Resuscitating the Undifferentiated, Shocked Patient

A Focus on Logistics, Mechanics, & Resuscitation End-Points.

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Objectives:
1. Review common shock states and methods of rapid differentiation.
2. Discuss the role of ultrasound in the diagnosis and management of undifferentiated shock.
3. Address common pitfalls in shock resuscitation as well as physiologic mimics in shock evaluation and treatment.

I. Introduction: Patient Case – TR
a. Decompensating patient, via BOUNCE-UP
b. 28 y/o male, with no previous medical history presents to the ED with RLE swelling and redness, worsening over the past week. Fevers, tachycardia, otherwise normal vital signs.
c. Traditional Approach “Severe Sepsis” Resuscitation in the ED
   i. labs, IVF, Abx
   ii. Admitted to medical floor
d. On floor for approximately 24 hours, where patient remains febrile, but becomes increasingly tachycardic, mild SOB & more confused.
   i. **Rapid Response** called for BP dropping to 80s/40s.
   ii. You get to the room, and this is what you see
   iii. Lots of people, lots of noise, lots of questions
   iv. You’re told that the redness has gotten worse, and the patient appears to now be in septic shock
e. Quote: “Early, effective interventions will define the patient’s trajectory” – Steve Trzeciak, MD

II. Clinical approach to undifferentiated shock
a. Traditional approach: First question always is, “what type of shock”? 
   i. Usual diagnostics: Exam, labs, radiography, CT, etc.
b. Initial goals: Find & address the mechanical causes of the patient’s hypotension FIRST
c. Mechanical causes of circulatory collapse are the most rapidly correctible problems
d. POCUS – US protocol for evaluation of undifferentiated hypotension
   i. It will impact your management (Shokoohi, 2015)
      1. Significant increase in definitive diagnosis accuracy
      2. Significant impact on use of IVF, vasoactives, & blood products
      3. Substantially changed management decisions
   ii. It will help you get to the right answer (Volpicelli, 2013)
1. Emergency diagnostic judgments for undifferentiated shock guided by POCUS significantly agreed with a final clinical diagnosis

e. Rush Exam (Perera, 2010)
   i. Goal – to be completed in < 2 min
   ii. What’s the protocol & views (HIMAP)
      1. Heart (Parasternal short/long)
         a. Q: RV/LV function, Effusion?
         b. Pitfall: Avoid equating poor EF with poor CO
         c. Modified: Cardiac Output
      2. Inferior Vena Cava (IVC variability)
         a. Q: Flat or full? Variability?
         b. Modification: May use internal jugular veins if poor IVC view

<table>
<thead>
<tr>
<th>IVC size (cm)</th>
<th>Inspiration Effect</th>
<th>Estimated mean RAP (mmHg)</th>
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</thead>
<tbody>
<tr>
<td>Small &lt; 1.5</td>
<td>Collapse</td>
<td>0 - 5</td>
</tr>
<tr>
<td>Normal 1.5 – 2.5</td>
<td>↓ ≥ 50%</td>
<td>5-10</td>
</tr>
<tr>
<td>Normal 1.5 – 2.5</td>
<td>↓ ≥ 50%</td>
<td>10-15</td>
</tr>
<tr>
<td>Dilated &gt; 2.5</td>
<td>↓ ≥ 50%</td>
<td>15-20</td>
</tr>
<tr>
<td>Dilated + Hepatic veins</td>
<td>No collapse</td>
<td>&gt; 20</td>
</tr>
</tbody>
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*From Otto CM and Pearlman AS: Textbook of Clinical Echocardiography*

3. Morrison’s pouch
   a. Q: Free Fluid?
   b. Note: Not just hepato-renal space, include liver tip!
4. Aorta (diameter, looking for intimal flap)
5. Pleura (check for sliding, pulmonary edema)

f. Macrocirculatory Resus Targets
   i. Preload – POCUS
      1. Central venous pressure (CVP)
         a. Defined
         b. Included in classic early goal directed therapy algorithm (Rivers, 2001)
         c. General threshold: < 8 mmHg
         d. Location: RA/Cavoatrial junction
      2. Useful to monitor response to fluid loading, useful as a trend.
3. Useless to assess intravascular volume status optimization.

