Management of the Thoracic ICU Patient

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Disclosures

- I have no personal financial disclosures
- I will not be discussing any off-label use of medications
Thoracic ICU Patient Management

- Critical Care Management
- Post-Operative Management of Thoracic Surgery Patients
- Situations in the ICU that Require Thoracic Surgery
Thoracic vs Cardiovascular Patient

- Differences in management philosophies
Thoracic ICU Patient Management

- Critical Care Management
  - Respiratory Failure
  - Shock
- Post-Operative Management of Thoracic Surgery Patients
- Situations in the ICU that Require Thoracic Surgery
Indications for Tracheal Intubation

• Increased work of breathing
  – RR > 35
• Failure to ventilate (Type 2 Failure)
  – Acute PaCO₂ > 50 mmHg
• Failure to oxygenate (Type 1 Failure)
  – PaO₂ / FiO₂ < 200
• Severe metabolic disturbance
  – Uncompensated metabolic acidosis
Indications for Tracheal Intubation (cont)

- Airway obstruction
  - Inhalation injury
  - Epiglottitis
  - Ludwig’s angina
- Inability to protect the airway
  - Head injury (GCS < 8)
  - Paralysis
  - Post-op management
- Tracheobronchial toilet

V (Ventilation)
O (Obstruction)
P (Protection)
P (PEEP)
S (Secretions)
Intubating in the ICU

- Higher risk of difficult intubation and adverse events - Preparation is important!
- Post-intubation hemodynamic instability
  - Preload
  - Afterload
- Acute post-intubation management
  - Sedation
  - EtCO₂
  - ABG / arterial line

Mechanical Ventilation Modes

- **Assist Control (Volume Control)**
  - Choose Volume, Rate, FiO₂, PEEP
  - Ventilator controls flow rate and time to give volume (constant)
  - Pressure (variable) depends on airway resistance, flow rate, compliance, and volume
Mechanical Ventilation Modes

- **Pressure Control**
  - Choose Inspiratory Pressure, Rate, FiO\textsubscript{2}, PEEP
  - Pressure (constant) is reached and maintained for specified inspiratory time, with variable inspiratory pause
  - Volume is variable

Drager Medical
Volume vs Pressure Control
Mechanical Ventilation Modes

• CPAP
  – Continuous airway pressure

• Pressure Support
  – Additional inspiratory support over CPAP
  – Patient dictates volume and respiratory rate
  – Ventilator monitors flow rate

• SIMV
  – Assist Control backup, Pressure Support ‘bonus’
### Acute Lung Injury and ARDS

**The New England Journal of Medicine**

![Image of the cover of the New England Journal of Medicine](image.png)

Open lung ventilation - ARDSNet

<table>
<thead>
<tr>
<th>Mild</th>
<th>PaO2/FiO2: 201 – 300 mm Hg</th>
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<tbody>
<tr>
<td>Moderate</td>
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<tr>
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<td>PaO2/FiO2: ≤ 100 mm Hg</td>
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</table>

- Non-compliant lungs with high Pplat
- Ventilator strategies
  - Tidal Volume 6 mL/kg
  - Plateau Pressures ≤ 30 cm H2O
  - High PEEP – 10 – 24 cmH2O


ARDSNet. *NEJM*, 2000
Weaning from Ventilator

- Spontaneous breathing trial
- Predicting extubation success
  - Tidal Volume
  - Respiratory Rate
  - Vital Capacity
  - NIF
  - MMV
  - RSBI
  - HR
  - SpO₂
  - ABG
- Barriers to extubation
  - Pulmonary
  - Cardiac
  - Neuromuscular
  - Psychiatric
  - Metabolic
  - Fluid overload
  - Nutritional
  - Obstructive
Shock

• What is it?
  – Inadequate end-organ perfusion
  – Insufficient delivery of oxygen and blood to organs

• Oxygen Delivery \((\text{DO}_2)\) = \(\text{CaO}_2 \times \text{CO}\)
• Oxygen Content \((\text{CaO}_2)\) = \(1.36 \times \text{Hb} \times \text{SaO}_2 + 0.0031 \times \text{PaO}_2\)
• Cardiac output \((\text{CO})\) = Stroke Volume x HR
• Stroke Volume \((\text{SV})\) = Preload x Contractility
Shock

• What causes it?
  – Hemorrhage
  – Pneumothorax, tamponade
  – PE
  – Sepsis
  – Myocardial infarction (cardiogenic)
  – Neurogenic injury
  – Dehydration
  – Heart failure

