

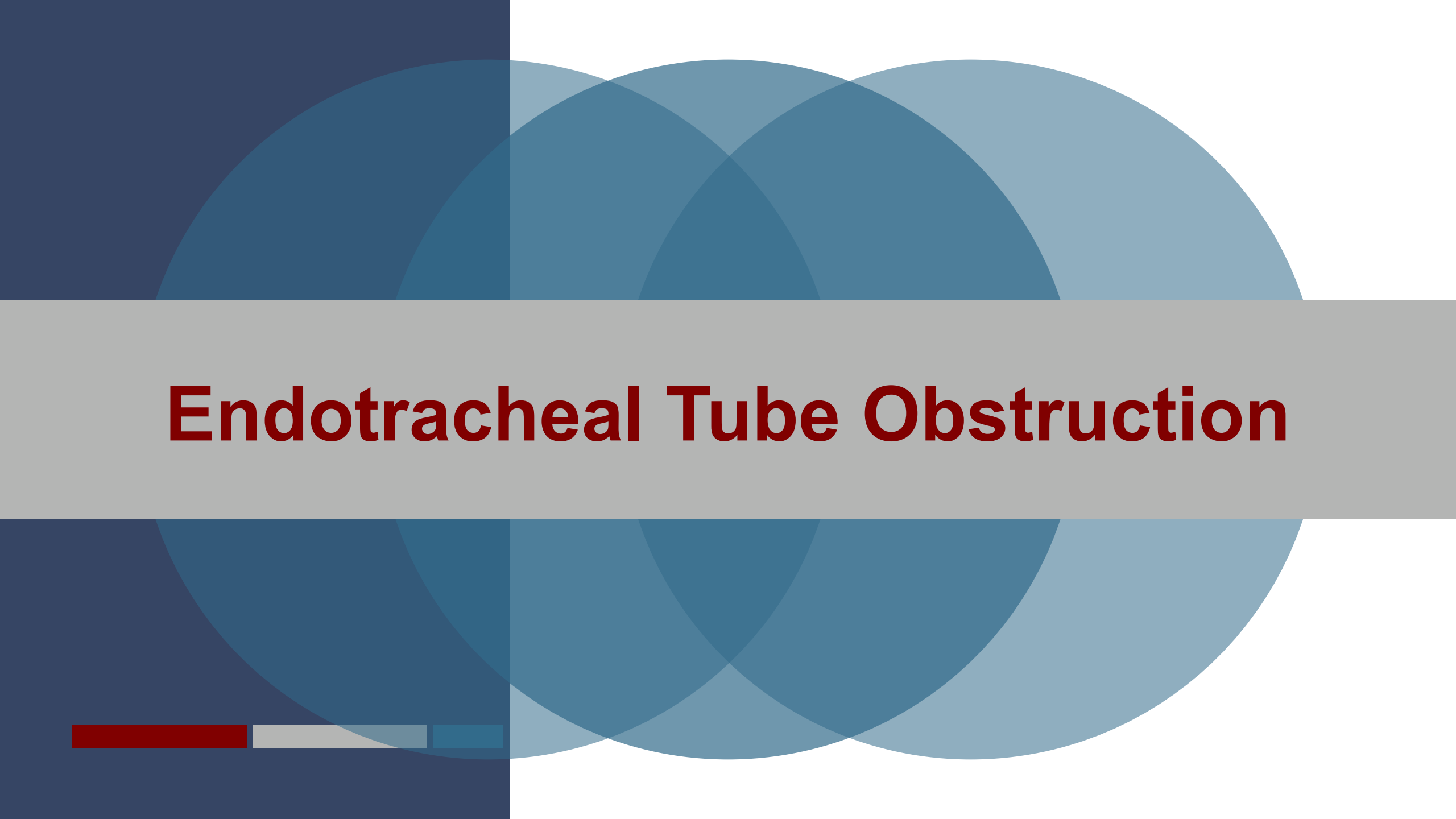
Division of Pulmonary and Critical Care Medicine

