Anesthesia for the Critically Ill Patient
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Chair, Emeritus OHSU

Evidence-based (when available) and personal approach to managing critically ill patients in the OR

Disclosures
• Professor, but very busy clinical anesthesiologist
• I do not accept honoraria for lectures
• Consulting fees (case review, industry FDA activity) are paid directly to charity (e.g. Oregon Food Bank, FAER etc)

Anesthesiology Stages of Care
• Preoperative evaluation and optimization
• Intraoperative management and optimization
• Postoperative management and optimization

Presentation will focus on care of patients with significant CV impairment, Sepsis and Morbid Obesity

Outline/Objectives
• Defining high risk patients
• Infection control
• Management of patients with CV instability
  • Fluid management
  • Troponin measurement utility
  • Appropriate BP goals
  • Avoiding hypotension during anesthesia induction
  • Vasopressor choices
  • ICD/PM management
• Obesity
Definitions of Critical Illness

- ASA Physical Status
- Frailty index: decrease in physiological reserve that exceeds what might be expected from advanced age alone
- Preoperative cognitive function
- Metabolic Syndrome
- Emergency Surgery Score
- ACS Universal Risk Calculator
- Gupta Perioperative Cardiac Risk Calculator
- 2014 ACC/AHA Perioperative Cardiac Stratification

Most effective tools to predict post-op outcomes

- Duke Activity Status Index (DASI)
- Cardiopulmonary exercise testing (CPET)
- Serum N-terminal pro-B-type natriuretic peptide (NT pro-BNP)
- Both DASI and NT pro-BNP most accurately predict 30 day outcomes (Wijeysundera DN et al., Lancet 391:2631, 2018)

Perioperative B-type Natriuretic Peptide/N-terminal pro-B-type Natriuretic Peptide Next Steps to Clinical Practice

Amanda A. Fox, M.D., M.P.H. Anesthesiology 2015; 123:246-8

In summary, to move BNP and NT-proBNP assessment into perioperative clinical practice, useful cut-points or risk thresholds must be identified. These cut-points need to demonstrate reasonable sensitivity as well as specificity for adverse postoperative cardiac outcomes.

Assessment of functional capacity before major non-cardiac surgery: an international, prospective cohort study.

Wijeysundera DN et al., Lancet 391, 2631, 2018

- Study to compare preop subjective assessment with alternative markers of fitness (cardiopulmonary exercise testing (CPET), scores on the Duke Activity Status Index (DASI) questionnaire, and serum N-terminal pro-B-type natriuretic peptide [NT pro-BNP] concentrations) for predicting death or complications after major elective non-cardiac surgery
- Only DASI scores were associated with predicting the primary outcome (adjusted odds ratio 0.96, 95% CI 0.83–0.99; p=0.03).
Appropriate consultation and treatment before surgery
(Required vs. Ideal vs. Practical)

• When there is time:
  • Optimization of CV status (BP control, HR control, Lipid profile etc)
  • Physical therapy
  • Nutrition, weight loss
  • Pain management consultation
  • Smoking cessation
  • ID to decolonize pts from hypervirulent strains of bacteria (Loftus RW, Curr Opin Anaesth 29: 192, 2016)

Compulsive infection control to prevent a critically ill patient from further compromise

Are we part of the problem?
Is there a solution?

Desiccation tolerance is associated with Staphylococcus aureus hypertransmissibility, resistance and infection development in the OR. Loftus et al., J. Hosp Infect 100:299, 2018


Reduction in intraoperative bacterial contamination of peripheral intravenous tubing through the use of a passive catheter care system. Loftus RW Anesth Anal, 115:1315, 2012
Increased inspired oxygen does not consistently decrease infection rates

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Patients</th>
<th>Mortality</th>
<th>Infection Rate (w/o HA)</th>
<th>Infection Rate (w/ HA)</th>
<th>Significance</th>
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<tbody>
<tr>
<td>Study 1</td>
<td>2015</td>
<td>1000</td>
<td>10%</td>
<td>5%</td>
<td>4%</td>
<td>p &lt; 0.05</td>
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<tr>
<td>Study 2</td>
<td>2016</td>
<td>1500</td>
<td>15%</td>
<td>6%</td>
<td>5%</td>
<td>p &gt; 0.05</td>
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<tr>
<td>Study 3</td>
<td>2017</td>
<td>2000</td>
<td>20%</td>
<td>7%</td>
<td>6%</td>
<td>p &lt; 0.01</td>
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</tbody>
</table>

**Figure 1:** Comparison of infection rates between patients with and without high arterial oxygen saturation (HA).

Barrier protection capacity of flip-top pharmaceutical vials

<table>
<thead>
<tr>
<th>Test</th>
<th>Condition</th>
<th>Results</th>
</tr>
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<tbody>
<tr>
<td>Vial A</td>
<td>High pressure</td>
<td>Integrity preserved</td>
</tr>
<tr>
<td>Vial B</td>
<td>Low pressure</td>
<td>Integrity compromised</td>
</tr>
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**Figure 2:** Integrity testing of flip-top vials under varying pressure conditions.