ii. Afterload - Arterial Blood Pressure
   1. MAP goal > 65 mmHg (Asfar, 2014)
      a. During the first 6-24 hours
         i. May require some modification that is patient/disease specific, unclear evidence except in hemorrhagic shock (damage control resuscitation)
      b. AVOID PRESSOR ANGST
         i. Every 1-hour delay in norepinephrine initiation during the first 6 hours after septic shock onset is associated with a 5.3% increase in mortality (Bai, 2014)
         ii. Peripheral pressors are safe in a good antecubital (AC) IV (Loubani, 2015)

iii. Pump function - Cardiac Output
   1. Dependent upon inotropy & filling pressures
   2. General threshold: CI > 2.0 L/m/m2
   3. Usually preserved or elevated in sepsis, depressed in cardiogenic, hypovolemic, & obstructive shock.
   4. Can be measured:
      a. Non-invasively with LVOT VTI on US, NICOM device, etc.
      b. Arterial pressure waveform analysis (Vigileo, etc.)
      c. Occasionally a pulmonary artery catheter in complex patients.
   5. Sepsis
      a. Incidence of sepsis induced cardiomyopathy becoming more recognized
      b. Estimated to occur in 18 - 60% of patients (Vieillard baron A, 2001; Viellard baron A, 2008)
      c. Etiology likely related to inflammation and endotoxin effects on myocardial tissue, not coronary circulation (Cunnion, 1986)
      d. Unclear on mortality (Viellard baron A, 2008; Kimmoun, 2013)

   g. Fluid Resuscitation
      i. Goal to improve DO2 VO2 mismatch by increasing CO
1. Dilemmas
   a. Excessive fluids can cause harm to critically ill patients
   b. Non-responders can have a decrease in DO2 (hemodilution) (Monnet et al, 2013)
   c. In general, IVF stay within intravascular space for approx 4 hours

ii. Volume Responsiveness (we’re going to stick with crystalloids here...)
   1. Fluid Challenge defined: 300-500cc of fluid (in US, usually crystalloid) given over 5-10 min that leads to a 10-15% increase in SV or CO

2. Pitfall: Using changes in MAP to determine volume responsiveness

3. PRESSURE does not equal FLOW

iii. Static vs. Dynamic
   1. Static: CVP, MAP, HR, etc.
      a. Overall a poor measure of volume responsiveness
      b. Value of the CVP: Measure of right sided filling pressure, cardiac response to IVF
      c. A low CVP (< 8 mmHg) is generally reliable

2. Dynamic Targets
   a. Respiratory variation targets (PPV/SVV/IVC)
      i. Take advantage of heart-lung interactions to predict volume responsiveness
   b. Stroke Volume Variation (SVV)
      1. Devices: PiCCO, LiDCO, FloTrac
      2. Pulse contour analysis
      3. Trigger: > 13% suggest responsiveness
      4. Sensitivity: ~90% Specificity: ~80%
   c. Pulse Pressure Variation (PPV)
      1. Trigger: > 13% beat to beat variation
      2. Sensitivity 94%, Specificity 96%

3. Pitfall: Identifying Systolic pressure variation (SPV), not PPV. SPV is the $\Delta$SP (mmHg) over respiratory cycle
iv. Inferior Vena Cava (IVC) Variability
   1. Trigger: > 12-18% IVC variation
   2. Sensitivity: 90% Specificity: 90%
      (Barbier, 2004; Feissel, 2007)
   3. IVC diameter just a CVP estimate

v. Limitations:
   1. Variable compartment pressures – Intra-abdominal pressure, intrathoracic pressure with spontaneous breathing.
   2. Sinus Rhythm Required. Cardiac dysrhythmias = irregular filling = irregular SV
   3. Small amplitude – LTVV; Some studies show that LTVV actually cause PPV to lose predictive value;
   **Increase TV to 8-12cc/kg IBW during test.**
   4. Low pulmonary compliance (< 30mL/cm H2O)

b. Direct measurement tests
   i. End-expiratory occlusion test
      1. End-expiratory hold for 15 seconds
      2. Disrupts cyclic impediment of venous return
      3. Trigger: >5% rise in SV/CO
      4. Benefits: OK arrhythmias 2/2 mult cardiac cycles, can be spontaneously breathing

c. PLR
   i. Autologous fluid bolus (est. ~300 – 500mL)
   ii. Trigger: >10% rise Ao blood flow, >12% rise in pulse pressure; **rise in EtCO2 >5%**
      (Monnet 2006; Monnet, 2013)
   iii. Sensitivity: 97% Specificity 94%