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 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

$$\text{Airway Resistance } R = \frac{8\eta l}{\pi r^4}$$

R = resistance

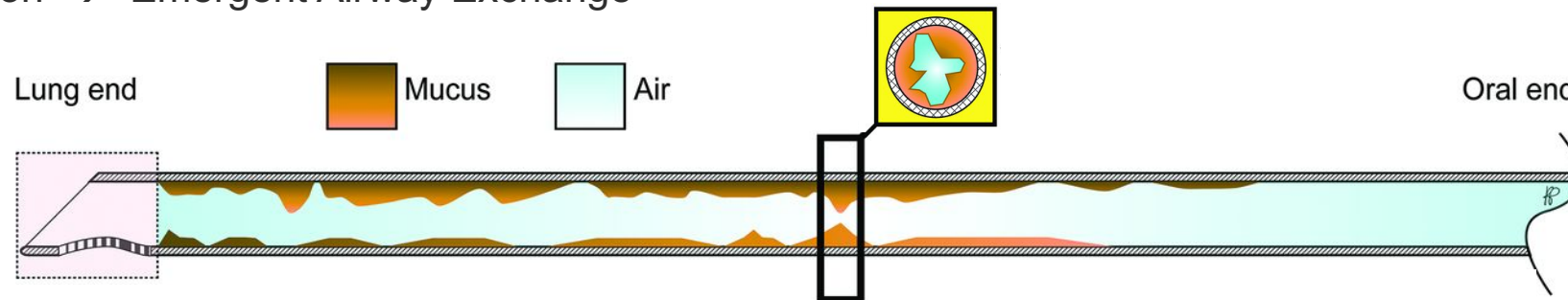
η = viscosity

l = tube length

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

In decelerating flow, $\uparrow$ Paw is much less sensitive (Pplat may $\uparrow$ if autoPEEP develops, but less than Paw)

Compliance $\downarrow$ as auto-PEEP $\uparrow$

AC/VC

1. Elevated peak airway pressures (Paw)
2. Prolonged exp times

PSV/PC

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

Note: Vt may not fall until near complete occlusion

Mechanics

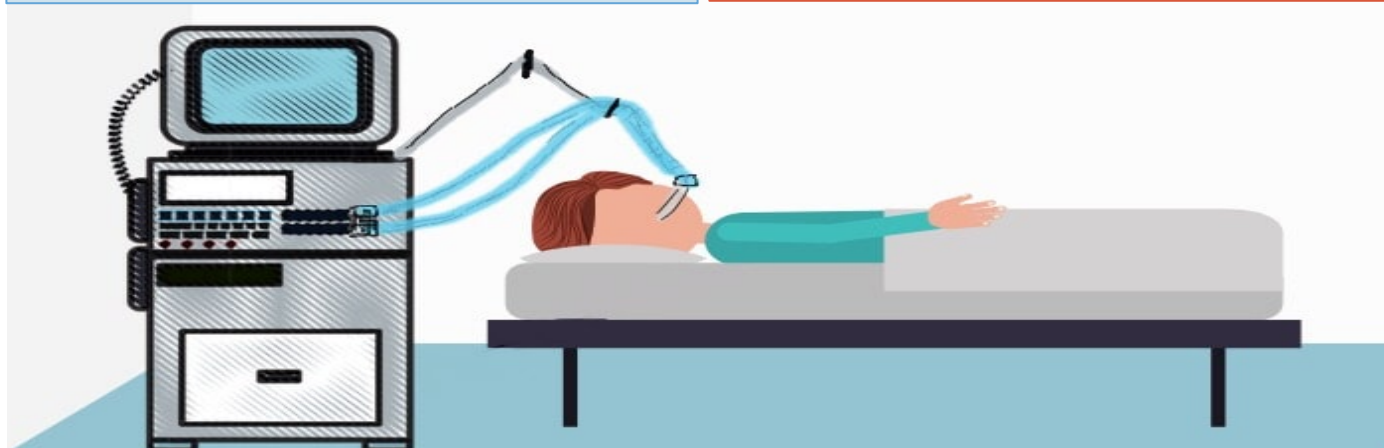
1. Increasing airway resistance (Raw)
2. Progressive auto-PEEP
3. Decreasing compliance

Patient

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

What about tidal volume?

