CRITICAL CARE MANAGEMENT
RESPIRATORY SYSTEM

-B. SHIVRAJ
Topics

• ARDS
• Ventilator and modes
• Aspiration
• Pneumothorax & hemothorax
Introduction

• Securing the airway.
• ABC of resuscitation
• Most vital organ
• Supplies oxygen-> energy source for all cells
ARDS

- Non cardiogenic pul edema/ AHMD/ CLS/ SLS/ shock lung.
- Definition
- Aetiology
- Pathology
- Severity scoring
- Management
ARDS Definition

• Severe, acute lung injury involving diffuse alveolar damage, increased microvascular permeability and non cardiogenic pulmonary edema
• Acute refractory hypoxemia
• High mortality- 40%-60%
ARDS Criteria

- Acute onset of respiratory failure
- Bilateral infiltrate on CXR (some cases do present unilaterally or with pleural effusion)
- PCWP < 18 or absence of left atrial htn,
- PaO2/FiO2 < 200
ARDS
mechanism of lung injury

- Activation of inflammatory mediators and cellular components resulting in damage to capillary endothelial and alveolar epithelial cells
- Increased permeability of alveolar capillary membrane
- Influx of protein rich edema fluid and inflammatory cells into air spaces
- Dysfunction of surfactant
Surfactant
Stages of ARDS

1. Exudative (acute) phase - 0-4 days
2. Proliferative phase - 4-8 days
3. Fibrotic phase - >8 days
4. Recovery
ARDS Treatment

- Ventilator-induced lung injury: oxygen toxicity was one of the most important factors in the progression of ARDS and resultant mortality. Recently, it was found that high volume (volutrauma) and high press (barotrauma) are equally if not more detrimental to these pts.
- Treatment strategy is one of low volume and high frequency ventilation (ARDSNet protocol).
- Search for and treat the underlying cause.
- Treat abdominal infection promptly with antibiotics/surgery.
- Ensure adequate nutrition.
- DVT prophylaxis.
- Prevent and treat any nosocomial infection.
- Consider short course of high dose steroids (20-60mg prednisolone) in patients with chronic unresolved disease.
When all else fails..

- Prone (gravitation atelectasis).
- Inhaled nitric oxide (marginal benefit)
- High frequency oscillation ventilation
ARDSnet and Long-term outcome

120pts randomized to low Vt or high Vt
  a) 25% mortality with low tidal volume
  b) 45% mortality with high tidal volume

20% had restrictive defect and 20% had obstructive defect 1 yr after recovery

Standardized tested showed health-related quality of life lower than normal

No difference in long-term outcomes between tidal volume group
Pneumothorax

- **Definition** –
  
  "Pneumo" - gas  
  "Thorax" – chest cavity

- **Pathophysiology** –
  - Pleural space
    - Baseline (-) pressure space
    - Parietal Pleura
    - Visceral Pleura
  - **Normal inspiration**
    - Diaphragm
    - Transmit (-) Pressure
  - **Pathologic inspiration**
    - Excess gas disrupts transmission of (-) pressure
Types of Pneumothorax

- **Spontaneous Pneumothorax**
  - Primary - rupture of subpleural bleb
  - Secondary - underlying lung/pleural disease
    - Emphysema, chronic bronchitis, asthma, TB.

- **Traumatic Pneumothorax:**
  - Open
    - Chest wall is penetrated: outside air enters pleural space
  - Closed
    - Chest wall is intact -> Fractured rib
Types of Pneumothorax

• Tension Pneumothorax
  – Injury to pleura creates a tissue flap that opens on inspiration and closes on expiration (ball valve effect).
  – Mediastinal shift

• Variations
  – Hemo-thorax
  – Chylo-thorax
    • Injury to thoracic duct
  – Empyema
    • Synpneumonic effusions in community-acquired pneumonia
Pneumothorax

• Signs and symptoms of a pneumothorax include:
  – Sudden, sharp chest pain
  – Shortness of breath
  – Chest tightness
  – Tachycardia
  – Rapid, shallow breaths
Physical Exam - Signs

