Surgical Critical Care

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Objectives

Medical Expert:
1. Evidence and indications for hemodynamic monitoring (arterial catheter, central venous catheter, pulmonary artery catheter)
2. Definition, classification of shock
3. Diagnosis and management of various causes of shock (hypovolemic, cardiogenic, septic, neurologic and anaphylactic)
4. Evidence and end points of resuscitation
5. Definition, classification and management of respiratory failure (acute lung injury, ARDS, indications for tracheostomy)
6. Methods and indications for various modes of ventilation support
7. Etiology, diagnosis, grading and management of abdominal compartment syndrome
8. Etiology, diagnosis and management of acute renal failure (indications for dialysis)
9. Pathophysiology and management of sepsis
10. Goal directed therapy in ICU
11. Definition and microbiology of surgical site infections
12. Nutrition in the critically ill patient (TPN, enteral feeds)

Collaborator:
1. Evidence for critical care out reach teams

Health Advocate:
1. Prophylaxis in critically ill patient (GI, VAP, DVT etc....)

Manager:
1. Indications for admission and discharge from ICU

Scholar:
1. Review of some of the most recent seminal papers on topic (Staff to lead Discussion)
Agenda

1. Introduction to ICU
2. Shock, hemodynamic monitoring, and resuscitation
3. Sepsis
4. Respiratory failure, mechanical ventilation, ECMO, tracheostomy
5. Abdominal compartment syndrome
6. Nutrition for the critically ill patient
Intensive Care Unit
ICU

• Specific unit in hospital where advanced monitoring and organ support are available
  • Mechanical ventilation
  • Renal replacement therapy
  • Invasive cardiac monitoring
  • Vasopressors
  • Equipment
  • Close monitoring: high nurse to patient ratio (1:1 or 1:2)

• Postoperative monitoring in medically ill patients or for postoperative complications
Prophylaxis in ICU

• VTE
  • LMWH

• Peptic ulcer
  • PPI

• Ventilation associated pneumonia
  • Elevate head of bed
  • Daily sedation “vacations” and assessment of readiness to extube
  • Daily oral care with chlorhexidine
Shock
Recognizing shock

Neurologic
- Restlessness
- Anxiety
- Lethargy
- Confusion

Respiratory
- Rapid breathing
- Shallow respiration

Cardiovascular
- Tachycardia
- Thready pulse
- Low cardiac output
- Low blood pressure

Metabolism
- Low temperature
- Thirst
- Acidosis
- Low urine output

Skin
- Pale
- Clammy
- Cool
Hypovolemic shock
Causes

• Hemorrhagic
  • Trauma
  • GI bleed

• Non-hemorrhagic
  • Absolute fluid loss (renal, GI)
  • Redistributive or third spacing
### Hypovolemic/hemorrhagic shock

#### Table 8.4

**Classification of Hemorrhagic Shock**

<table>
<thead>
<tr>
<th>Blood loss (mL)</th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
<th>Class IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 750</td>
<td>750–1,500</td>
<td>1,500–2,000</td>
<td>&gt;2,000</td>
<td></td>
</tr>
<tr>
<td>Blood loss (%)</td>
<td>Up to 15</td>
<td>15–30</td>
<td>30–40</td>
<td>40</td>
</tr>
<tr>
<td>Heart rate</td>
<td>&lt;100</td>
<td>&gt;100</td>
<td>&gt;120</td>
<td>&gt;140</td>
</tr>
<tr>
<td>Blood pressure</td>
<td>Normal</td>
<td>Normal</td>
<td>Decreased</td>
<td>Decreased</td>
</tr>
<tr>
<td>Pulse pressure</td>
<td>Normal</td>
<td>Decreased</td>
<td>Decreased</td>
<td>Decreased</td>
</tr>
<tr>
<td>Respiratory rate</td>
<td>14–20</td>
<td>20–30</td>
<td>30–40</td>
<td>&gt;35</td>
</tr>
<tr>
<td>Urine output (mL/h)</td>
<td>&gt;30</td>
<td>20–30</td>
<td>5–15</td>
<td>Minimal</td>
</tr>
<tr>
<td>Mental status</td>
<td>Normal</td>
<td>Mildly anxious</td>
<td>Anxious and confused</td>
<td>Confused and lethargic</td>
</tr>
<tr>
<td>Fluid replacement</td>
<td>Crystalloid</td>
<td>Crystalloid</td>
<td>Crystalloid and blood</td>
<td>Crystalloid and blood</td>
</tr>
</tbody>
</table>
Cardiogenic shock
Causes

• Myocardial
  • Ischemia
  • Infarction
  • Contusion

• Valvular
  • Infection
  • Ruptured papillary muscle
  • Stenosis

• Arrhythmia
Obstructive shock

Tension Pneumothorax
Air enters the pleural space, compresses the lung, and shifts the mediastinum.

