Shock and Monitoring

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Shock

Anaerobic metabolism

Lactic acidosis

"Dysoxia"

Activation of inflammatory cascades

Inadequate DO₂

Organ system dysfunction
Shock

- Normal cardiovascular system
- Pathophysiology of shock
- Categories of shock
- Resuscitation
- Monitoring
Key components of CV system

- **Intravascular volume**
- **Cardiac output**
  - Preload
  - Heart rate
  - Contractility
  - Afterload

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Key components of CV system

- Resistance circuit – arterioles
  - Distribution of organ flow

- Capillaries
  - Leak
  - Obstruction to flow
  - Shunts

- Venous capacitance vessels
  - Vary venous return
Organ blood flow

Most dependent upon mean arterial pressure (MAP)

Autoregulation

- Maintained during large variations of MAP
- 60-130 mmHg
- Can be impaired - hypertension
Autoregulation

- % normal organ blood flow
- Mean Arterial Pressure (mmHg)
- Normotensive
- Hypertensive

Exemplary Care  Cutting-edge Research  World-class Education
Supply and demand

O₂ delivery:
- Hemoglobin
- Saturation
- Cardiac output

O₂ demand:

\[ \text{VO}_2 = \text{DO}_2 \times \text{ER}_O_2 \]

ER = extraction ratio

20-60%
O$_2$ supply dependency

Oxygen consumption

Oxygen delivery

Critical DO2
Critical DO2

Dysoxia
Lactic acidosis
Cytopathic Hypoxia

🍃 **Sepsis**
- Normal oxygen delivery
- Impaired mitochondrial $O_2$ utilization

🌿 **Mediators**
- Inflammatory cytokines
- Inhibition of pyruvate dehydrogenase
- Inhibition of cytochrome a,a3 by NO
- Irreversible inhibition of one or more mitochondrial respiratory complexes by peroxynitrite
- Poly(ADP-ribose) polymerase-1
Reperfusion Injury

Ischemia

<table>
<thead>
<tr>
<th>ATP</th>
<th>Hypoxanthine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Xanthine Dehydrogenase</td>
</tr>
<tr>
<td></td>
<td>Xanthine Oxidase</td>
</tr>
<tr>
<td>Reperfusion</td>
<td>O₂</td>
</tr>
<tr>
<td>Oxygen radical formation</td>
<td>Lipid mediator release</td>
</tr>
<tr>
<td>Endothelial cell dysfunction</td>
<td>Neutrophil chemotaxis</td>
</tr>
<tr>
<td></td>
<td>Microvascular changes</td>
</tr>
<tr>
<td>Tissue injury</td>
<td></td>
</tr>
</tbody>
</table>
It’s not the fall that gets you....
Organ failure

- Ischemic Injury
- Organ Damage
- Inflammatory mediators (TNF, NO, free radicals)
- Reperfusion injury
Classifications of shock

Hypotension

Hypodynamic
Low CO (narrow PP)

Pulmonary edema?

No

JVD?

No

Hypovolemia
Hemorrhage
Dehydration

Yes

RV failure
Obstructive
PE
Tamponade
PTX

Yes

Cardiogenic shock
MI
Valvular dz

Hyperdynamic
Low SVR (wide PP)

Distributive shock
Sepsis
Neurogenic shock
Adrenal insufficiency
Liver failure
Anaphylaxis
Medications
Hemorrhagic shock

- Most common cause of hypotension in trauma patients

- Initial fluid should be crystalloid

- Transfusion
  - Hypotensive after 2 L crystalloid (ATLS)
  - Earlier for severe shock

- Uncontrolled hemorrhage
  - Stop hemorrhage
  - Limited fluid resuscitation
Cardiogenic shock

- Resuscitation simultaneous with revascularization
- Patients may need higher than normal filling pressures (poor LV compliance)
- Inotropes may worsen ischemia
- Pacing may be helpful for relative bradycardia
- Intra-aortic balloon pump improves coronary perfusion and decreases afterload
Pulmonary embolism

 риск факторов

 Hypercoagulability, stasis, trauma

 Presentation

 Respiratory
 Cardiovascular

 Diagnosis

 CT angio, VQ, echo, angio, d-dimer

 Management

 Anticoagulation, thrombolytic, embolectomy
 Prevent the next one -?filter
Cardiac tamponade

- Pentrating trauma more common than blunt
- Beck’s triad (hypotension, distant heart sounds, JVD) obscured by hypovolemia
- High index of suspicion
- Diagnose: echo or pericardial window
- Treatment:
  - Need sternotomy or thoracotomy (trauma)
  - Pericardiocentesis (non-trauma)
Septic shock

- Decreased preload
  - Hypovolemia (capillary leak)
  - Increased venous capacitance

- Vasodilatation

- Cardiac dysfunction
  - Ventricular dilatation
  - Decreased ejection fraction

- Cytopathic hypoxia
Endstage shock

Irreversible shock
Terminal hypodynamic state

Cardiac
defcompensation
Vasomotor
dysfunction

Exemplary Care  Cutting-edge Research  World-class Education
Initial management

ABCs
Initial management

Resuscitation
- Ventilation
  - ?intubation early
- Infusion
  - Bolus to effect
  - ?blood
  - Clear lactate
- Pump therapy
  - Inotropic support
  - Afterload reduction
- Vasodilatation
  - Vasopressor support

Definitive therapy
- Stop bleeding
- Circulatory assist
- Antibiotics and drainage/debridement
Monitoring

- Exemplary Care
- Cutting-edge Research
- World-class Education
CVP

- Only elevated in disease
  - RV dysfunction
  - Pulmonary hypertension
  - LV dysfunction
  - Tamponade
  - Hyperinflation
  - Intravascular volume expansion

- Poor correlation with volume responsiveness
PAOP and Preload

Muscle

LVEDV

LVEDP

LAP

PAOP
CVP and PAOP

Functional Hemodynamic Monitoring

Positive press → ↓RV filling → ↓RV output → ↓LV filling → ↓LV output

2-3 heart beats later

Positive pressure ventilation changes LV output
Resp variation in pulse pressure

Limitations: spontaneous breathing, arrhythmias.