• Unstable patients vs. Stable patients
  – Vital Signs
• Asymmetric chest expansion
• Deviated trachea
• Diminished breath sounds unilaterally
• Hyper-resonance unilaterally
• Decreased tactile fremitus
Treatment

• **Small pneumothorax**
  – Resolve over days to weeks
  – Supplemental oxygen and observation

• **Tension pneumothorax**
  – Immediate decompression via chest tube or needle thoracostomy

• **Spontaneous pneumothorax**
  – Asymptomatic – outpatient, follow up with serial CXR
  – Symptomatic – inpatient, chest tube
  – Recurrent pneumothorax – CT to evaluate need for thoracotomy
Tension PTX

Normal

Lung
Heart
Airleak

PTX
Tension PTX

R L

heart
Hemothorax

• Causes of a Spontaneous Hemothorax

  – Pulmonary: PE, infarction, Tb, AVM’s
  – Pleural: torn adhesions
  – Neoplastic: primary, metastatic (*melanoma*)
  – Blood Dyscrasias: thrombocytopenia, hemophilia, anticoagulation
  – Thoracic Pathology: ruptured aorta, dissection
  – Abdominal Pathology: pancreatic pseudocyst, hemoperitoneum
Hemothorax

• Radiograph showing left sided hemothorax
Hemothorax

*The Pathophysiologic Process*

- the accumulation of pleural blood forms a stable clot
- ventilation & oxygenation becomes impaired
  - mechanical compression of the lung parenchyma
  - mediastinal shift
  - flattening of the hemidiaphragm
Hemothorax

*The Pathophysiologic Process*

- over time, the clot is partially-absorbed, leaving behind loculated fluid and fibrinous septations
- macro-fibrin deposition begins to provide a structural framework
- this “peel” slowly contracts to entrap the underlying lung
Hemothorax

• General Management Options
  – thoracentesis: *bedside / ultrasound-guided / C.T.-guided*
  – thoracostomy drainage: “”the MAINSTAY””
  – thoracotomy: *massive hemothorax / instability / chronic hemothorax*
  – local fibrinolytic therapy: *urokinase (1000 IU/ml) in 150cc solution*
Hemothorax- drainage

Undrained hemothorax increases the risk of empyema & fibrothorax

• Large collections should be drained slowly to minimize the development of *re-expansion-pulmonary-edema*
ICD insertion

- Arm by the ear
- 4-5\textsuperscript{th} ICS in the mid-axillary line
- Directed upwards
- Position checked with rpt CXR
Underwater-Seal Drainage of Chest

One-bottle system

Collection and water seal
Fluid level fluctuates with respiration
Bottle initially primed with about 200 ml saline for water seal

Two-bottle system

From patient
Collection
Water seal
Air vent

Three-bottle system

From patient
Collection
Water seal
Air vent
Suction regulation by depth of tube in water
To suction
Aspiration

• Most dreaded complication by anesthetist.
• Pre-disposing factors:
  unconscious;
  loss of gag reflexes;
  alcoholic;
  pt on RT feeding;
  hiatus hernia
• Aspirate-> food;
  gastric contents;
  oropharyngeal secretions
Presentation

- Tachycardia; tachypnea; breathing difficulty; cyanosis.
- R/S-> crackles, wheeze, pink frothy sputum
- CXR-> initially – N ; later – consolidation
- Prevention ->1. feeding in propped up position; 2. lying on left pos to prevent asp of contents in unconscious pts.
Treatment

- FB-> removal (as appropriate)
- O2 support ; propped up
- Antibiotic cover to prevent secondary infection.
- Suction (under laryngoscopy/ bronchoscopy/ in ET tube)
Complications

- Aspiration pneumonitis
- Secondary bacterial infections
- Lung abscess, emphyema
- Necrotizing pneumonia
MECHANICAL VENTILATION

• Theory
  • Ventilation vs. Oxygenation
  • Pressure Cycling vs. Volume Cycling
• Modes
• Ventilator Settings
• Indications to intubate
• Indications to extubate
• Management algorithm
• FAQs
Principles (1): Ventilation

The goal of ventilation is to facilitate CO₂ release and maintain normal PₐCO₂

- **Minute ventilation** (Vₑ)
  - Total amount of gas exhaled/ min.
  - Vₑ = (RR) x (Tᵥ)
  - Vₑ comprised of 2 factors
    - Vₐ = alveolar ventilation
    - V₇ = dead space ventilation
  - Vₑ/ V₇ = 0.33
  - Vₑ regulated by brain stem, responding to pH and PₐCO₂.