• How do you differentiate?
<table>
<thead>
<tr>
<th></th>
<th>Preload</th>
<th>Contractility</th>
<th>Afterload</th>
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<tr>
<td>• Myocardial infarct</td>
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<td>• Heart failure</td>
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<tr>
<td>• Dysrhythmia</td>
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<td>Cardiac Output</td>
<td>SVR</td>
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</table>
Shock

• Assessing *volume status*

✓ Blood Pressure  ✓ Mucous Membranes  ✓ pH / Lactate
✓ Heart Rate  ✓ Mental Status  ✓ PAOP
✓ Urine Output  ✓ BUN/Cr  ✓ Cardiac Output
✓ Orthostatics  ✓ Echo *(LVEDV, IVC)*  ✓ SvO₂
Treating Shock

Reverse the underlying process causing shock

- **Septic shock**
  - Treat infection – source control, *early* antibiotics!
  - *Early Goal Directed Therapy* / Surviving Sepsis

- **Hemorrhagic shock**
  - Resuscitate with PRBC and fluids, PROPPR trial

- **Tension PTX**
  - 14 g needle, then chest tube

- **Pericardial tamponade**
  - Echo, pericardial drain

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Kumar, et al. *CCM*, 2006
Dellinger, et al. *Int Care Med*, 2013
Treating Shock

- Early Goal Directed Therapy / Surviving Sepsis Campaign
  - Improve perfusion to vital organs
  - Fluid resuscitation
  - Pressors
  - Inotropes
  - Blood - transfusion goals
Fluid Resuscitation

Crystalloid Choices

- **0.9 % Saline**
  - Na⁺ 154 mEq, Cl⁻ 154 mEq
  - Acidosis, mortality, kidney injury

- **Lactated Ringer’s**
  - Na⁺ 130 mEq, Cl⁻ 90 mEq, K⁺ 4 mEq, Lactate 26 mEq
  - Avoid in hyponatremia

- **D5 ½NS (0.45 %)**
  - Na⁺ 77 mEq, Cl⁻ 77 mEq

### Human Serum

<table>
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<tr>
<th>electrolyte</th>
<th>concentration (mEq/L)</th>
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<td>Na⁺</td>
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<td>K⁺</td>
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<tr>
<td>Cl⁻</td>
<td>100</td>
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<tr>
<td>HCO₃⁻</td>
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Fluid Resuscitation

Crystalloid Choices

• Saline
  – Hyperchloremic metabolic acidosis
    ✓ Increased nitric oxide synthase
  – Higher mortality in MICU
  – Acute kidney injury with hyperchloremic solutions

• Lactated Ringer’s
  – Not suitable in head injury
  – Can worsen hyponatremia
  – Contains Potassium - Absolute K+ vs relative K+
Colloid Choices

• **Albumin 5 %**
  - Higher mortality in head injury
  - No survival benefit in all patients

• **Synthetic colloids** *(hydroxyethyl starch)*
  - Cheaper, no infectious potential
  - Increased risk of renal injury in sepsis

• **Albumin 25 %** *(salt-poor albumin)*
Pressors vs Inotropes

- **Pressors**
  - Increasing blood pressure via vasoconstriction
  - Pressure vs flow
  - Can decreased cardiac output
  - Can cause peripheral ischemia

- **Inotropes**
  - Increases flow, may increase pressure
  - Primary objective to increase cardiac output
  - Prone to tachycardia
Pressors and Inotropes

• Catecholamines
  – Receptor activation increases cAMP
  – $\alpha_1$ receptors on smooth muscle – vasoconstriction
  – $\beta_1$ receptors on myocardium – inotropism
  – $\beta_1$ receptors on SA node – chronotropism
  – $\beta_2$ receptors on bronchioles – bronchodilation
  – $\delta$ receptors on renal arteries – vasodilation
Catecholamines

- Phenylephrine and vasopressin vasoconstrict without β activity (tachycardia, contractility)
- Dobutamine and milrinone increase contractility, with possible tachycardia and vasodilation
Pressors and Inotropes

- **Milrinone**
  - Phosphodiesterase-3 inhibitor $\rightarrow$ ↑cAMP $\rightarrow$ ↑Ca$^+$
  - Inotropism
  - Tachycardia, atrial fibrillation, vasodilation