Tracheal Deviation

Hyperresonance

Decreased Breath Sounds

Whisper...

Treated with needle decompression in the 2nd intercostal space at the midclavicular line, followed by tube thoracostomy.

Is the chest tube in yet?!
Causes

• Tension pneumothorax

• Cardiac tamponade
  • Beck’s Triad
    • Hypotension
    • Muffled heart sounds
    • JVD

• Positive pressure ventilation

• Mediastinal tumor
Distributive shock

- Septic
- Anaphylactic
  - Drugs
  - Venoms
- Neurogenic
  - Spinal cord injury
### TABLE I: Commonly used inotropic and vasopressor medications

<table>
<thead>
<tr>
<th>Medication</th>
<th>Dose range</th>
<th>Mechanism</th>
<th>Indications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norepinephrine</td>
<td>1-20 μg/min</td>
<td>$\alpha_1, \alpha_2, \beta_1$</td>
<td>Inotrope and vasoconstrictor</td>
</tr>
<tr>
<td>Epinephrine</td>
<td>1-20 μg/min</td>
<td>$\alpha_1, \alpha_2, \beta_1, \beta_2$</td>
<td>Inotrope and vasoconstrictor</td>
</tr>
<tr>
<td>Dopamine</td>
<td>1-20 μg/kg/min</td>
<td>$\alpha_1, \alpha_2, \beta_1, \beta_2, \text{dopamine}$</td>
<td>Inotrope and vasoconstrictor</td>
</tr>
<tr>
<td>Dobutamine</td>
<td>2-20 μg/kg/min</td>
<td>$\beta_1, \beta_2$</td>
<td>Inotrope and vasodilator</td>
</tr>
<tr>
<td>Phenylephrine</td>
<td>20-200 μg/min</td>
<td>$\alpha_1$</td>
<td>Vasoconstrictor</td>
</tr>
<tr>
<td>Isoproterenol</td>
<td>1-20 μg/min</td>
<td>$\beta_1, \beta_2$</td>
<td>Inotrope and chronotrope</td>
</tr>
<tr>
<td>Milrinone</td>
<td>0.25-0.75 μg/kg/min</td>
<td>Phosphodiesterase 3 inhibitor</td>
<td>Inotrope and vasodilator</td>
</tr>
<tr>
<td>Vasopressin</td>
<td>0.01-0.04 U/min</td>
<td>Vasopressin $V_1$ and $V_2$ receptors</td>
<td>Vasoconstrictor in catecholamine-resistant shock</td>
</tr>
</tbody>
</table>
Monitoring the shock state
Hemodynamic monitoring

- Vitals
  - HR
  - BP

- Arterial catheters
  - Continuous monitoring of systemic arterial pressure
  - Frequent arterial blood gas monitoring
  - Complications: infection, thrombosis
  - Radial or dorsalis pedis preferred to brachial or femoral
Central venous catheters

- **Indications**
  - Long term venous access for TPN, vasoactive medications
  - Measure central venous pressure (CVP)
- **Complications**
  - Dysrhythmias
  - Pneumothorax
  - Arterial puncture + intimal flap
  - Pseudoaneurysm
  - Hemorrhage
  - Air embolism
- **CVP monitoring**
  - Assess right heart function
  - Assess volume status
  - ScvO2
Pulmonary arterial catheters
Pulmonary arterial catheters

- Can directly measure:
  - CVP
  - Right arterial pressure
  - Pulmonary arterial pressure
  - Right ventricular end – diastolic pressure
  - Pulmonary capillary wedge pressure
    - Estimation of left ventricular end diastolic pressure
    - Low PCWP indicates low LV end diastolic volume
  - Mixed oxygen saturation
- Measurements provide information on volume status, cardiac performance
- **Current evidence does not demonstrate survival benefit and may be associated with higher morbidity**
Esophageal Doppler
Pulse contour derived cardiac output (FLO TRAC)