Rule out tube biting



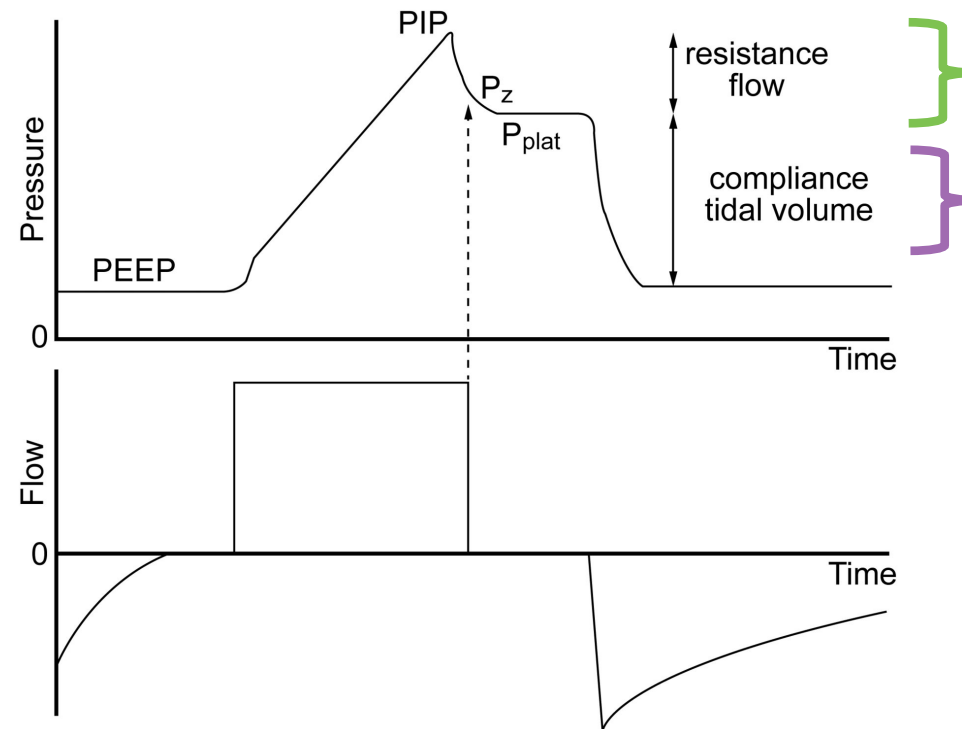
Understanding Peak Pressures

Peak Airway/Inspiratory Pressure

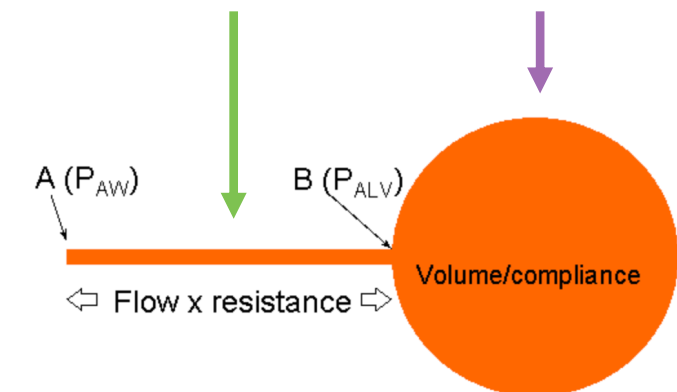
- Pressure necessary to overcome airway resistance + lung/chest wall compliance
- Influenced by resistance, inspiratory flow rate and pattern, Vt, and ETT size

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)



$$P_{aw} = \underbrace{\text{Flow} \times \text{Resistance}}_{PIP - P_{plat}} + \underbrace{\frac{\text{Volume}}{\text{Compliance}}}_{P_{plat} - PEEP} + PEEP$$



Signs of ETT Obstruction in PSV/PC

Inspiratory Airway Pressures

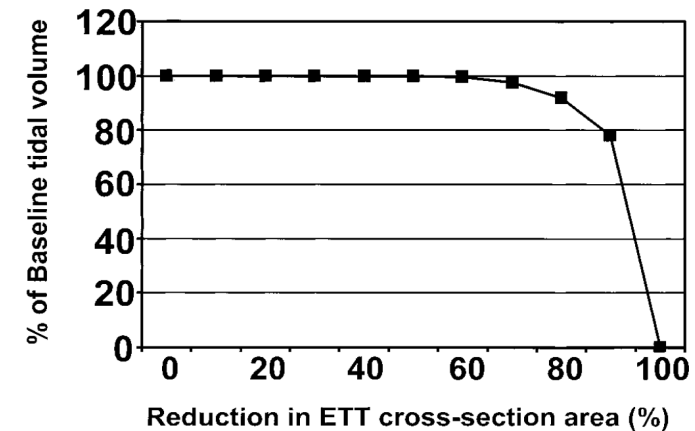
- Airway pressures are preset and therefore FIXED
- Won't vary with resistance
- Not helpful to detect obstruction