- **Ventilation in context of ICU**
  - Increased CO₂ production
    - fever, sepsis, injury, overfeeding
  - Increased V₇
    - atelectasis, lung injury, ARDS, pulmonary embolism
  - **Adjustments:** RR and Tᵥ
Principles (2): Oxygenation

The primary goal of oxygenation is to maximize O$_2$ delivery to blood ($P_aO_2$)

- **Alveolar-arterial O$_2$ gradient ($P_AO_2 - P_aO_2$)**
  - Equilibrium between oxygen in blood and oxygen in alveoli
  - A-a gradient measures efficiency of oxygenation
  - $P_aO_2$ partially depends on ventilation but more on V/Q matching.

- **Oxygenation in context of ICU**
  - V/Q mismatching
    - Patient position (supine)
    - Airway pressure, pulmonary parenchymal disease, small-airway disease
  - Adjustments: FiO$_2$ and PEEP
Pressure ventilation vs. volume ventilation

Pressure-cycled modes deliver a fixed pressure at variable volume. Volume-cycled modes deliver a fixed volume at variable pressure.

• **Pressure-cycled modes**
  - Pressure Support Ventilation (PSV)
  - Pressure Control Ventilation (PCV)
  - CPAP
  - BiPAP

• **Volume-cycled modes**
  - Control
  - Assist
  - Assist/Control
  - Intermittent Mandatory Ventilation (IMV)
  - Synchronous Intermittent Mandatory Ventilation (SIMV)

Volume-cycled modes have the inherent risk of volutrauma.
Pressure Support Ventilation (PSV)

Patient determines RR, $V_e$, inspiratory time - a purely spontaneous mode

- **Parameters**
  - Triggered by pt’s own breath
  - Limited by pressure
  - Affects inspiration only

- **Uses**
  - Complement volume-cycled modes (i.e., SI MV)
  - PSV alone
    - Used alone for recovering intubated pts who are not quite ready for extubation
  - BiPAP (CPAP plus PS)

PSV is most often used together with other volume-cycled modes. PSV provides sufficient pressure to overcome the resistance of the ventilator tubing, and acts during inspiration only.
Pressure Control Ventilation (PCV)

Ventilator determines inspiratory time - no patient participation

- **Parameters**
  - Triggered by time
  - Limited by pressure
  - Affects inspiration only.

- **Disadvantages**
  - Requires frequent adjustments to maintain adequate $V_E$
    - Pt with noncompliant lungs may require alterations in inspiratory times to achieve adequate $T_V$
CPAP and BiPAP

CPAP is essentially constant PEEP; BiPAP is CPAP plus PS

• **Parameters**
  - CPAP – PEEP set at 5-10 cm H2O
  - BiPAP – CPAP with Pressure Support (5-20 cm H2O)
  - Shown to reduce need for intubation and mortality in COPD pts

• **Indications**
  - When medical therapy fails (tachypnea, hypoxemia, respiratory acidosis)
  - Use in conjunction with bronchodilators, steroids, oral/parenteral steroids, antibiotics to prevent/delay intubation
  - Weaning protocols
  - Obstructive Sleep Apnea
Assist/Control Mode

Ventilator delivers a fixed volume

- Control Mode
  - Pt receives a set number of breaths and cannot breathe between ventilator breaths
  - Similar to Pressure Control

- Assist Mode
  - Pt initiates all breaths, but ventilator cycles in at initiation to give a preset tidal volume
  - Pt controls rate but always receives a full machine breath

- Assist/Control Mode
  - Assist mode unless pt’s respiratory rate falls below preset value
  - Ventilator then switches to control mode
  - Rapidly breathing pts can overventilate and induce severe respiratory alkalosis and hyperinflation.
IMV and SIMV