• Transducer that can be hooked up to any arterial line

• Uses pressure points and vascular resistance to calculate:
  • Stroke volume
  • Continuous cardiac output
  • Stroke volume variability - % of variability in stroke volume between inspiration and expiration
    • > 13% in a patient with normal lung compliance suggest patient is dry

• Full mechanical ventilation patients with fixed volume and RR only
POCUS

• Safe and effective

• Immediate images that is in real time and dynamic

• Assists in **procedural guidance** → improve success and decrease complications

• **Diagnostic assessment**
  • FAST – intra-abdominal fluid, pericardial fluid
  • Pulmonary assessment – pneumothorax, pleural effusion, consolidation
  • Assessment of volume status
  • Basic assessment of cardiac function
<table>
<thead>
<tr>
<th>Type of Shock</th>
<th>Cardiac Function</th>
<th>IVC</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Septic</td>
<td>Hyperdynamic/</td>
<td>Narrow; collapses with</td>
<td>IV fluids +/- vasopressors</td>
</tr>
<tr>
<td></td>
<td>Hypodynamic</td>
<td>inspiration</td>
<td></td>
</tr>
<tr>
<td>Cardiogenic</td>
<td>Hypodynamic</td>
<td>Dilated; little or no</td>
<td>Inotropes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>collapse with inspir.</td>
<td></td>
</tr>
<tr>
<td>Hypovolemic</td>
<td>Hyperdynamic</td>
<td>Narrow &amp; collapses</td>
<td>IV fluids/blood</td>
</tr>
<tr>
<td>Cardiac Tamponade</td>
<td>Pericardial effusion;</td>
<td>Dilated; no collapse</td>
<td>Pericardiocentesis</td>
</tr>
<tr>
<td>(Obstructive)</td>
<td>diastolic collapse RV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulmonary Embolus</td>
<td>Dilated RA &amp; RV</td>
<td>Dilated; little or no</td>
<td>Thrombolytics</td>
</tr>
<tr>
<td>(Obstructive)</td>
<td></td>
<td>colapse</td>
<td></td>
</tr>
</tbody>
</table>
Resuscitation
Fluid resuscitation

- **Crystalloids**
  - *Lactated ringers*
  - *Normal saline*
  - Isotonic
  - Rapidly replaces interstitial fluid compartment

- **Colloids**
  - *Albumin*
  - Increases oncotic pressure and protects lung from interstitial edema

- **Blood products**
  - pRBC
End points of resuscitation

- Vitals
  - BP
  - HR

- End organ function
  - Urine output
    - 0.5-1 mL/kg/hr for adults
    - 1 mL/kg/hr for kids
    - 1-2 mL/kg/hr in toddlers < 2 yrs of age

- Mental status
End points of resuscitation

• Physiologic biomarkers
  • Lactate
    • Elevation indicates shift from aerobic to anaerobic metabolism due to underperfusion/lack of oxygen delivery
    • Time required to normalize serum lactate = prognostic factor
  • Base deficit
    • Amount of a fixed base that must be added to an aliquot of blood to restore the pH to 7.40
    • Time required to normalize has even greater prognostic significance than that of lactate

• Lactate $\geq 4$ mmol/L or base deficit $\geq 6$ mEq/L should be considered in shock until proven otherwise
Sepsis
SIRS → septic shock

SIRS
- Temp. >38°C or <36°C, HR >90, RR >20 or PaCO₂ <32, WBCs >12,000 or <4,000 or >10% bands

Sepsis
- SIRS + Infection

Severe Sepsis
- Sepsis + End Organ Damage

Septic Shock
- Severe Sepsis + Hypotension
New definitions?

