Shock Management With Non-Invasive Monitoring

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DISCLOSURE

Dr. Latham has declared no conflicts of interest related to the content of his presentation.
Disclosure

- No Business Interests
- No Consulting
- No Speakers Bureau
- No Off Label Use to Discuss
Objectives

- Describe the goal of resuscitation in shock.
- Describe the utility of the heart-lung interaction to predict volume responsiveness.
- Recognize the limitations of respiratory induced variability in hemodynamics to predict volume responsiveness.
- Recognize applications and limitations of bioreactance derived hemodynamic monitoring.
- Recognize applications and limitations of doppler indexed CO estimate derived hemodynamic monitoring.
- Recognize applications and limitations of pulse contour analysis derived hemodynamic monitoring.
Clinical Case

- JP is a 42 yo female admitted with a 4 day history of progressive dyspnea, cough, fevers, and myalgia. She is profoundly hypoxemic on presentation with diffuse alveolar infiltrates on her CXR and is immediately intubated in the ED. She is hypotensive and severe sepsis is recognized. She is given appropriate antibiotic coverage and bolused 30 mL/Kg of crystalloid. Her rapid flu is positive.

- Vent settings: Vt 350 (6mL/Kg), RR 28, PEEP 12, FiO2 1.0
- Post fluid vitals: T 39, BP 80/40, HR 95 (NSR), RR 28
- PPV: 18
- Pulse Contour Analysis: SVI 35, CI 3.3, SVV 19
Clinical Case Question

Which of the following would you do next?
A. Start Norepinephrine. She’s had all the fluid she needs.
B. Bolus crystalloid and re-assess the PPV/SVV
C. Perform a PLR and assess for >10% change in SVI
D. Await the CVP when central line placement is completed
Which of the following would you do next?

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C. Perform a PLR and assess for >10% change in SVI
D. Await the CVP when central line placement is completed
Goal of Resuscitation

- Achieve Adequate Perfusion Pressure
  - MAP > 65 mmHg
    - Volume Replacement
    - Vasopressors
    - Inotrope
- Improve Microcirculatory Flow
  - Rapidly treat underlying cause of shock
- Limit Tissue Edema
Volume Expansion in Shock

- Assess for Volume Responsiveness
  - 50% of Critically Ill are Volume Responsive

CVP ROC: 0.56
PPV ROC: 0.96
SVV ROC: 0.84

Volume Expansion in Shock

- Heart-Lung Interaction

Volume Expansion in Shock

- Heart-Lung Interactions

Volume Expansion in Shock

- Technology Derived Stroke Volume
  - Bioreactance
    - NICOM
  - Pulse contour analysis
    - EV1000
    - LiDCO
    - PiCCO
  - Doppler based
    - Esophageal Doppler
    - USCOM
    - Bedside Echo
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Clinical Case Question

- Which of the following will alter the accuracy of PPV/SVV

A. Tidal Volume > 8mL/Kg
B. Spontaneous Respirations on Ventilator
C. HR/RR > 3.6
D. Sinus Rhythm
E. Normal Chest Wall Compliance
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- PPV: 18

- Pulse Contour Analysis: SVI 35, CI 3.3, SVV 19
Tidal Volume Effects on PPV/SVV

- 60 Patients
- Single Center
- PA Cath as control
  - Responders vs Non
- PPV ROC Curves
  - $V_t > 8$: 0.89
  - $V_t < 8$: 0.71
- Change in CI
  - Unaffected by $V_t$

RR effects on PPV/SVV

- 13 Patients
- Mechanically ventilated
  - RR varied 14 to 30-40
- PPV altered by RR
  - 21% at RR of 14
  - 4% at RR 30-40
- HR/RR > 3.6
- CI not effected by RR

Optimal PPV/SVV Parameters

- Mechanically Ventilated
  - No Spontaneous Respirations
  - $V_t > 8\text{mL/Kg}$
- No Arrhythmia
- $HR/RR > 3.6$
- No valvular disease
- Total respiratory compliance $> 30 \text{mL/cm H}_2\text{O}$
Optimal PPV/SVV Parameters

- Mahjoub, et al.
  - Br J of Anesth 2013
  - Doi:10.1093/bja/aet442
- Prospective Observ
- 26 ICU’s
- 311 Patients
- Very low percentage of patients meet all criteria.
Goal of Resuscitation

- Achieve Adequate Perfusion Pressure
  - MAP > 65 mmHg
    - Volume Replacement
    - Vasopressors
    - Inotropic
- Improve Microcirculatory Flow
  - Rapidly treat underlying cause of shock
- Limit Tissue Edema
Volume Responsiveness

- **Technique**
  - Passive Leg Raise (PLR)
  - End Expiratory Hold
  - Volume Expansion
    - 500mL w/in 30 min

- **Technology**
  - Bioreactance
  - Doppler Derived
  - Pulse Contour Analysis
Volume Responsiveness