Tidal Volumes and Flow

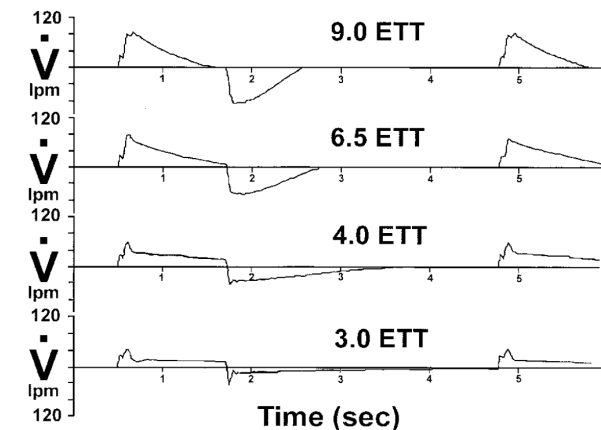
- In spontaneously breathing patients, Vt doesn't drop until near complete occlusion of ETT
- Flow reductions can appear subtle
- Prolonged insp/exp times may suggest airway narrowing

PSV/PC may allow dangerous levels of ETT obstruction to build up undetected

ΔV_t on PC w/ Progressive ETT Occlusion



Δ Flow on PC w/ Progressive ETT Occlusion



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

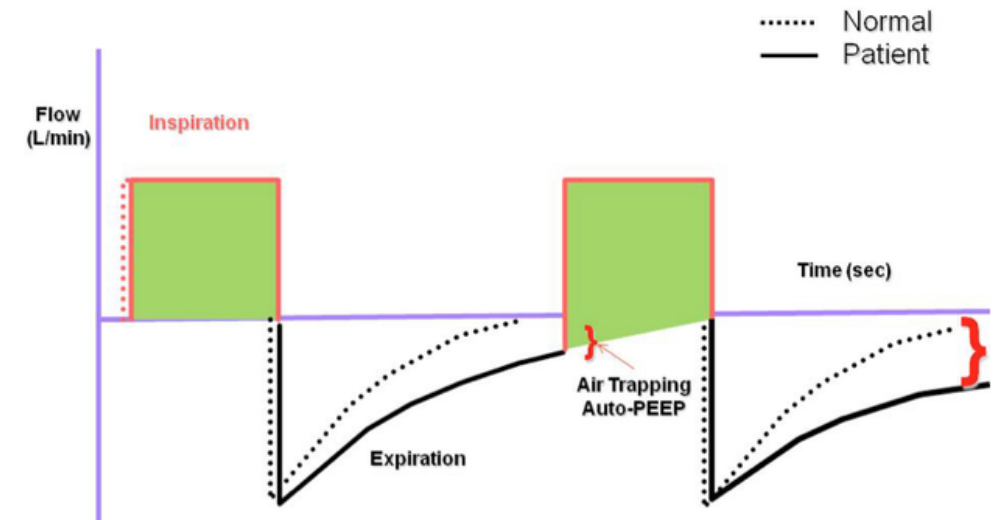
- Will be prolonged in ETT obstruction

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

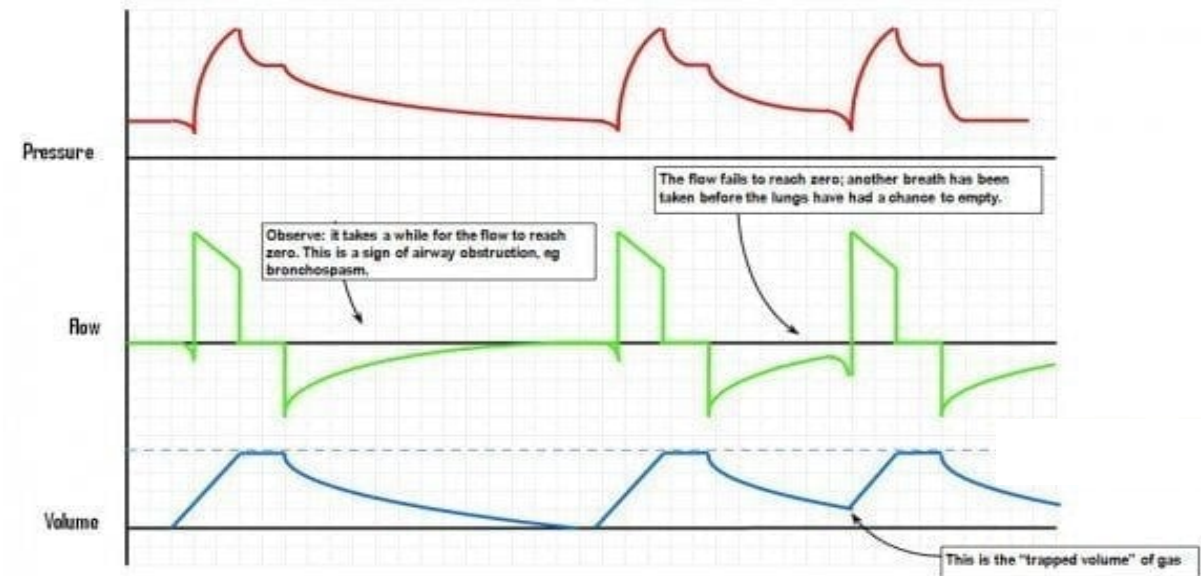
1. Elevated peak airway pressures (Paw)
2. Prolonged exp times



Signs of ETT Obstruction in Any Mode

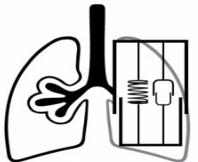
Increasing Airway Resistance (Raw)

- 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**



Monitoring Resistance

	Normal Lungs	ARDS	COPD
Resistance (cmH2O/L/s)	10 – 15	10 – 15	10 – 30
Compliance (ml/cmH2O)	> 60	10 – 50	> 60
Peak Airway Pressure (cmH2O)	< 20	< 35	20-60



Airway Resistance (Raw)

$$Raw = (PIP - Pplat) / Flow$$

[on 60L/min (1L/s) flow, equation becomes $Raw = PIP - Pplat$]