Def’n of sepsis: life-threatening organ dysfunction caused by a dysregulated host response to infection
Def’n of septic shock: subset of sepsis in which particularly profound circulatory, cellular, and metabolic abnormalities are associated with a greater risk of mortality than with sepsis alone
- Vasopressor requirement with maintain a MAP of 65 mmHg
- Serum lactate > 2 mmol/L in the absence of hypovolemia
<table>
<thead>
<tr>
<th>System</th>
<th>Score</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiration</td>
<td></td>
<td>≥400 (53.3)</td>
<td>&lt;400 (53.3)</td>
<td>&lt;300 (40)</td>
<td>&lt;200 (26.7) with respiratory support</td>
<td>&lt;100 (13.3) with respiratory support</td>
</tr>
<tr>
<td>Pao\textsubscript{2}/Fi\textsubscript{O}\textsubscript{2}, mm Hg (kPa)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coagulation</td>
<td></td>
<td>≥150</td>
<td>&lt;150</td>
<td>&lt;100</td>
<td>&lt;50</td>
<td>&lt;20</td>
</tr>
<tr>
<td>Platelets, ×10\textsuperscript{3}/μL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liver</td>
<td></td>
<td>&lt;1.2 (20)</td>
<td>1.2-1.9 (20-32)</td>
<td>2.0-5.9 (33-101)</td>
<td>6.0-11.9 (102-204)</td>
<td>&gt;12.0 (204)</td>
</tr>
<tr>
<td>Bilirubin, mg/dL (μmol/L)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiovascular</td>
<td></td>
<td>MAP ≥70 mm Hg</td>
<td>MAP &lt;70 mm Hg</td>
<td>Dopamine &lt;5 or dobutamine (any dose)\textsuperscript{b}</td>
<td>Dopamine 5.1-15 or epinephrine ≤0.1 or norepinephrine ≤0.1\textsuperscript{b}</td>
<td>Dopamine &gt;15 or epinephrine &gt;0.1 or norepinephrine &gt;0.1\textsuperscript{b}</td>
</tr>
<tr>
<td>Central nervous system</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glasgow Coma Scale score\textsuperscript{c}</td>
<td>15</td>
<td>13-14</td>
<td>10-12</td>
<td>6-9</td>
<td>&lt;6</td>
<td></td>
</tr>
<tr>
<td>Renal</td>
<td></td>
<td>&lt;1.2 (110)</td>
<td>1.2-1.9 (110-170)</td>
<td>2.0-3.4 (171-299)</td>
<td>3.5-4.9 (300-440)</td>
<td>&gt;5.0 (440)</td>
</tr>
<tr>
<td>Creatinine, mg/dL (μmol/L)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urine output, mL/d</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;500</td>
<td>&lt;200</td>
</tr>
</tbody>
</table>

Abbreviations: Fi\textsubscript{O}\textsubscript{2}, fraction of inspired oxygen; MAP, mean arterial pressure; Pao\textsubscript{2}, partial pressure of oxygen. \textsuperscript{a} Adapted from Vincent et al.\textsuperscript{27} \textsuperscript{b} Catecholamine doses are given as μg/kg/min for at least 1 hour. \textsuperscript{c} Glasgow Coma Scale scores range from 3-15; higher score indicates better neurological function.
Screening

Box 4. qSOFA (Quick SOFA) Criteria

- Respiratory rate $\geq 22$/min
- Altered mentation
- Systolic blood pressure $\leq 100$ mm Hg
The baseline Sequential [Sepsis-related] Organ Failure Assessment (SOFA) score should be assumed to be zero unless the patient is known to have preexisting (acute or chronic) organ dysfunction before the onset of infection. qSOFA indicates quick SOFA; MAP, mean arterial pressure.
A Randomized Trial of Protocol-Based Care for Early Septic Shock

The ProCESS Investigators*

ABSTRACT

Goal-Directed Resuscitation for Patients with Early Septic Shock

The ARISE Investigators and the ANZICS Clinical Trials Group*
Surviving Sepsis Campaign: Association Between Performance Metrics and Outcomes in a 7.5-Year Study

Mitchell M. Levy, MD, FCCM; Andrew Rhodes, MB BS, MD (Res); Gary S. Phillips, MAS; Sean R. Townsend, MD; Christa A. Schorr, RN, MSN; Richard Beale, MB BS; Tiffany Osborn, MD, MPH; Stanley Lemeshow, PhD; Jean-Daniel Chiche, MD; Antonio Artigas MD, PhD; R. Phillip Dellinger, MD, FCCM