Volume-cycled modes typically augmented with Pressure Support

- **IMV**
  - Pt receives a set number of ventilator breaths
  - Different from Control: pt can initiate own (spontaneous) breaths
  - Different from Assist: spontaneous breaths are not supported by machine with fixed $T_V$
  - Ventilator always delivers breath, even if pt exhaling

- **SIMV**
  - Most commonly used mode
  - Spontaneous breaths and mandatory breaths
  - If pt has respiratory drive, the mandatory breaths are synchronized with the pt’s inspiratory effort
Ventilator settings to improve <oxygenation>

PEEP and FiO₂ are adjusted in tandem

- **FiO₂**
  - Simplest maneuver to quickly increase PₐO₂
  - Long-term toxicity-
    - Free radical damage

- **Inadequate oxygenation despite 100% FiO₂ usually due to pulmonary shunting**
  - Collapse - Atelectasis
  - Pus-filled alveoli - Pneumonia
  - Water/ Protein - ARDS
  - Water - CHF
  - Blood - Hemorrhage
Ventilator settings to improve oxygenation

PEEP and FiO₂ are adjusted in tandem

- **PEEP**
  - Increases FRC
    - Prevents progressive atelectasis and intrapulmonary shunting
    - Prevents repetitive opening/closing (injury)
  - Enables maintenance of adequate PₐO₂ at a safe FiO₂ level

- **Disadvantages**
  - Increases intrathoracic pressure (may require pulmonary a. catheter)
  - May lead to ARDS
  - Rupture: PTX, pulmonary edema

Oxygen delivery (DO₂), not PaO₂, should be used to assess optimal PEEP.
Vent settings to improve ventilation

RR and \( T_V \) are adjusted to maintain \( V_E \) and \( P_aCO_2 \)

• **Respiratory rate**
  • Max RR at 35 breaths/ min
  • Efficiency of ventilation decreases with increasing RR
    • Decreased time for alveolar emptying

• **\( P_{IP} \)**
  • Elevated \( P_{IP} \) suggests need for switch from volume-cycled to pressure-cycled mode
  • Maintained at <45 cm H\(_2\)O to minimize barotrauma

• **\( T_V \)**
  • Goal of 10 ml/ kg
  • Risk of volutrauma
Alternative Modes

- **I:E inverse ratio ventilation (IRV)**
  - In ARDS and severe hypoxemia
  - Prolonged inspiratory time (3:1) leads to better gas distribution with lower PIP
  - Elevated pressure improves alveolar recruitment

- **Prone positioning**
  - Addresses dependent atelectasis
  - Relief of diaphragmatic pressure from abdominal viscera
  - Improved drainage of secretions
  - Logistically difficult*
  - No mortality benefit demonstrated.

- **High-Frequency Oscillatory Ventilation (HFOV)**
  - High-frequency, low amplitude ventilation
  - Avoids repetitive alveolar open and closing that occur with low airway pressures
  - Avoids overdistension that occurs at high airway pressures
  - Well tolerated, consistent improvements in oxygenation.

- **Disadvantages**
  - Potential hemodynamic compromise
  - Pneumothorax
  - Neuromuscular blocking agents
Non Invasive Positive Pressure Ventilation

- Deliver PS and CPAP via tight fitting mask
  (BiPAP: bi-level positive airway pressure)
- Dyspnea protocol
- May still need sedation
Treatment of respiratory failure

The critical period before the patient needs to be intubated

- **Prevention**
  - Incentive spirometry
  - Mobilization
  - Humidified air
  - Pain control
  - Turn, cough, deep breathe

- **Treatment**
  - Medications
    - Albuterol
    - Theophylline
    - Steroids
  - CPAP, BiPAP
  - Intubation
Indications for intubation

How the values trend should significantly impact clinical decisions

• Criteria
  • Clinical deterioration
  • Tachypnea: RR > 35
  • Hypoxia: pO2 < 60mm Hg
  • Hypercarbia: pCO2 > 55mm Hg
  • Minute ventilation < 10 L/min
  • Tidal volume < 5-10 ml/kg
  • Negative inspiratory force < 25cm H2O (how strong the pt can suck in)