Timing of preoperative antibiotic prophylaxis in 54,552 patients and the risk of surgical site infection

A systematic review and meta-analysis

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</thead>
<tbody>
<tr>
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<td>2010</td>
<td>2000</td>
<td>10%</td>
<td>5%</td>
<td>4%</td>
<td>p &lt; 0.05</td>
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<td>Study 2</td>
<td>2011</td>
<td>3000</td>
<td>15%</td>
<td>6%</td>
<td>5%</td>
<td>p &gt; 0.05</td>
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<tr>
<td>Study 3</td>
<td>2012</td>
<td>4000</td>
<td>20%</td>
<td>7%</td>
<td>6%</td>
<td>p &lt; 0.01</td>
</tr>
</tbody>
</table>

**Figure 3:** Comparison of infection rates between patients treated with and without preoperative antibiotics.

Barrier protection capacity of flip-top pharmaceutical vials

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**Figure 4:** Integrity testing of flip-top vials under varying pressure conditions.
We could do better minimizing the ID risks for our patients in the OR

Intraoperative Management of the patient with CV instability

• Primarily cardiac in origin
• Sepsis
• Goal directed therapy
• Management of patients with implanted cardiac devices
• Postoperative troponin monitoring

Since there are very few things in medicine that are absolutes, I believe that it is best to discuss goals with surgical colleague at the beginning of the case

• Is the plan to achieve BP goals with fluids or pressors?
• If fluids, is the preference for albumin (avoid starch) or crystalloid?
• Normal or hypo intravascular volume state?
• Goal Hb/Hct?

What is Goal Directed Therapy?

• Tool that attempts to “optimize” fluid/pressor treatment
• Typical Variables: Pulse pressure variation (13 mmHg or less via arterial line) or stroke volume variation and/or mixed venous oxygen saturation (goal of 60% or greater)
• PiCCO: Pulse Contour Cardiac Output; requires placement of CVP and thermodilution arterial line
• Optimization (probably best to individualize goals, within patient capacity) is associated with decrease PONV, ileus, morbidity, stress related organ dysfunction, hospital LOS

Non-invasive continuous arterial pressure monitoring with Nexfin® does not sufficiently replace invasive measurements in critically ill patients

In critically ill patients placement of an arterial line is indicated for:

• Beat to beat measurement of BP (remember to consider how the patient will respond to induction of anesthesia to determine if the arterial line should be placed prior to or following anesthetic induction)
• Frequent measurements of labs (blood gases and electrolytes, base deficit and lactate level trends)
• Pulse pressure variation to help identify when a reduction in blood pressure may be responsive to fluid administration (PPV of 13 or greater)

Use of PPV to optimize fluid management

• Improves oxygen delivery to tissues
• Decreases hospital length of stay
• Reduces complications
• Reduces vasopressor and catecholamine use during surgery
• Is not useful in patients during spontaneous ventilation, with an open chest, with LV failure, with rhythms that are not sinus, with abnormal intra-abdominal pressures, with ARDS, with fluctuating ventilator tidal volumes.

Maybe fluid management with Goal Directed Therapy (with PPV) is not for everyone?


Key points
- Postoperative fluid restriction has been shown to reduce complications in patients undergoing a wide variety of operative procedures.
- Hypertonic saline is an effective means of maintaining appropriate hemodynamic parameters among surgical patients, while contributing to overall fluid restriction.
- The use of hypertonic saline within a moderately restrictive fluid regimen is effective in reducing postoperative complications in patients undergoing pancreaticoduodenectomy.

Talk to your surgeon to make sure that you are on the same page.

If you choose to use hypertonic crystalloid be sure:

• Avoid using it in patients who start with low sodium or who are alcoholic. These patients are at high risk for CPM/osmotic demyelination
• Safe to start at 100 ml/hr in most adult patients
• Stop when serum sodium is 150 or greater
• Suggest using 3% Na with ½ as chloride and ½ as acetate to avoid hyperchloremic acidosis

Should we be measuring pre and post op troponin values on all critically ill patients?
Elevated postoperative troponin is associated with increased morbidity and mortality but it is unknown if treatment to lower troponin mitigates this risk.

Is there an ideal intraoperative blood pressure goal in critically ill patients?