**TO BE COMPLETED WITHIN 3 HOURS:**

1) Measure lactate level
2) Obtain blood cultures prior to administration of antibiotics
3) Administer broad spectrum antibiotics
4) Administer 30 ml/kg crystalloid for hypotension or lactate ≥4mmol/L

**TO BE COMPLETED WITHIN 6 HOURS:**

5) Apply vasopressors (for hypotension that does not respond to initial fluid resuscitation) to maintain a mean arterial pressure (MAP) ≥65 mm Hg
6) In the event of persistent arterial hypotension despite volume resuscitation (septic shock) or initial lactate ≥4 mmol/L (36 mg/dL):
   - Measure central venous pressure (CVP)*
   - Measure central venous oxygen saturation (ScvO2)*
7) Remeasure lactate if initial lactate was elevated*
Respiratory Failure
Acute respiratory failure

Def’n: respiratory system failure or dysfunction resulting in abnormalities of gas exchange, including oxygenation and/or CO2 elimination

Common etiologies include:
- Pneumonia
- Atelectasis
- Aspiration
- Pulmonary edema
- ARDS
- PE
Classification

**Hypoxemic respiratory failure (type I):** PaO2 < 60 mmHg on room air
- Most common form of respiratory failure
- Major immediate threat to organ function

**Hypercapnic respiratory failure (type II):** PaCO2 > 50 mmHg on room air

**Acute lung injury and ARDS**

<table>
<thead>
<tr>
<th>TABLE 9.3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RECOMMENDED CRITERIA FOR ACUTE LUNG INJURY AND ACUTE RESPIRATORY DISTRESS SYNDROME</strong>&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TIMING</th>
<th>OXYGENATION</th>
<th>CHEST RADIOGRAPH</th>
<th>PULMONARY ARTERY WEDGE PRESSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute lung injury (ALI)</td>
<td>Acute onset</td>
<td>PaO$_2$/FiO$_2$ $\leq$ 300 regardless of PEEP level</td>
<td>$\leq$ 18 when measured or no clinical evidence of left atrial hypertension</td>
</tr>
<tr>
<td>Acute respiratory distress syndrome (ARDS)</td>
<td>Acute onset</td>
<td>PaO$_2$/FiO$_2$ $\leq$ 200 regardless of PEEP level</td>
<td>Bilateral infiltrates on frontal chest radiograph</td>
</tr>
</tbody>
</table>
ARDS

FiO₂ = Fraction of inspired oxygen
- Atmospheric air is 20% O₂ but we often give supplemental O₂

PaO₂ = partial pressure of oxygen in arterial blood

PaO₂/FiO₂ ratio = oxygen level in the blood (arterial) to oxygen concentration that is breathed
- Helps determine problems with oxygen exchange/ventilation
- > 500 is normal

---

**TABLE 6: New acute respiratory distress syndrome “Berlin” definition 2012**

<table>
<thead>
<tr>
<th>Acute respiratory distress</th>
<th>Syndrome (ARDS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timing</td>
<td>Within 1 week of a known clinical insult or new or worsening respiratory symptoms (<em>New addition, AECC stated “acute onset” with no definition</em>)</td>
</tr>
<tr>
<td>Chest imaging</td>
<td>Bilateral opacities on chest radiograph or chest computed tomographic scan (<em>No change from AECC definition</em>)</td>
</tr>
<tr>
<td>Origin of edema</td>
<td>Respiratory failure not fully explained by cardiac failure or fluid overload (<em>No change from AECC definition, but removed pulmonary artery wedge pressure criterion from definition given declining use of PA catheters</em>)</td>
</tr>
<tr>
<td>Oxygenation</td>
<td></td>
</tr>
<tr>
<td>Mild</td>
<td>PaO₂/FiO₂ ratio 201-300 mm Hg with PEEP or CPAP ≥ 5 cm H₂O (<em>The term “acute lung injury, ALI” in AECC definition was removed, and added a minimum level of PEEP</em>)</td>
</tr>
<tr>
<td>Moderate</td>
<td>PaO₂/FiO₂ ratio 101-200 mm Hg with PEEP ≥ 5 cm H₂O</td>
</tr>
<tr>
<td>Severe</td>
<td>PaO₂/FiO₂ ratio ≤ 100 mm Hg with PEEP ≥ 5 cm H₂O</td>
</tr>
</tbody>
</table>
Prevention