- Passive Leg Raise
  - Reversible Volume Expansion
    - 250-350 mL
  - 3-5 Minutes in supine position
- Caution
  - Labile Hemodynamics
  - Severe Ventilatory Insufficiency
  - At Risk Airway
Passive Leg Raise

- Meta-Analysis
  - 9 Articles
  - 366 Pooled Interventions
  - ICU/Shock
  - Mixed CI/SVI assessment
    - Doppler derived
    - Pulse contour analysis
  - Mixed spontaneous ventilation
  - Mixed Rhythms

- Results
  - PLR Accurately Predicts Volume Responsiveness
  - $\Delta \text{SVI/CI} > \Delta \text{PP}$
  - Unaffected
    - Technology used
    - Spontaneous Respiration
    - Arrhythmia

Cavallaro, F. Inten Care Med. 2010; 36:1475-83.
## Passive Leg Raise

### Table

<table>
<thead>
<tr>
<th>Boluses</th>
<th>% Resp</th>
<th>AUC</th>
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<tbody>
<tr>
<td>15</td>
<td></td>
<td>0.95</td>
</tr>
<tr>
<td>22</td>
<td>45</td>
<td>0.96</td>
</tr>
<tr>
<td>71</td>
<td>52</td>
<td>0.96</td>
</tr>
<tr>
<td>24</td>
<td>54</td>
<td>0.96</td>
</tr>
<tr>
<td>24</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>50</td>
<td>0.89</td>
</tr>
<tr>
<td>34</td>
<td>50</td>
<td>0.89</td>
</tr>
<tr>
<td>102</td>
<td>46</td>
<td>0.89</td>
</tr>
<tr>
<td>34</td>
<td>68</td>
<td>0.94</td>
</tr>
<tr>
<td>30</td>
<td>67</td>
<td>0.96</td>
</tr>
<tr>
<td>30</td>
<td>67</td>
<td>0.92</td>
</tr>
<tr>
<td>34</td>
<td>41</td>
<td>0.94</td>
</tr>
<tr>
<td>Overall</td>
<td>366</td>
<td>52.9</td>
</tr>
</tbody>
</table>

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Clinical Question

- JP undergoes and end-expiratory hold for 15 seconds to assess for volume responsiveness. Which of the following is a contraindication to an end-expiratory hold?

A. Spontaneous respirations on the vent
B. Atrial Arrhythmia
C. Pao/FiO2 < 200
D. PEEP > 10
E. None of the Above
JP undergoes and end-expiratory hold for 15 seconds to assess for volume responsiveness. Which of the following is a contraindication to an end-expiratory hold?

A. Spontaneous respirations on the vent
B. Atrial Arrhythmia
C. Pao/FiO2 < 200
D. PEEP > 10
E. None of the Above

A B C D E 20% 20% 20% 20% 20%

15
Volume Expansion in Shock

- Heart-Lung Interaction

End-Expiratory Hold

- 15 Second Pause at End-Expiration
  - Same maneuver to test for intrinsic PEEP
- Non-Invasive Maneuver
- Duration of Test Shorter than PLR
- Requires Fast Hemodynamic Assessment
  - 5-10 Secs
End-Expiratory Hold

- 34 Critically Ill Patients
- 32% Arrhythmias
- 68% Spontaneous Resp
  - Mild effort
- Compared Δ CI
  - PLR/EEH/VE
- Pulse contour analysis

<table>
<thead>
<tr>
<th></th>
<th>Responders (n = 23)</th>
<th>Nonresponders (n = 11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sepsis (n)</td>
<td>22</td>
<td>10</td>
</tr>
<tr>
<td>ARDS (n)</td>
<td>18</td>
<td>5</td>
</tr>
<tr>
<td>Tidal volume (mL/kg)</td>
<td>6.8 ± 1.1</td>
<td>6.8 ± 1.1</td>
</tr>
<tr>
<td>Total PEEP (cm H₂O)</td>
<td>8 ± 3</td>
<td>7 ± 2</td>
</tr>
<tr>
<td>LV ejection fraction (%)</td>
<td>53 ± 9</td>
<td>53 ± 5</td>
</tr>
<tr>
<td>Pao/FiO₂ (mm Hg)</td>
<td>123 ± 57</td>
<td>195 ± 122</td>
</tr>
<tr>
<td>I/E ratio</td>
<td>0.4 ± 0.1</td>
<td>0.3 ± 0.1</td>
</tr>
</tbody>
</table>
| Patients receiving norepinephrine (n) | 18 | 5
| Rate of norepinephrine infusion (µg/kg/min) | 1.0 ± 0.3 | 1.1 ± 0.4 |

