COVID-19 Bootcamp: Airway Management

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Endotracheal Tube Obstruction
What adverse event do these cases have in common?

**Case 1:** 37 year old man with EtOH cirrhosis, septic shock, intubated for hypercarbic RF, with **increased WOB** and **peak pressuring** on the vent

**Case 2:** 73 year old man with AML, ARDS, intubated and paralyzed for hypoxic RF, with **progressive autoPEEP** and worsening shock

**Case 3:** 26 year old man intubated with pneumonia, RT unable to suction secretions given **inability to pass suction catheter**
Occluded Endotracheal Tubes

Increased incidence of ETT obstruction in COVID-19 patients

Possible contributors:
- Decreased frequency of suctioning (minimizing personnel in and out of rooms)
- Increased incidence when using passive humidification (HME)
- ? Pathophysiology of COVID-19 resulting in particularly thick secretions
Endotracheal Tube (ETT) Obstruction

**Causes**
- Secretion build up → narrowed ETT lumen → increased resistance

**Timing**
- Over 1-2 weeks → luminal diameter decreases ~ 9-15% (0-84%)
- Degree of narrowing correlates with duration of ventilation
- Clinically significant narrowing can occur in as little as 5 days

**Consequences**
- Pathogen Biofilm → Ventilator Associated Pneumonia
- Airway Resistance → Increased WOB → Prolonged Vent Wean
- Loss of Ventilation → Emergent Airway Exchange

**Airway Resistance**

\[ R = \frac{8\eta l}{\pi r^4} \]

- \( R \) = resistance
- \( l \) = tube length
- \( \eta \) = viscosity
- \( r \) = radius

The Hagen-Poiseuille Equation describes resistance: pressure drop from flow through long thin cylindrical tube.

- 13% ↓ Diameter → 200% ↑ Resist
- 25% ↓ Diameter → 316% ↑ Resist
- 50% ↓ Diameter → 1600% ↑ Resist
Signs of ETT Obstruction

**AC/VC**
1. Elevated peak airway pressures (Paw)
2. Prolonged exp times

**Patient**
1. Difficulty passing the suction catheter
2. Resp distress/retractions/increased WOB
3. Respiratory efforts failing to trigger breath

**PSV/PC**
1. PSV: Prolonged insp/exp times
2. PC: Prolonged exp times

**Note:** Vt may not fall until near complete occlusion

**Mechanics**
1. Increasing airway resistance (Raw)
2. Progressive auto-PEEP
3. Decreasing compliance

**Compliance ↓** as **auto-PEEP ↑**

In descelerating flow, ↑ Paw is much less sensitive (Pplat may ↑ if autoPEEP develops, but less than Paw)

What about tidal volume?

Rule out tube biting
Understanding Peak Pressures

**Peak Airway/Inspiratory Pressure**
- Pressure necessary to overcome airway resistance + lung/chest wall compliance
- Influenced by resistance, inspiratory flow rate and pattern, Vt, and ETT size

Peak Inspiratory Pressure becomes elevated when airway resistance increases (on AC/VC mode ventilation)

**Airway Pressure & Flow Waveforms**
(Constant Flow AC/VC Aka Square Wave)
Signs of ETT Obstruction in PSV/PC

Inspiratory Airway Pressures
- Airway pressures are preset and therefore FIXED
- Won't vary with resistance
- Not helpful to detect obstruction

Tidal Volumes and Flow
- In spontaneously breathing patients, Vt doesn’t drop until near complete occlusion of ETT
- Flow reductions can appear subtle
- Prolonged insp/exp times may suggest airway narrowing

PSV/PC may allow dangerous levels of ETT obstruction to build up undetected
Signs of ETT Obstruction in AC/VC

Inspiratory Airway Pressures
- Peak airway pressures are elevated when resistance increases
- Inner diameter reductions from 9.0mm baseline:
  - 6.0mm → PIP 115% of baseline levels
  - 5.0mm → PIP 150% of baseline levels
  - 4.0mm → PIP 200% of baseline levels

Inspiratory and Expiratory Times
- Will be prolonged in ETT obstruction

Tidal Volumes and Flow
- Expiratory flow is reduced and may not return to baseline, resulting in progressive autoPEEP/hyperinflation
- While inspiratory tidal volume is set, expiratory tidal volume may be reduced in ETT obstruction

AC/VC
1. Elevated peak airway pressures (Paw)
2. Prolonged exp times
Increasing Airway Resistance (Raw)

- Raw should be measured Q shift along with PIP, Pplat
- Must be measured in AC/VC square wave
- Patient must be passive for accurate measurement
- Flow 60L/min (1L/s) facilitates calculations (denominator = 1)
- Ventilator should calculate and display for you 😊
- Raw > 15 is abnormal

Auto-PEEP

- Progressive autoPEEP due to insufficient exhalation

Difficulty Passing Suction Catheter

- Red flag for obstruction
Unexplained asynchrony or difficulty tolerating spontaneous vent modes warrant evaluation.

Progressive autoPEEP & elevated Paw/Raw on AC/VC square wave warrant urgent intervention.

Clinical Instability and/or Inability to Pass Suction Catheter?