Preoperative
• Smoking cessation 8 weeks prior to surgery
• Optimization of chronic pulmonary diseases

Intraoperative
• Regional anesthesia if possible

Postoperative
• Adequate pain control
• Prevention of aspiration
• Deep breathing exercises
• Chest physio/incentive spirometry
Noninvasive ventilation

- Provides positive pressure ventilation without the need for an invasive airway
- First line in ARF due to COPD exacerbation
  - Lower mortality rates
  - Decreased need for intubation
  - Less complications
  - Reduced length of hospital stay
- Safe for adult patients with ARF due to acute cardiogenic pulmonary edema
Intubation & mechanical ventilation

**Volume modes:** tidal volume is set and airway pressure is variable (depends on pulmonary compliance and airway resistance)

1. Controlled mechanical ventilation (CMV)
2. Assist-control ventilation (ACV)
3. Synchronous intermittent mandatory ventilation (SIMV)

**Pressure modes:** airway pressure is set and tidal volume is variable

1. Pressure control ventilation (PCV)
2. Pressure support ventilation (PSV)
3. Pressure regulated volume control (PRVC)
4. Airway pressure release ventilation (APRV)
Management

Tidal volume: 6 mL/kg
**ECMO**

**VV ECMO:** removes deoxygenated blood from the venous circulation, removes CO2, and oxygenates the blood and returns it to the right atrium and ventricle.

**Indication:** any adult patient suffering from acute onset and potentially reversible severe respiratory failure with significant hypoxia or hypercarbia despite maximal ventilator management.
## Tracheostomy

**Advantages**
- Patient comfort
- Decreased nursing care
- Better patient communication
- Decrease the need for ventilator dependence
- Decreases risk of subglottic stenosis

### TABLE 1: Indications for tracheostomy or cricothyroidotomy

<table>
<thead>
<tr>
<th>Indication</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilator dependence</td>
<td>Facilitation of ventilation support</td>
</tr>
<tr>
<td></td>
<td>Prolonged intubation</td>
</tr>
<tr>
<td>Airway obstruction</td>
<td>Anatomic abnormalities</td>
</tr>
<tr>
<td></td>
<td>Angioedema</td>
</tr>
<tr>
<td></td>
<td>Burns</td>
</tr>
<tr>
<td></td>
<td>Failed intubation</td>
</tr>
<tr>
<td></td>
<td>Infection leading to obstruction</td>
</tr>
<tr>
<td></td>
<td>Laryngeal dysfunction</td>
</tr>
<tr>
<td></td>
<td>Neck irradiation</td>
</tr>
<tr>
<td></td>
<td>Neoplasm</td>
</tr>
<tr>
<td></td>
<td>Neurologic dysfunction or injury</td>
</tr>
<tr>
<td></td>
<td>Obstructive sleep apnea</td>
</tr>
<tr>
<td></td>
<td>Postoperative</td>
</tr>
<tr>
<td></td>
<td>Traumatic obstruction</td>
</tr>
<tr>
<td>Pulmonary toilet</td>
<td>Aspiration</td>
</tr>
<tr>
<td></td>
<td>Excessive bronchopulmonary secretions</td>
</tr>
</tbody>
</table>
# Complications

<table>
<thead>
<tr>
<th>Early (within 7 days)</th>
<th>Late (after 7 days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Bleeding</td>
<td>• Laryngotracheal stenosis</td>
</tr>
<tr>
<td>• Pneumothorax</td>
<td>• Tracheoinominate fistula</td>
</tr>
<tr>
<td>• Pneumomediastinum</td>
<td>• Tracheoesophageal fistula</td>
</tr>
<tr>
<td>• Subcutaneous emphysema</td>
<td>• Tracheomalacia</td>
</tr>
<tr>
<td>• Infection</td>
<td>• Vocal cord paralysis (rare)</td>
</tr>
<tr>
<td>• Loss of airway (accidental decannulation)</td>
<td></td>
</tr>
<tr>
<td>• Airway obstruction</td>
<td></td>
</tr>
</tbody>
</table>
Decannulation

- Off ventilator for at least 48 hours
- Little secretion/suction requirement
- Downsize – after 7-10 days until stoma track is well formed
- Trial capped period 24-48 hours
Abdominal Compartment Syndrome
Abdominal compartment syndrome

