** SROC Curve

**Text:**

Diagnostic accuracy of passive leg raising for prediction of fluid responsiveness in adults: systematic review and meta-analysis of clinical studies.
Dynamic indices of preload responsiveness

Respiratory variability of stroke volume or its surrogates

Passive leg raising

End-expiratory occlusion test
**Hypothesis**

Fluid responders should be identified by an increase of their CO during the end-expiration occlusion test.

*Transient increase* in preload and thus in CO in preload-responsive patients.

*Cyclic decrease* in preload.
Predicting volume responsiveness by using the end-expiratory occlusion in mechanically ventilated intensive care unit patients

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

Fluid responsiveness can be reliably predicted by assessing (more or less invasively) the variability of stroke volume (or of its surrogates).

In cases of spontaneous breathing activity and/or arrhythmias, and/or low tidal volume passive leg raising and/or end-expiratory occlusion tests are good alternatives.