- **NO**
  - Urgent Management
    - Give 2mL 3% saline or 2mL 20% Mucomyst +/- albuterol via Aerogen® inline nebulizer
    - After treatment, perform inline suctioning
    - If available, use in-line EndOclear catheter vs. Fogarty balloon to strip secretions/biofilm (Fogarty requires anesthesia or IPulm)
  - Consider bronch if unclear if obstruction in ETT or native airway

- **YES**
  - Emergent Management
    - Call Airway Rapid Response overhead for emergent airway intervention
    - ETT exchange or reintubation (exchange catheter preferred, alternatively VL or DL at provider discretion given comfort)
    - Call Anesthesia for consideration of airway intervention (If unable to effectively & rapidly address ETT concerns via consult, can call Airway RR)

Concern for persistent ETT obstruction

**Urgent Management**

- Give 2mL 3% saline or 2mL 20% Mucomyst +/- albuterol via Aerogen® inline nebulizer
- After treatment, perform inline suctioning
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**Emergent Management**

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- ETT exchange or reintubation (exchange catheter preferred, alternatively VL or DL at provider discretion given comfort)
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**NOTE:** Airway Rapid Response previously used for emergent airway loss → Now can be called for unstable airway with risk of impending airway loss

**Succion Catheter RED FLAGS:**
- Difficulty passing → urgent intervention
- Inability to pass → emergent intervention

**a)** To prevent bronchospasm

**b)** If Aerogen not available, directly instill medication into ETT, DO NOT use open nebs
EndOclear Catheter ETT Clearance Device

- Flexible central tube with smooth disc-shaped wiper at distal end
  - Tube is inserted into adapter until blue safety stop
  - Distal wiper is deployed into open position
  - Catheter is pulled out of ETT removing secretions & biofilm
Things to Remember

Background
- ETT occlusion can occur at any time point during course of mechanical ventilation.
  → Higher incidence in COVID-19 patients, especially when using passive humidification (HME filter)
- Small decreases in diameter results in large increases in resistance
- Risk of prolonged vent wean, VAP, obstruction or even loss of airway

Monitoring
- Progressive occlusion can go undetected on PSV/PC or in AC when inspiration is in a decelerating flow
- Monitor resistance on AC/VC mode in square wave flow, Q12 hours and with clinical/ventilator changes

Management
- Increased airway resistance, difficulty passing the suction catheter, unexplained asynchrony or difficulty tolerating spontaneous vent modes warrant urgent intervention
- Inability to pass the suction catheter warrants emergent intervention
- Consider in line nebulized saline or Mucomyst and/or biofilm stripping for stable patients with suspected ETT occlusion
- Call airway rapid response for unstable patients with suspected ETT occlusion
Monitoring Resistance

<table>
<thead>
<tr>
<th>Normal Lungs</th>
<th>ARDS</th>
<th>COPD</th>
</tr>
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<tbody>
<tr>
<td>Resistance (cmH2O/L/L)</td>
<td>10 – 15</td>
<td>10 – 15</td>
</tr>
<tr>
<td>Compliance (ml/cmH2O)</td>
<td>&gt; 60</td>
<td>10 – 50</td>
</tr>
<tr>
<td>Peak Airway Pressure (cmH2O)</td>
<td>&lt; 20</td>
<td>&lt; 35</td>
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**Raw > 15 is abnormal**

Measure Q12h & with clinical/ventilator changes warranting reassessment

- Place patient on AC/VC square wave flow pattern to measure
- Patient must be passive for accurate measurement; if high concern for obstruction, consider temporary sedation +/- paralysis to obtain accurate vent mechanics

**On AC/VC Square Wave**

- On flow 60L/min: Raw = PIP – Plat
- Other flow rates: Raw = (PIP – Plat) / Flow (L/s)
  (Vent will calculate & display Raw)

**Urgent Management**

- Give 2mL 3% saline or 2mL 20% Mucomyst +/- albuterol® via Aerogen® inline nebulizer

**Emergent Management**

- Call Airway Rapid Response overhead for emergent airway intervention
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**ETT Obstruction Overview**

- ↑ Incidence in COVID-19, especially with non-humidified vent circuits
- Small decreases in ETT diameter result in large increases in resistance
- Unexplained asynchrony or difficulty tolerating spont modes warrant evaluation
- Progressive autoPEEP & ↑ Paw/Raw on AC/VC square wave warrant urgent mgmt

**Suction Catheter RED FLAGS:**

- Difficulty passing → Paw on AC/VC square wave warrant urgent mgmt; emergent intervention

**Treatng & Reversing ETT Obstruction**

- Clinical Instability and/or Inability to Pass Suction Catheter?

**NO**

- Consider bronch if unclear if obstruction in ETT or native airway

**YES**

- Inability to pass → emergent intervention

**Concern for persistent ETT obstruction**

- NOTE: Airway Rapid Response previously used for emergent airway loss
- Now can be called for unstable airway with risk of impending airway loss

  a) To prevent bronchospasm
  b) If Aerogen not available, directly instill medication into ETT, DO NOT use open nebs

Created by Jen Ginestra, MD, Pulmonary & Critical Care Medicine; Adapted from UPHS Critical Care Committee Guidelines