End-Expiratory Hold

<table>
<thead>
<tr>
<th></th>
<th>B0</th>
<th>PLR</th>
<th>B1</th>
<th>EEH</th>
<th>B2</th>
<th>VE</th>
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</thead>
<tbody>
<tr>
<td>Res</td>
<td>2.3</td>
<td>2.9</td>
<td>2.4</td>
<td>2.7</td>
<td>2.4</td>
<td>3.3</td>
</tr>
<tr>
<td>NR</td>
<td>3.4</td>
<td>3.4</td>
<td>3.4</td>
<td>3.4</td>
<td>3.5</td>
<td>3.5</td>
</tr>
</tbody>
</table>

AUC 0.872 [0.849-0.985]

Effects of end-expiratory pause on cardiac index

AUC 0.937 [0.797-0.990]

Effects of passive leg raising on cardiac index

End-Expiratory Hold

End-Expiratory Hold

- Alternative to PLR
- High AUC
- Not Effected by Spont Resp
- Not Effected by Arrhythmia
- Not Effected by High PEEP
- Need Rapid Assessment of Changes in SVI/CI
  - Pulse Contour Analysis
  - Doppler Derived Beat to Beat Analysis
Volume Responsiveness

- **Technique**
  - Passive Leg Raise (PLR)
  - End Expiratory Hold
  - Volume Expansion
    - 500mL w/in 30 min

- **Technology**
  - Bioreactance
  - Doppler Derived
  - Pulse Contour Analysis
Bioreactance

- Completely Non-Invasive
- 4 Electrodes on Chest
  - Assess change in current
- Spontaneous Breathing
- Mobile Patient
- Updates every minute
Bioreactance

- Tested in Various Settings
  - ER
  - ICU
  - Pregnancy
  - Pulmonary HTN
- Not Effected by External Electronics
- Applicable in Non-Physician Algorithms

- Limitations
  - Electrode Durability
  - Innaccurate
    - Severe AI
    - Thoracic Aneurysms
    - Balloon Pump
    - LVAD
    - ? Dense Infiltrates
    - Cautery
Doppler Derived CO

- Bedside Echo/US
- Esophageal Doppler
- USCOM
- SV = Vti x CSA
  - VTI = Velocity Time Integral
    - Velocity of blood flow per time through a vessel
  - CSA = Cross Sectional Area
    - LVOT
    - Distal Aorta
    - Large Arteries
Doppler Derived CO

- Pleuripotential Advantages
  - Shock Assessment
  - Cardiac/Pulmonary/Abdominal/Vascular
  - Volume Responsiveness
    - IVC
    - Doppler derived SV
      - Echo
      - Automated devices
      - Spontaneously Breathing
Doppler Derived CO

- **Limitations**
  - Additional training
  - Availability of machines
  - Continuous monitoring unavailable
    - Limits resuscitation algorithms
Pulse Contour Analysis

- **Estimation of SV**
  - Area under the curve
    - Systolic portion
  - Presumed constants
    - Vascular compliance
    - Aortic impedance
    - PVR
  - Pulse Regularity
    - Improves accuracy

\[
CO = \text{cal} \times HR \times \int \left( \frac{P(t)}{R_p} + C_p(p) \times \frac{dP}{dt} \right) dt
\]
Pulse Contour Analysis

- Currently Available Devices
  - PiCCO
    - Calibration (Thermodilution)
  - LiDCO
    - Calibration (Lithium)
    - Non-calibration
  - Vigileo/EV-1000/FloTrac/VolumeView
    - Non-calibration—FloTrac
    - Calibration—VolumeView (Thermodilution)
Pulse Contour Analysis

- **Advantages**
  - Simple to use
  - Real time data
  - Utilize arterial line already in place
  - Continuous CO
  - Non-physician resuscitation protocols

- **Disadvantages**
  - Requires excellent waveforms
  - Re-calibration
  - SVV Limited to Optimal Parameters
    - Sinus Rhythm
    - Vt >8 mL/Kg
    - HR/RR > 3.6
    - No Spontaneous Resp
Clinical Question

- The greater the fluid balance the higher the mortality?
  A. True
  B. False
The greater the fluid balance the higher the mortality?

A. True
B. False
Goal of Resuscitation

- Achieve Adequate Perfusion Pressure
  - MAP > 65 mmHg
    - Volume Replacement
    - Vasopressors
    - Inotrope
- Improve Microcirculatory Flow
  - Rapidly treat underlying cause of shock
- Limit Tissue Edema
Fluid Balance and Mortality

Fluid Balance and Mortality

Summary

- Follow Goals of Resuscitation
  - MAP > 65
  - Reverse underlying process
  - Avoid tissue edema

- Respiratory Induced Hemodynamic Variability
  - Clinical parameters limit actual utility

- ΔSVI/Cl Cornerstone of Volume Response
Summary

- Simulate Volume Challenge
  - PLR
  - End-Expiratory Hold
- Utilize Technology to Assess $\Delta$SVI/CI
  - Limitations exist with each technology
- Confident Volume Resuscitation