• Initial vent settings
  • FiO2 = 50%
  • PEEP = 5cm H2O
  • RR = 12 - 15 breaths/ min
  • VT = 10 - 12 ml/kg
    • COPD = 10 ml/kg (prevent overinflation)
    • ARDS = 8 ml/kg (prevent volutrauma)
     • Permissive hypercapnea
  • Pressure Support = 10cm H2O
Extubation

• Weaning
  – Is the cause of respiratory failure gone or getting better?
  – Is the patient well oxygenated and ventilated?
  – Can the heart tolerate the increased work of breathing?
• (cont.)
  – decrease the PEEP (4-5)
  – decrease the rate(<30/min)
  – decrease the PIP (as needed)
  – “AWAKE PATIENT”
• What you want to do is decrease what the ventilator does and see if the patient can make up the difference…. 
Indications for extubation

No weaning parameter completely accurate when used alone

• **Clinical parameters**
  - Resolution/ Stabilization of disease process
  - Hemodynamically stable
  - Intact cough/ gag reflex
  - Spontaneous respirations
  - Acceptable vent settings
    - $\text{FiO}_2 < 50\%$, PEEP $< 8$, $\text{PaO}_2 > 75$, pH $> 7.25$

• **General approaches**
  - SIMV Weaning
  - Spontaneous breathing trials
    - Demonstrated to be superior

<table>
<thead>
<tr>
<th>Numerical Parameters</th>
<th>Normal Range</th>
<th>Weaning Threshold</th>
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<tbody>
<tr>
<td><strong>P/ F</strong></td>
<td>$&gt; 400$</td>
<td>$&gt; 200$</td>
</tr>
<tr>
<td><strong>Tidal volume</strong></td>
<td>5 - 7 ml/kg</td>
<td>5 ml/kg</td>
</tr>
<tr>
<td><strong>Respiratory rate</strong></td>
<td>14 - 18 breaths/min</td>
<td>$&lt; 40$ breaths/min</td>
</tr>
<tr>
<td><strong>Vital capacity</strong></td>
<td>65 - 75 ml/kg</td>
<td>10 ml/kg</td>
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<tr>
<td><strong>Minute volume</strong></td>
<td>5 - 7 L/min</td>
<td>$&lt; 10$ L/min</td>
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Spontaneous Breathing Trials

SBTs do not guarantee that airway is stable or pt can self-clear secretions

- **Settings**
  - PEEP = 5, PS = 0 - 5, FiO₂ < 40%
  - Breathe independently for 30 - 120 min
  - ABG obtained at end of SBT

- **Failed SBT Criteria**
  - RR > 35 for >5 min
  - SₐO₂ <90% for >30 sec
  - HR > 140
  - Systolic BP > 180 or < 90mm Hg
  - Sustained increased work of breathing
  - Cardiac dysrhythmia
  - pH < 7.32

<table>
<thead>
<tr>
<th>Causes of Failed SBTs</th>
<th>Treatments</th>
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<td>Anxiety/Agitation</td>
<td>Benzodiazepines or haldol</td>
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<tr>
<td>Infection</td>
<td>Diagnosis and tx</td>
</tr>
<tr>
<td>Electrolyte abnormalities (K⁺, PO₄⁻)</td>
<td>Correction</td>
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<tr>
<td>Pulmonary edema, cardiac ischemia</td>
<td>Diuretics and nitrates</td>
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<tr>
<td>Deconditioning, malnutrition</td>
<td>Aggressive nutrition</td>
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<tr>
<td>Neuromuscular disease</td>
<td>Bronchopulmonary hygiene, early consideration of trach</td>
</tr>
<tr>
<td>Increased intra-abdominal pressure</td>
<td>Semirecumbent positioning, NGT</td>
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<tr>
<td>Hypothyroidism</td>
<td>Thyroid replacement</td>
</tr>
<tr>
<td>Excessive auto-PEEP (COPD, asthma)</td>
<td>Bronchodilator therapy</td>
</tr>
</tbody>
</table>
Continued ventilation after successful SBT