• Normal intra-abdominal pressure is **5-7 mmHg** in a closed abdomen

• Gold standard measurement is bladder pressure
  • End expiration
  • Supine
  • Relaxed/sedated state
  • Instill 25cc NS
  • Measure 30-60 sec after instillation
Causes of increased abdominal pressure

- Intra-abdominal hemorrhage or ascites
- Circumferential torso burn
- Reduction of large ventral hernia
- Bowel distension
- Pneumoperitoneum

- **Secondary ACS** – in the absence of abdominopelvic pathology and is entirely caused by edema following shock and aggressive resuscitation
Intra-abdominal hypertension

- IAP > 12 mmHg

<table>
<thead>
<tr>
<th>Grade</th>
<th>IAH Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>IAP 12-15 mmHg</td>
</tr>
<tr>
<td>II</td>
<td>IAP 16-20 mmHg</td>
</tr>
<tr>
<td>III</td>
<td>IAP 21-25 mmHg</td>
</tr>
<tr>
<td>IV</td>
<td>IAP &gt;25 mmHg</td>
</tr>
</tbody>
</table>
Systemic effects of IAH

CNS
- ↑ ICP
- ↓ CPP

Cardiovascular
- Hypovolemia
- ↓ venous return
- ↓ CO
- ↑ SVR
- ↑ PAOP, CVP

Hepatic
- ↓ portal blood flow
- ↓ lactate clearance

Gastrointestinal
- ↓ celiac / SMA blood flow

Pulmonary
- ↑ PIP, Paw
- ↑ Qs/Qt, Vd/Vt
- ↓ compliance/lung volume
- Atelectasis
- Hypoxia
- Hypercarbia

Thoracoabdominal
- Elevated diaphragm
- ↑ intrathoracic pressure
- IVC distortion
- ↓ wall compliance
- ↓ abd wall blood flow

Renal
- ↓ renal blood flow
- ↓ UOP
- ↓ GFR

Courtesy of Dr. Mele/Parry
Abdominal compartment syndrome

• Sustained elevated IAP > **20 mmHg** associated with new end organ damage/failure

• **Triad of ACS**
  • IAP > 20 mmHg
  • Adverse effect on end-organ(s)
  • Abdominal decompression has beneficial effects
Patient has IAP ≥ 12 mmHg
Begin medical management to reduce IAP
(GRADE 1C)

Measure IAP at least every 4-6 hours or continuously.
Titrated therapy to maintain IAP ≤ 15 mmHg (GRADE 1C)

Evacuate intraluminal contents

- Insert nasogastric and/or rectal tube
- Initiate gastro-/colo-prokinetic agents (GRADE 2D)

Evacuate intra-abdominal space occupying lesions

- Abdominal ultrasound to identify lesions
- Minimize enteral nutrition (GRADE 1D)
- Administer enemas (GRADE 1D)
- Consider colonoscopic decompression (GRADE 1D)

Improve abdominal wall compliance

- Ensure adequate sedation & analgesia (GRADE 1D)
- Remove constrictive dressings, abdominal eschars
- Percutaneous catheter drainage (GRADE 2C)
- Consider surgical evacuation of lesions (GRADE 1D)

Optimize fluid administration

- Avoid excessive fluid resuscitation (GRADE 2C)
- Aim for zero to negative fluid balance by day 3 (GRADE 2C)
- Resuscitate using hypertonic fluids, colloids
- Fluid removal through judicious diuresis once stable

Optimize systemic / regional perfusion

- Goal-directed fluid resuscitation
- Hemodynamic monitoring to guide resuscitation
- Consider hemodialysis / ultrafiltration

Step 4

If IAP > 20 mmHg and new organ dysfunction / failure is present, patient’s IAH / ACS is refractory to medical management. Strongly consider surgical abdominal decompression (GRADE 1D).
CCTC

- Sept 9, 2015 - Dec 31, 2015
- 45 ± 6% prevalence of IAH
- 55% had Grade I IAH
- 8/128 (6.25%) developed ACS
- IAH was an independent predictor of ICU mortality