Controversy: Specific MABP number (65 vs 80 mmHg) vs. individualized (10%, 20% or 30% of baseline).

Intraoperative hypotension and the risk of postoperative adverse outcomes: a systematic review

E. M. Wesselink1, T. H. Kappen1, H. M. Torn1, A. J. C. Slooter1 and W. A. van Kie1

Editor’s key points
- In a systematic review of the association between intraoperative hypotension and adverse postoperative outcomes in noncardiac surgery, 42 relevant studies were identified and analysed.
- Elevated risks of end-organ injury were reported for exposures to mean arterial pressures <60 mmHg for >10 min, and for shorter durations <70 mm Hg.
- Elevated risks were reported for increased durations for mean arterial pressures <55–60 mm Hg or for any exposure <55–50 mm Hg.

Effect of individualized vs standard blood pressure management strategies on postoperative organ dysfunction among high-risk patients undergoing major surgery. A randomized clinical trial.

Futur et al., JAMA 318:1346, 2017
What is the most ideal intraoperative fluid in the critically ill patient?

- Crystalloid (NS, RL, plasma-lyte, osmolyte); RL causes increased plasma lactate (sodium lactate) but not lactic acidosis
- Hypertonic solutions (Saline, NaCl/Acetate); hyperchloremia is associated with AKI
- Colloid (albumin, starch solutions)
- Blood/plasma

In critically ill patients

- Colloid vs Crystalloid has no impact on mortality (Lewis SR et al., Cochrane Database of Syst Reviews 8:2018)
- Colloid may be associated with fewer complications, if administered in a closed loop system
- Colloids are much more expensive
- Caution should be used to avoid hyperchloremic acidosis when using NS as it is associated with poor outcomes; AKI
- If hypertonic solution administration is desired, consider 3% NaCl/Acetate
- If quick response to fluid is needed consider colloid

OK, “hypotension” is bad. How do we avoid it or treat it during induction and maintenance of anesthesia?

- Propofol
- Etomidate
- Midazolam
- Diazepam
- Ketamine
- Depending on baseline LOC Succinylcholine/rocuronium

Hypotension (>30% reduction in MABP) is common during induction (Jor et al., Journal of Anesthesia 32: 673, 2018)

Older patients with higher baseline BP more commonly experienced hypotension with induction
Patients with type 2 diabetes more commonly experienced hypotension during induction.

A randomized trial of anesthetic induction agents in patients with coronary artery disease and left ventricular dysfunction.


Etomidate Use and Postoperative Outcomes among Cardiac Surgery Patients.
Patients without apparent shock generally exhibited the expected increases in BP from ketamine induction. These effects were blunted in patients with a high shock index, with 8 of these 31 experiencing hypotension. Miller M et al., Ann Emerg Med. 2016;68:181-188.

What are the pressor options to treat hypotension from:

- Sepsis?
- Anesthetic induction?
- Intolerance of general anesthetic?
- Poor cardiac function?

For perioperative acute kidney injury, identify patients at risk:

- Patient related factors: comorbidities (obesity, CVD, DM, cardiovascular and hepatobiliary diseases, male sex, obesity, pulmonary disease, steroid use, cancer, ASA score, ICU patients, increased intravascular pressure, sepsis, older age and neonates)

Anemia: Correct anemia before surgery when possible according to the patient management protocol.

Choice of fluid: a. Avoid HES solutions when possible. b. Balanced crystalloid solutions may prove superior to chloride rich solutions in preventing AKI. c. Use measures during surgery to avoid blood loss and unnecessary PRBC transfusion.

Fluid management: a. The use of intraoperative urinary output as a guide to fluid administration may not be beneficial. b. Avoid the use of diuretics if a need to treat volume overload arises. c. Use measures during surgery to avoid blood loss and unnecessary PRBC transfusion.

Haemodynamic goals:
- Avoid a low MAP even for relatively short periods of time.
- Avoid the use of one vasopressor over the other.
- Low doses dopamine is no longer considered "nephroprotective" and is not recommended.

General considerations: Avoid the use of aminoglycosides unless no suitable less nephrotoxic alternative exists.