Inherent risks of intubation balanced against continued need for intubation

- Commonly cited factors
  - Altered mental status and inability to protect airway
  - Potentially difficult reintubation
  - Unstable injury to cervical spine
  - Likelihood of return trips to OR
  - Need for frequent suctioning
**Ventilator management algorithm**


### Initial intubation
- **SaO₂ < 90%**
  - Increase FiO₂ (keep SaO₂ > 90%)
  - Increase PEEP to max 20
  - Identify possible acute lung injury
  - Identify respiratory failure causes

- **SaO₂ > 90%**
  - Adjust RR to maintain PaCO₂ = 40
  - Reduce FiO₂ < 50% as tolerated
  - Reduce PEEP < 8 as tolerated
  - Assess criteria for SBT daily

### Acute lung injury
- **SaO₂ < 90%**
  - Low TV (lung-protective) settings
    - Reduce TV to 6 ml/kg
    - Increase RR up to 35 to keep pH > 7.2, PaCO₂ < 50
    - Adjust PEEP to keep FiO₂ < 60%

### No injury
- **SaO₂ > 90%**
  - Continue lung-protective ventilation until:
    - PaO₂/FiO₂ > 300
    - Criteria met for SBT

### Fail SBT
- **SaO₂ < 90%**
  - Dx/Tx associated conditions (PTX, hemothorax, hydrothorax)
  - Consider adjunct measures (prone positioning, HFOV, IRV)

- **SaO₂ > 90%**
  - Consider tracheostomy
  - Resume daily SBTs with CPAP or tracheostomy collar

### Persistently fail SBT
- **SaO₂ < 90%**
  - Consider PSV wean (gradual reduction of pressure support)
  - Consider gradual increases in SBT duration until endurance improves

### Prolonged ventilator dependence
- **SaO₂ > 90%**
  - Consider tracheostomy
  - Resume daily SBTs with CPAP or tracheostomy collar

### Pass SBT
- **SaO₂ < 90%**
  - Dx/Tx associated conditions (PTX, hemothorax, hydrothorax)
  - Consider adjunct measures (prone positioning, HFOV, IRV)

- **SaO₂ > 90%**
  - Criteria met for SBT

### Extubate
- **SaO₂ < 90%**
  - Continue lung-protective ventilation until:
    - PaO₂/FiO₂ > 300
    - Criteria met for SBT

- **SaO₂ > 90%**
  - Consider tracheostomy
  - Resume daily SBTs with CPAP or tracheostomy collar

### Extubate
- **SaO₂ < 90%**
  - Continue lung-protective ventilation until:
    - PaO₂/FiO₂ > 300
    - Criteria met for SBT

- **SaO₂ > 90%**
  - Consider tracheostomy
  - Resume daily SBTs with CPAP or tracheostomy collar
Need for tracheostomy

Prolonged intubation may injure airway and cause airway edema

**Advantages**

- Issue of airway stability can be separated from issue of readiness for extubation
  - May quicken decision to extubate
- Decreased work of breathing
- Avoid continued vocal cord injury
- Improved bronchopulmonary hygiene
- Improved pt communication

**Disadvantages**

- Long term risk of tracheal stenosis
- Procedure-related complication rate (4% - 36%)
Complications

- Oxygen toxicity
- Barotrauma/volutrauma
- Ventilator Associated Pneumonia
- Sinusitis
- Risks from associated devices (CVLs, A-lines)
- Unplanned Extubation
Foreign body

• Acute emergency
• m/c children
• Present with gasping; choking; cyanosis; acute resp difficulty; tacycardia.
• Heimlich manuvoure
• Visualisation ->
Magill forceps
Tracheostomy

- Emergency / elective
- 2-4th tracheal rings
- Indications: securing airway, prolonged ventilation, for extubation.
- Procedure
- Post op care
Laryngoscope with Macintosh blade
ORO PHARYNGEAL AIRWAY
LMA
Combitube
Cricothrodotomy

- Or mini tracheosotomy
- Over the crico-thyroid membrane
- As an emergency procedure to secure airway
THANK YOU.