Courtesy of Pat Murphy
Nutrition
Nutrition in the critically ill

• Sources of energy
  • Carbohydrates
    • Brain cells and red blood cells are obligate users of glucose
  • Fat
  • Protein
• Starvation adaptation
  • Brain cells and RBCs develop the capacity to use ketones as an energy source
  • Proteins are a significant energy source in critically ill patients
Basal metabolic rate

Harris-Benedict equation

Women:
\[
\text{BEE} = 655 + (9.6 \times \text{weight in kilos}) \\
+ (1.8 \times \text{height in cm}) - (4.7 \times \text{age in years})
\]

Men:
\[
\text{BEE} = 66 (13.7 \times \text{weight in kilos}) \\
+ (5 \times \text{height in cm}) - (6.8 \times \text{age in years})
\]

- Basal requirements in healthy adults are typically in the range of **25 kcal/kg/day**
- The critically ill patient requires ~ **35 kcal/kg/day**
**TABLE 9.4**

PREDICTED INCREASE IN CALORIC REQUIREMENTS AS A FUNCTION OF STRESSOR

<table>
<thead>
<tr>
<th>Physiologic Stress</th>
<th>Stress Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation</td>
<td>1.1</td>
</tr>
<tr>
<td>Peritonitis, major infection, or long bone fracture</td>
<td>1.25</td>
</tr>
<tr>
<td>Severe injury/infection or multiple organ failure</td>
<td>1.5</td>
</tr>
<tr>
<td>Thermal injury</td>
<td></td>
</tr>
<tr>
<td>10% BSA</td>
<td>1.25</td>
</tr>
<tr>
<td>20%–30% BSA</td>
<td>1.5</td>
</tr>
<tr>
<td>40% BSA</td>
<td>1.75</td>
</tr>
<tr>
<td>&gt;50% BSA</td>
<td>2.0</td>
</tr>
</tbody>
</table>

BSA, body surface area.
Indirect calorimetry

• More accurate measurement of energy expenditure

• Uses O2 uptake

• Burning 1 kcal requires ~ 200mL of oxygen
Protein metabolism

• In normal metabolism, protein catabolism occurs but the amino acids get recycled into making new protein

• In starvation/critical illness → protein catabolism occurs without corresponding protein intake → negative protein balance

• In starvation, carbohydrates get utilized first and the body turns to protein for energy

• Acute inflammation and surgical wounds divert protein from other body tissues
  • Proteins that would otherwise strengthen the diaphragm or myocardium or participate in host defense are less available
Measuring protein reserve

- We can measure body substances that are maintained by rapid protein synthesis

  - **Prealbumin** (1/2 life = 2 days)
    - Negative acute phase reactant
  
  - Retinal binding protein (1/2 life = 10 days)
  
  - Transferrin (1/2 life = 8 days)
  
  - Albumin (1/2 life = 21 days)
  
  - IGF1
    - Relative independence of the inflammatory state of the patient
Nutritional support

• **Goal:** provide sources of energy so that endogenous proteins are not required for energy

• **Early enteral nutrition** (within 36 hrs of admission) has been shown to be associated with significantly lowered risk of infection and a shorter hospital length of stay

• If risk of aspiration → post-pyloric feeds
  • Prokinetics may help but there’s no evidence for routine use

• Feeds should be given by continuous infusion rather than large boluses
TPN

• Indications
  • non-stressed patient with severe protein calorie malnutrition, scheduled to undergo surgery
    • TPN given 7 days before surgery is associated with decrease in infection rates
  • Patient with short gut syndrome → bridge to intestinal transplantation or nutritional supplementation
  • Failure of oral or enteral nutrition
Immunonutrition

• There are immune-modulating enteral formulas that contain pharmacologic properties which **enhance immune function** and **decrease inflammation**

• More expensive, so should be reserved for patient population at need
  • Patients who have undergone major gastrointestinal surgery
  • Trauma patients
  • Burn patients (TSA > 30%)
  • Head and neck cancer patients
  • Patients requiring mechanical ventilation

• Major components that contribute to immune enhancement include:
  • Arginine
  • Omega 3 fatty acids
  • Glutamine
References

- Greenfields ch. 8 shock
- Greenfields ch. 9 surgical critical care
- Cameron chapter on surgical critical care
- Sabiston ch. 23 surgical critical care
- World Society of Abdominal Compartment Syndrome