- **Vasopressin**
  - **V1** receptor
    - Increases inositol triphosphate (IP3) $\rightarrow$ ↑Ca$^+$
    - *Vasoconstriction*, platelet aggregation, release of von Willebrand factor
  - **V2** receptor – increases water reabsorption
Dosing of Pressors and Inotropes

- Phenylephrine
- Norepinephrine
- Epinephrine
- Dopamine
- Dobutamine
- Milrinone
- Vasopressin

- 0-200 mcg/min
- 1-20 mcg/min
- 1-10 mcg/min
- 1-20 mcg/kg/min
- 1-10 mcg/kg/min
- 0.375 – 0.625 mcg/mg/min
- 0.04 U/min
Adrenal Insufficiency

• Multiple causative mechanisms
  – Septic shock
  – Chronic steroid use
  – Etomidate-induced adrenal insufficiency
  – Hypothalamic-pituitary-adrenal (HPA) axis disease

• Perioperative management
  – Poor data support of prophylactic stress dose, except patients with HPA axis disease

• Therapeutic stress dose steroids
  – Steroids when all else fails

Thoracic ICU Patient Management

- Critical Care Management

- Post-Operative Management of Thoracic Surgery Patients
  - Pneumonectomy
  - Tracheal resection and reconstruction

- Situations in the ICU that Require Thoracic Surgery
Pneumonectomy

• First pneumonectomy for tuberculosis by Macewen in 1895, completed in multiple stages

• Indications
  – Non-small cell lung cancer
  – Infection, tuberculosis, bronchiectasis, inflammatory lung disease
Pneumonectomy

Preoperative risk stratification

• Respiratory mechanics

  Post-op FEV1 % = pre-op FEV1 % X (1 – % lung removed)

  – goal post-op FEV1 % > 40 %

• Cardiopulmonary function

  – $\text{VO}_{2\text{max}} > 15 \text{ mL/kg/min (approx 3 flights)}$
  – Climb > 2 flight of stairs
  – Age < 75 yo associated with lower mortality

Pneumonectomy – Intra-Op

• Intra-op physiologic alterations
  – Increased right heart afterload – consider CVP
  – **Fluid restriction** to reduce edema
  – **Positioning** – Brachial plexus injury
    ✓ Dependent arm – clavicle pressing into retroclavicular space
    ✓ Nondependent arm – stretch injuries with flexion of cervical spine, abduction of arm > 90 degrees

www.mesothelioma.com
Pneumonectomy – Intra-Op

Post-thoracotomy Anesthetic Management:

Predicted Postoperative FEV1 (ppoFEV1 %)

- > 40%
  - Extubate in Operating Room if:
    - Patient AWaC (alert, warm and comfortable)

- 30-40%
  - Consider extubation based on:
    - Exercise tolerance
    - DLCO
    - V/Q scan
    - Associated diseases

- < 30%
  - Staged weaning from mech. ventilation

Slinger, Soc Cardiovasc Anesth Monograph 2004
Pneumonectomy – Post-Op

- Postpneumonectomy pulmonary edema
  - 4% incidence, mortality 50% or higher
  - More common with right pneumonectomy
  - Risk factors after lung resection
    - Pneumonectomy
    - Excessive fluid administration
    - High intraoperative ventilatory pressure index
    - Preop alcohol abuse
  - Requires modification of routine management

Pneumonectomy - Postop

• Postpneumonectomy pulmonary edema

• Prevention – Intraop
  – Tidal volume 5 – 6 mL/kg
  – PIP < 35 cmH₂O, P_{plat} < 25 cmH₂O
  – Solumedrol for prevention
    ✓Reduced PPPE, no increase in bronchopleural fistula incidence
Pneumonectomy - PPPE

“...the most important thing that we can do in terms of recognizing this problem is to watch our anesthetists as they start loading the patient up with fluid.“

Zeldin, 1984

- Overall goal is to minimize fluid administration without jeopardizing renal function

Pneumonectomy – Post-Op

• Post-pneumonectomy space
  – Avoid suction or standard underwater seal system
  – Temporary drainage catheter vs no drains
  – CXR immediately post-op

• Cardiac herniation
  – Incomplete or breakdown of closure of pericardium
  – Torsion of the heart
    ✓ Impaired venous return ✓ Tachycardia ✓ Ischemia
    ✓ Elevated CVP ✓ Shock ✓ Outflow obstruction
  – Surgical emergency – redo-thoracotomy
Pneumonectomy – Post-Op