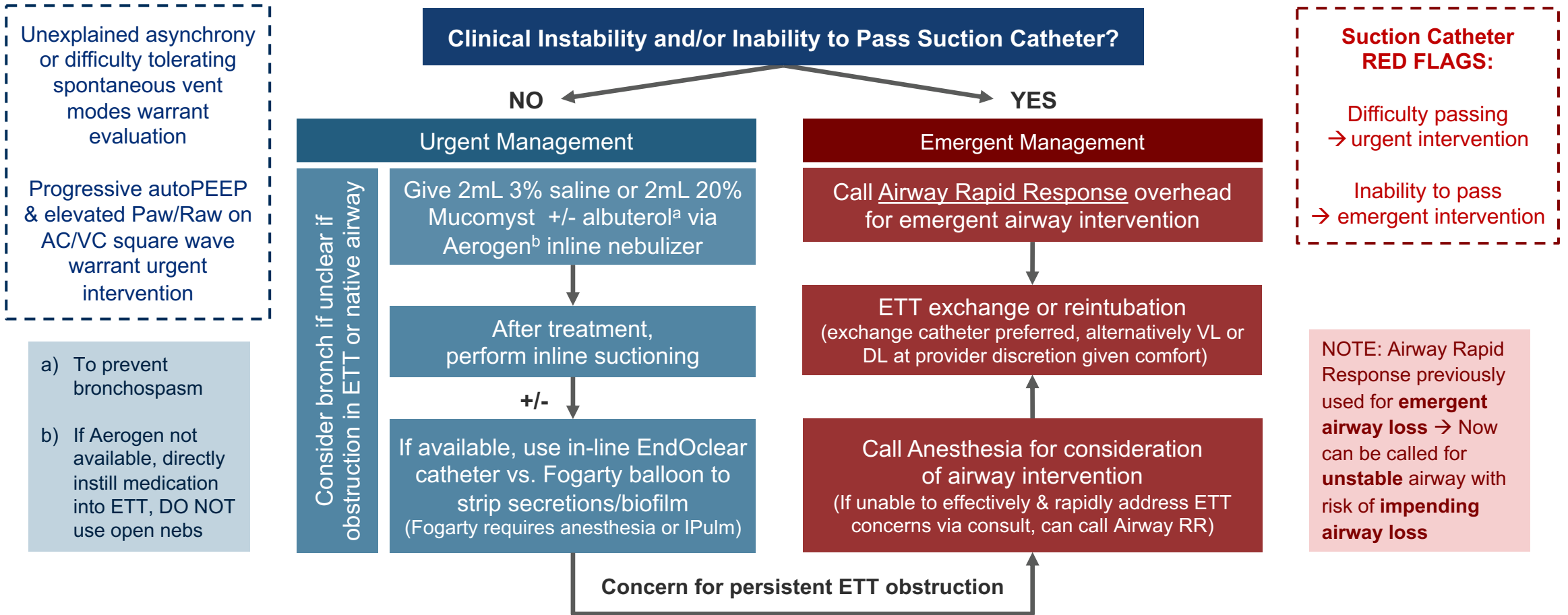
Auto-PEEP

- Progressive autoPEEP due to insufficient exhalation

Difficulty Passing Suction Catheter

- Red flag for obstruction