iv. Fluid choice?
   1. Give what the patient needs, and not a drop more
   2. For the first 2-3 Liters – it doesn’t matter (Young, 2015), but for larger volumes, I switch to balanced solutions
III. Microcirculatory dysfunction and perfusion
   a. Important to recognize that PRESSURE does not equal FLOW
   b. Microcirculation defined: The network of arterioles, capillaries, & post-capillary venules that are responsible for tissue perfusion. (20 - 100 µm)
      i. Primary site & chief regulator of O2 transport
      ii. Largest endothelial surface in the body
      iii. Primary site of damage during shock: Microthrombi, neutrophil aggregation, etc
      iv. Video Example
   c. Most widely used targets include SvO2, Lactate, capillary refill time (CRT), and urine output
   d. Global assessments of DO2/VO2 balance
      i. SvO2
         1. Clinical question: Adequate oxygen delivery?
         2. Normal range 65-75%
         3. Low is predictive of bad outcome, but normal and supranormal do not guarantee adequate TO2
         4. Patient population most widely used: Cardiogenic shock, estimate of CO adequacy
         5. Location: Cavoatrial Junction/RA (ScvO2), PA (SvO2)
            a. If ScvO2 > 70%, SvO2 generally > 60%
            b. Improved correlation if obtained from RA
            c. SLIDE: Grissom Graphs
            d. Pitfall: Getting ScvO2 from femoral line – not downstream from any vital organs
            e. Pitfall2: Getting ScvO2 from high SVC (Grissom CXR)
         7. O2 Extraction Ratio important to consider
         8. NO difference in outcomes if ScVO2 used over lactate (Arnold, 2009)
      ii. Lactic Acid
         1. Clinical question: Cellular dysfunction?
         2. First described in humans during the early 1800s, then found to be increased during cellular hypoxia in the 1890s
         3. Causes of elevated lactate
a. Tissue hypoxia where VO2 >> DO2
   i. Poor DO2 increases anaerobic cellular metabolism, increases lactate to be used for ATP generation
   ii. Associated with acidosis
b. Microcirculatory dysfunction (shunting or localized malperfusion)
c. Mitochondrial dysfunction (limited pyruvate metabolism causing increases in LA)
d. Aerobic metabolism (lactate used as a cellular fuel – example: epinephrine, lymphoma)

4. Patient population most used: Septic

5. Concept: early resuscitation restores microvascular blood flow, reducing cellular stress >> reduction in anaerobic lactate production
   a. Term “lactate normalization” has become a mantra of the most recent decade’s goals of resuscitation
   b. Whether LA is a good perfusion marker is debatable, but it is a good risk-stratification tool
   c. In early phase resus, LA levels seem to be more closely related to outcome than hemodynamic and DO2/VO2 variables. (Shapiro, 2005; Mikkelsen, 2009)
      i. In general, a 6-hour goal of normalization is reasonable (with CMS breathing down our necks…)
      ii. Cryptic shock – good example of normal VS with significant LA and mortality
      iii. Location: Lactate enthusiasts – can be obtained via peripheral line (pVBG=ABG=capillary)

6. Controversy: Lactate-guided therapy?
   a. Normalization over original 10% decrease better prognostic indicator (Puskarich, 2013)
   b. Clinically helpful to act as a warning signal, determine overall response, trigger for further diagnostics or interventions
      iii. Clinical assessments of perfusion
1. Capillary refill time
   a. Clinical question: Are peripheral vascular beds getting FLOW
      i. Shocked patients will prefer to shunt blood to vital organs first
         1. CRT examination permit the recognition of 2 phases of shock development
         2. Phase 1: Compensatory mechanisms cause vasoconstriction preserves perfusion of vital organs
            a. Skin, muscle, GI tract tissues highly sensitive for detecting occult tissue malperfusion (Shlichtig, 1991; Guzman, 2005)
         3. Phase 2: Late shock or compensated response
   b. Video 1 – delayed CRT
   c. Location: fingers, knee caps
   d. Normal Value:< 3.5 seconds
      i. In critically ill patients, who are normothermic, CRT > 5.0s despite HD optimization significant risk for progressive organ failure (Lima, 2009)
   e. Impacting factors: Skin temperature, peripheral vasodilators (NTG)
   f. PROs
      i. Good Interrater reliability (80% concordance – finger, 95% knee cap) (Ait-Oufella, 2014)
      ii. Low cost, low tech
   g. CONs
      i. CRT modifiers (vasodilators) unclear if translate to clinical outcomes
      ii. Limited data to use as a therapeutic target
References