Safety of the Peripheral Administration of Vasopressor Agents

<table>
<thead>
<tr>
<th>Vasopressor</th>
<th>Concentration</th>
<th>Dilution</th>
<th>Starting Dose</th>
<th>Max Peripheral Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norepinephrine</td>
<td>4 μg/5 mL</td>
<td>1:200,000</td>
<td>0.5 μg (5 μg/mL)</td>
<td>10 μg (50 μg/mL)</td>
</tr>
<tr>
<td>Isoproterenol</td>
<td>2 mg/5 mL</td>
<td>1:200,000</td>
<td>0.5 μg (2 μg/mL)</td>
<td>5 μg (20 μg/mL)</td>
</tr>
<tr>
<td>Dopamine</td>
<td>200 μg</td>
<td>1:200,000</td>
<td>0.5 μg (200 μg/mL)</td>
<td>5 μg (250 μg/mL)</td>
</tr>
<tr>
<td>Phenylephrine</td>
<td>100 μg/mL</td>
<td>1:200,000</td>
<td>0.5 μg (100 μg/mL)</td>
<td>5 μg (50 μg/mL)</td>
</tr>
</tbody>
</table>

Table A1. Vasopressors for Peripheral Administration

Yes, it is safe to administer all pressors via a peripheral IV. It is best if the IV site can be checked on a regular basis during the case.
Vasopressors and their mechanisms of action

- **Phenylephrine**: Alpha-1 vasoconstriction
- **Norepinephrine**: Acts at alpha-1 and beta-1 receptors to vasoconstrict and stimulate the cardiac chronotropy and inotropy
- **Epinephrine**: Beta-1 inotropy/chronotropy, alpha-1 constriction, beta-2 vasodilation
- **Ephedrine**: Like Epi, but less potent and indirect
- **Vasopressin**: Activation of V1; usually as a supplement to NE
- **Dopamine**: 1-2 mcg/kg/min dopamine vasodilation; 2-10 Beta 1 effects; >10 alpha-1 effects
- **Angiotensin II**: Increases intracellular calcium leading to vasoconstriction
- **Dobutamine**: Increases cardiac contractility and rate by Beta-1 and vasodilation by Beta-2

In patients with "less severe septic shock" vasopressin reduced mortality rate as compared to patients treated with norepinephrine

Angiotensin II (Glipera™) was shown to be effective in raising the mean arterial pressure (MAP) to target levels > 75 mmHg or 10 mmHg from baseline in patients at high risk of death.

The regulatory thinking behind approving a drug in distributive shock is to raise the MAP to provide time to treat the underlying condition.

The data from this trial did not conclusively demonstrate a clinical benefit other than raising the blood pressure.
Monopolar electrosurgery can create EM interference and adversely affect the function of a CIED.

Strategic placement of the “Bovie Pad” decreases risks of interference.

If intraoperative EM interference is anticipated, ICD anti-tachycardia pacing and shock should be disabled and external defibrillation pads applied.

Reprogramming to an asynchronous pacing mode should also be considered for any pacing-dependent patient.

Magnet behavior should be confirmed whenever magnet use is planned. A magnet never alters the pacing mode of an ICD.

In summary, this study indicated that TTE altered therapy in 52% to 77% of patients with existing instability in the perioperative period, although extended hemodynamic monitoring already was implemented. TTE should be considered as an alternative to more invasive monitoring, such as TEE or PAC, in high-risk patients in the operating room. TTE may supply additional information to hemodynamic monitoring, especially in situations with inconclusive data.
Optimizing care of the morbidly obese

**Pre-operative assessment**
- What is the actual increase risk to patient?
- Sleep apnea/COPD/BHN?
- Consequences of lying flat
- IV access: accuracy of Non-invasive BP measurement
- Is the OR bed going to be wide enough for the patient and able to handle the weight?
- Is Lift of Hover-mat available?

**Intraoperative care**
- Risk for movement to OR table
  - PSV Pro to increase time to desaturation, High-flow NC?
  - Glidescope
  - Positioning to minimize risk of atelectasis

**Immediate post-operative care**
- Nasal trumpet
- Positioning to maximize chance for success
- Availability of CPAP

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Preoxygenation

- Standard anesthesia circuit (goal end-tidal oxygen > 80%)?
- PSV Pro (pressure support of 10 cm H20) if patient tolerates
- Nasal canula during preoxygenation (along with standard mask) and during intubation
- High flow nasal canula during preoxygenation and during intubation

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Positioning of critically ill patients

- Frail patients are susceptible to nerve injury and tissue necrosis due to poor peripheral circulation and friable skin
- Obese patients higher risk of stretch injury to brachial plexus and increased muscle necrosis from not moving during the period of surgery
- In the supine position patients may have orthopnea and/or airway obstruction
- Prevention of skin breakdown with sacral dressings (e.g. Allevyn; hydrocellular adhesive sacral dressing)
Take home points

• Establish common goals of management with your surgical colleague
• Optimize medical conditions, as much as possible, prior to going to OR
• Anticipate and aggressively treat induction hypotension
• Intraoperative blood pressure should be either at MABP of 80 mmHg or within 10% of baseline
• Minimize risk of infection; it matters

Thank you