Treating / Reversing ETT Obstruction



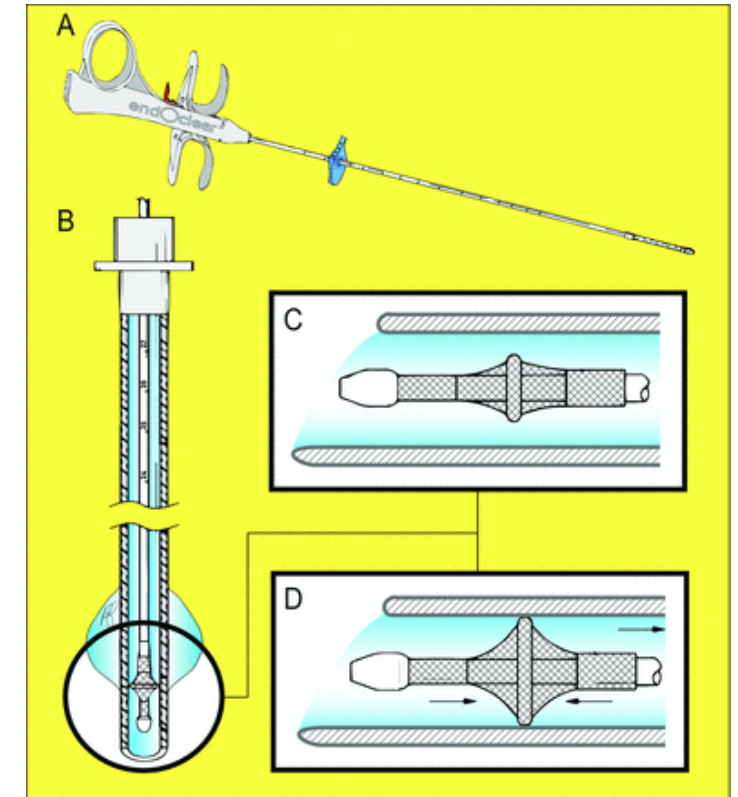
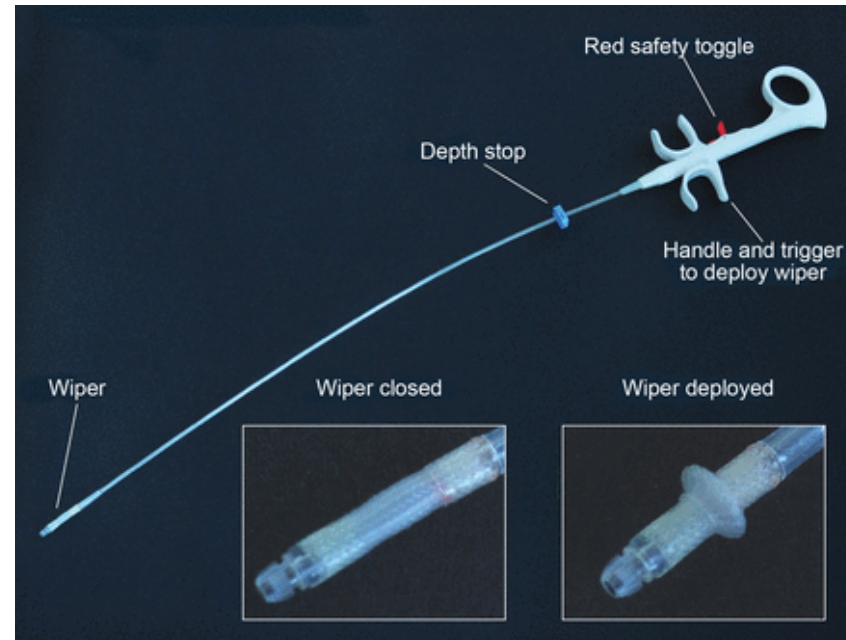
EndOclear Catheter ETT Clearance Device