Passive Leg Raising

- Semirecumbent position
- Passive leg raising
### Passive Leg Raising

<table>
<thead>
<tr>
<th>Variable</th>
<th>Area Under the Curve</th>
<th>$p$ vs. 0.500</th>
<th>Best Cut-Off Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compliance of the respiratory system $&gt;30$ cm H$_2$O/mL ($n = 26$)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Pulse pressure variation at baseline</td>
<td>$0.98 \pm 0.03$</td>
<td>$&lt;.0001$</td>
<td>$12%$</td>
</tr>
<tr>
<td>Passive leg-raising–induced changes in CI</td>
<td>$0.91 \pm 0.06$</td>
<td>$&lt;.0001$</td>
<td>$10%$</td>
</tr>
<tr>
<td>End-expiratory occlusion-induced changes in CI</td>
<td>$0.97 \pm 0.03$</td>
<td>$&lt;.0001$</td>
<td>$5%$</td>
</tr>
<tr>
<td>Global end-diastolic volume index at baseline</td>
<td>$0.69 \pm 0.11^a$</td>
<td>$.090$</td>
<td>—</td>
</tr>
<tr>
<td>Compliance of respiratory system $\leq 30$ cm H$_2$O/mL ($n = 28$)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulse pressure variation at baseline</td>
<td>$0.69 \pm 0.10$</td>
<td>$.04$</td>
<td>$4%$</td>
</tr>
<tr>
<td>Passive leg-raising–induced changes in CI</td>
<td>$0.94 \pm 0.05^a$</td>
<td>$&lt;.0001$</td>
<td>$10%$</td>
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<td>$0.93 \pm 0.05^a$</td>
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<td>$5%$</td>
</tr>
<tr>
<td>Global end-diastolic volume index at baseline</td>
<td>$0.48 \pm 0.11^a$</td>
<td>$.980$</td>
<td>—</td>
</tr>
</tbody>
</table>

Preload Echo

- **Distensibility index**
  \[ \text{Max-min} \ D_{IVC} \times 100\% \]
  \[ \text{Min} \ D_{IVC} \]

- **Collapsibility index**
  \[ \text{Max-min} \ D_{IVC} \times 100\% \]
  \[ \text{Max} \ D_{IVC} \]

- **Resp variability index**
  \[ \Delta D_{IVC} = \text{Max-min} \ D_{IVC} \times 100\% \]
  \[ \text{Mean} \ D_{IVC} \]

Mixed venous oxygen - SvO2

- Decrease SvO₂
  - Decrease DO₂
    - Hb, O₂ sat, cardiac output
  - Increase O₂ demands
    - Fever, sepsis, exercise
  - Normal >65%
  - Critical value ~40%

- Resuscitation endpoint for sepsis and cardiogenic shock

- Sepsis -> maldistribution of blood flow
  - SvO₂ normal with tissue dysoxia still present
Oxidative Metabolism

- Glucose → Pyruvate → Lactate
- Acetyl CoA
- Citric acid Cycle
- NADH/FADH₂
- Electron transport chain
- ADP → 34 ATP
- O₂ → H₂O

Remember 2:38
Base Deficit

- **Definition**
  - Amount of base needed to normalize pH with normal PCO₂

- **Limitations**
  - Administration of bicarbonate
  - Alcohol intoxication
  - Hyperchloremic metabolic acidosis
  - Seizures
  - Pre-existing acidosis
Lactate

- Excess production
  - Anaerobic metabolism
  - Initial level and time to clearance useful

- Decreased metabolism (liver, kidney)

- Washout during reperfusion

- Sepsis
  - Increase flux of alanine from muscle
  - Decreased PDH activity
  - Decreased hepatic clearance
  - Dysfunctional mitochondrial respiration
Near Infrared Spectroscopy

**Measurements**
- $\text{PO}_2$
- $\text{PCO}_2$
- pH
- $\text{O}_2$ saturation of hemoglobin
- Tissue oxyhemoglobin coupling to cytochrome $a,a_3$ redox
  - Mitochondrial $\text{O}_2$

**Location**
- Muscle
- Stomach
- Bowel
- Liver
Hypotension

- Hypodynamic Low CO (narrow PP)
  - Pulmonary edema?
    - No
      - JVD?
        - No
          - Hypovolemia
          - Hemorrhage
          - Dehydration
            - Fluids
            - Blood
            - Hemostasis
            - Base deficit
            - Lactate
        - Yes
          - RV failure
          - Obstructive
          - PE
          - Tamponade
          - PTX
            - Fluids
            - Inotropes
            - Specific Tx
    - Yes
      - Cardiogenic shock
        - MI
        - Valvular dz
          - Inotropes
          - IABP
          - Revascularize
          - SvO₂

- Hyperdynamic Low SVR (wide PP)
  - Distributive shock
    - Sepsis
    - Neurogenic shock
    - Adrenal insufficiency
    - Liver failure
    - Anaphylaxis
    - Medications
  - Fluids
  - Vasopressors
  - EGDTx
  - Treat cause