- **Dysrhythmias**
  - Common after thoracotomy: Atrial fibrillation 3 – 33 %
  - Multifactorial causes:
    - COPD
    - Smoking
    - Hypoxemia
  - Limited preventative efficacy of amiodarone, beta blockers, and calcium channel blockers after CABG
  - No benefit of prophylactic digitalis after thoracotomy
  - Amiodarone effective prevention and treatment

Pneumonectomy – Post-Op

• Bronchopleural fistula
  – Incidence 1.5 – 8 %
  – Mortality 30 – 80 %
  – Risk Factors
    ✓ Diabetes
    ✓ Preoperative radiation
    ✓ Residual tumor at stump
    ✓ Low FEV₁ %
    ✓ Right-sided pneumonectomy

Pneumonectomy

Extrapleural Pneumonectomy

- Resection of ipsilateral lung, parietal pleura, ipsilateral diaphragm, ipsilateral pericardium
- Indicated for malignant pleural mesothelioma

Surgery in the treatment of malignant pleural mesothelioma: recruitment into trials should be the default position

Avijit Datta,1,2 Rhiannon Smith,2 Francesca Fiorentino,3 Tom Treasure4
Tracheal Resection and Reconstruction

• Indications for surgery
  – Tumors of trachea and carina
  – Congenital lesions
  – Infection / inflammation
  – Post-intubation stenosis
    ✓ Duration intubation
    ✓ Cuff overinflation
    ✓ Hypotension
Tracheal R & R

- Anatomy of arterial supply and associated nerves
  - 10 to 13 cm
  - 18 to 24 C-shaped rings
  - Membranous posterior wall
  - Neck movement varies position
  - Segmental arterial supply inferior thyroid, bronchial, internal innominate arteries

Tracheal R & R – Post-op

• Early extubation
  – Small ETT or tracheostomy tube
    ✓ Pressure control ventilation
    ✓ Sedation - Dexmedetomidine
  – T-Tube

• ICU Care
  – Pain control
    ✓ Acetaminophen
    ✓ Ketorolac
    ✓ Tramadol
    ✓ Ketamine infusion
Tracheal R & R – Post-op

- Guardian stitch
- Pulmonary Toilet
  - Chest physical therapy
  - Follow-up bronchoscopy
- Reintubation
  - Bronchoscope
  - Evaluate vocal cords, anastomosis integrity
  - If cuffed ETT, cuff distal to anastomosis

Thoracic ICU Patient Management

• Critical Care Management

• Post-Operative Management of Thoracic Surgery Patients

• Situations in the ICU that Require Thoracic Surgery
  – Esophageal perforation
  – Bronchopleural fistula
  – Effusions
Esophageal perforation

- Dr Hermann Boerhaave and Baron von Wassenaer, Grand Admiral of Holland, in 1723
- Large meal with intentional vomiting
- Severe pain with non-productive retching
- Death within 24 hours
  - Tear in distal esophagus and gastric contents in pleural spaces on autopsy
Esophageal perforation

- Most cases today are iatrogenic (59 %)
  - Flexible endoscopy
    - 0.01 – 0.06 % perf rate
  - Sclerotherapy
    - 1 – 5 % perf rate

- Boerhaave syndrome (15 %), foreign body (12 %), penetrating trauma (9 %)

Esophageal perforation

- Four layers
- Muscular coat contains longitudinal and circular fibers
- Lack of serosal layer to give strength
- Arterial supply provided by superior and inferior thyroid aa, left gastric a, and splenic a.
Esophageal perforation

- High risk for morbidity and mortality
  - Significant sepsis or SIRS associated with syndrome
  - Mortality after operative repair from 12 – 36 %
  - Delayed surgical treatment can increase mortality from 30 – 50 %, up to 75 – 89 %
Esophageal perforation

- Presenting symptoms
  - Pain in chest, abdomen, or back
  - Subcutaneous emphysema
  - Dysphagia
  - Dyspnea
  - Hematemesis, melena
  - Hamman’s Sign – crunching with systolic click
  - Meckler’s Triad – Chest pain, emesis, SQ emphysema
Esophageal perforation

- Sequelae
  - Pneumothorax
  - Pneumomediastinum
  - Mediastinitis
  - Pericarditis
  - Empyema
  - Sepsis / Septic Shock
  - ARDS
  - Tracheal and spinal cord injury
Esophageal perforation

- Evaluation
  - CXR
  - CT
  - EKG
  - Esophagram
  - Esophagoscopy?