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

Penn Medicine COVID-19 Clinical Guide: Endotracheal Tube Obstruction

Updated 4/20/20 – Recommendations may evolve rapidly – Do not save file – If printed, update frequently – Check for latest version [here](#)



Signs of Loss of ETT Patency

AC/VC

↑ Peak airway pressures (Paw)
Prolonged exp times

PSV/PC

PSV: Prolonged insp/exp times
PC: Prolonged exp times

Note: Vt may not fall until near complete occlusion¹

Mechanics

↑ Airway resistance (Raw)
↓ Compliance
Progressive auto-PEEP

Patient

Difficulty passing suction catheter
Retractions/increased WOB
Resp efforts fail to trigger breaths



Monitoring Resistance

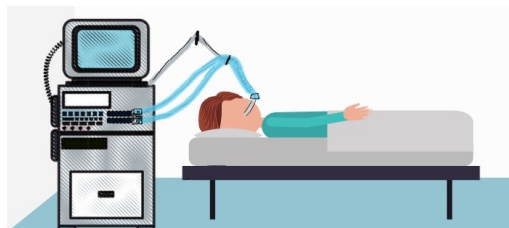
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Compliance (ml/cmH2O)	> 60	10 – 50	> 60
Peak Airway Pressure (cmH2O)	< 20	< 35	20-60

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)



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

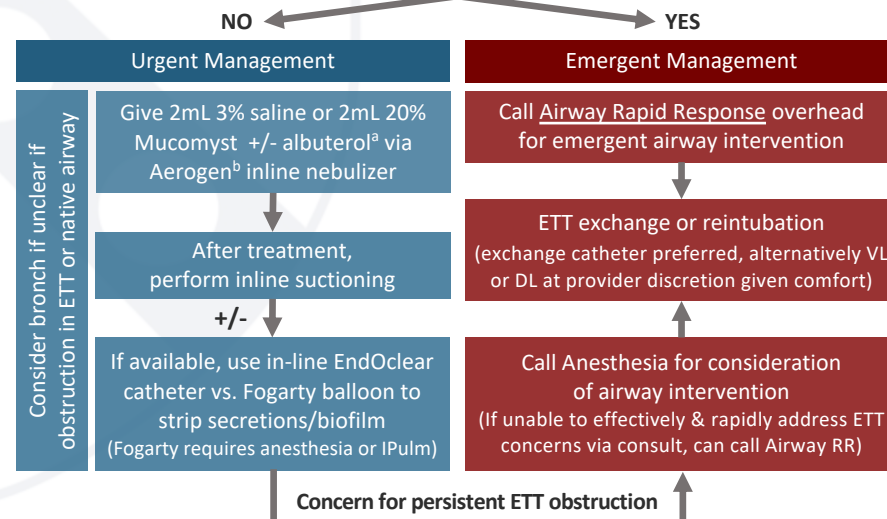
Suction Catheter RED FLAGS:

Difficulty passing → urgent intervention; Inability to pass → emergent intervention



Treating & Reversing ETT Obstruction

Clinical Instability and/or Inability to Pass Suction Catheter?



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

¹Tung. Anesth Analog. 2002