- Lab Studies
  - CBC
  - ABG / pH
Esophageal perforation

• Surgical Interventions
  – Indications
    ✓ Delayed institution of therapy
    ✓ Sepsis or decompensation
    ✓ Leakage of contrast material
  – Methods of treatment
    ✓ Open surgical – primary closure, resection
    ✓ Conservative – drainage, diversion
    ✓ Endoscopic – stent, clipping

Esophageal perforation

- Supportive Therapy
  - Pain Control
  - Antiemetics
  - Antibiotics
  - Fluid resuscitation
Bronchopleural Fistula

• Communication between bronchial tree and pleural space
  – Persistent pneumothorax despite chest tube
  – Procedural complications, trauma
  – Mechanical ventilation, ARDS 25 – 87 %

• Presentation
  ✓ Increased airway pressure
  ✓ Failed lung expansion
  ✓ Low tidal volumes
  ✓ Low airway pressures (w/ CT)
  ✓ Ventilator cycling
  ✓ Low minute ventilation
Bronchopleural Fistula

• Initial Management
  – Lung reexpansion with chest tube
  – Flexible bronchoscopy - Proximal defect may be identified
  – Ventilator management
    ✓ Minimize tidal volume
    ✓ Reduce inspiratory time
    ✓ Reduce PEEP
    ✓ Reduce Respiratory Rate
    ✓ Spontaneous breathing
    ✓ High-frequency ventilation
Bronchopleural Fistula

- Invasive therapy
  - Pleural abrasion and decortication
  - Thoracoplasty
  - Bronchial stump stapling
  - Sealant application via bronchoscope
    - Fibrin
    - Cyanoacrylate
    - Gelatin / Gelfoam
    - Tetracycline
Effusions

• Commonly observed in the ICU patient
  ✓ CABG ✓ VATS ✓ Abdominal surgery
  ✓ Atelectasis ✓ Pancreatitis ✓ Hemothorax
  ✓ Chylothorax ✓ Esophageal rupture ✓ ARDS
  ✓ CHF ✓ Pneumonia ✓ Hypoalbuminemia
  ✓ Pulmonary embolus ✓ Iatrogenic (CVL) ✓ Malignancy

• Thoracic Surgery interventions
  – Chest tube placement for exudative or recurrent
  – Pleurodesis
  – Pleurectomy
Effusions

- Diagnostic thoracentesis
  - Not required for CHF and atelectasis

- Therapeutic thoracentesis
  - Indicated for *symptomatic* effusions
  - Avoid excessive fluid removal (1.5L, -20 cmH$_2$O)
  - Poor correlation with volume removed and relief of dyspnea or lung volume improvement

Effusions

Risks of thoracentesis
- Pneumothorax 4 – 30 %
- Hypovolemia
- Hypoxemia
- Pulmonary edema

## Effusions

### Diagnostic Evaluation of Pleural Effusions in ICU

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<th>Transudative</th>
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<td>&gt; 0.5</td>
<td>&lt; 0.5</td>
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<td>&lt; 0.6</td>
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<td>LDH$_{Pleura}$</td>
<td>&gt; 2/3 Upper Limit</td>
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<tr>
<td>Cholesterol</td>
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# Effusions

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<td>Malignancy</td>
<td>Fluid overload</td>
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<td>Inflammatory disorders</td>
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<td></td>
<td>Chylothorax*</td>
</tr>
</tbody>
</table>
Effusion Management

• Non-Malignant Effusions
  – Thoracentesis for slow reaccumulation
  – Pleural catheter
    ✓ Need for repeat thoracentesis within a month
    ✓ Least invasive, outpatient
  – Pleurodesis
    ✓ Talc: 77 – 79 % effective
    ✓ Fever, pain, GI upset, hypotension, SIRS, empyema

Sudduth, et al. CHEST, 1992
Effusion Management

• Malignant Effusions
  – Thoracentesis for slow reaccumulation
  – Pleural catheter consideration
  – Pleurodesis
    ✓ Intended for longer patient life expectancy
    ✓ Talc slurry usual first choice: 60 – 90 % effective
    ✓ Thorascopic talc more effective
    ✓ Alternatives: Doxycycline, bleomycin

Shaw. Cochrane database, 2004
Tracheostomy

• Indications
  – ‘Long-term’ ventilator dependence
  – Pulmonary toilet
  – Airway obstruction

• percutaneous tracheostomy vs operative tracheostomy
Thoracic ICU Patient Management

- Critical Care Management
- Post-Operative Management of Thoracic Surgery Patients
- Situations in the ICU that Require Thoracic Surgery

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