Mechanical Ventilation 101

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Caveat

- The goal of most ventilator runs is to keep the patient alive until their problem resolves. Like parachutes, there will never be an RCT.

- Lots of people ***know*** what's best, despite lack of evidence. In reality, if the patient is alive at 8:05 AM, you were on the right ventilator settings.

Respiratory system functions

- Enzymatic function (angiotensin conversion, etc.)
- Acid - base balance (pH)
- H_2O & heat homeostasis
- Production of speech, singing, shouting, bracing for physical effort
- Hemodynamic effects
- Immune barrier functions/airway protection
- CO_2 elimination
- O_2 uptake

Indications for mechanical ventilation

- Respiratory failure
  - -Hypoxemic
  - -Hypercarbic, including anesthesia
- Very rare specific indications (flail chest, DAH, hyperventilation for ICP)

- NOT airway support. You don't always have to ventilate an intubated patient.

Gas exchange paradigms

- Non-invasive
  - -Negative pressure
  - -Positive pressure
- Invasive
  - -Positive pressure
  - -High frequency
  - -Extracorporeal

Control variables

- **Pressure-pressure waveform unchanged with compliance/ resistance**
- **Time-volume waveform unchanged with compliance/resistance**
- **Volume-volume measured directly**
- **Flow-flow measured directly**

Trigger (phase) variables

- **Pressure**-inspiration begins when a pre-set pressure change is detected
- **Time**-inspiration begins when a pre-set time change is detected
- **Volume**-inspiration begins when a pre-set volume change is detected
- **Flow**-inspiration begins when a pre-set flow is detected

Cycle (phase) variables

- **Pressure**-inspiration ends when a pre-set pressure change is detected
- **Time**-inspiration ends when a pre-set time change is detected
- **Volume**-inspiration ends when a pre-set volume change is detected
- **Flow**-inspiration ends when a pre-set flow is detected

Limit (phase) variables

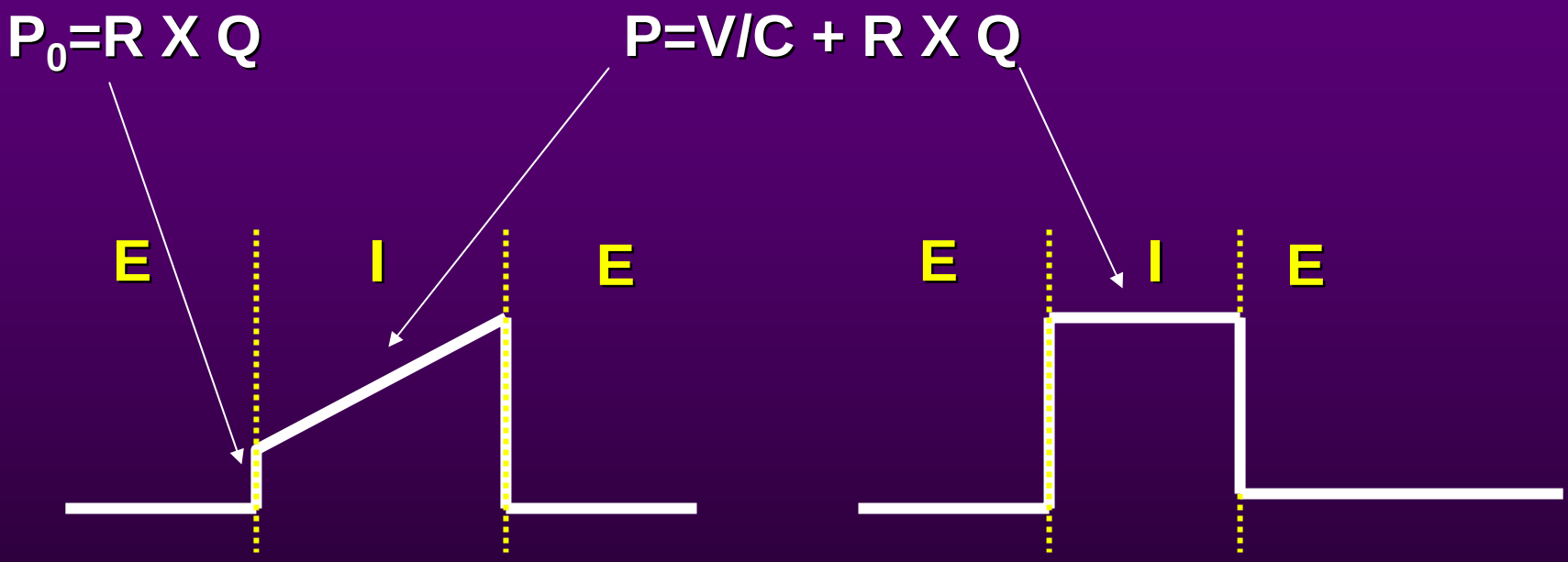
- **Pressure**-a pre-set peak pressure is reached and not exceeded
- **Volume**-pre-set peak volume
- **Flow**-pre-set peak flow is used

Breath Types

There are four basic breath types as follows:-

Breath Type	Phase Variable		
	Trigger	Limit	Cycle
MANDATORY	Machine	Machine	Machine
ASSISTED	Patient	Machine	Machine
SUPPORTED	Patient	Machine	Patient
SPONTANEOUS	Patient	Patient	Patient

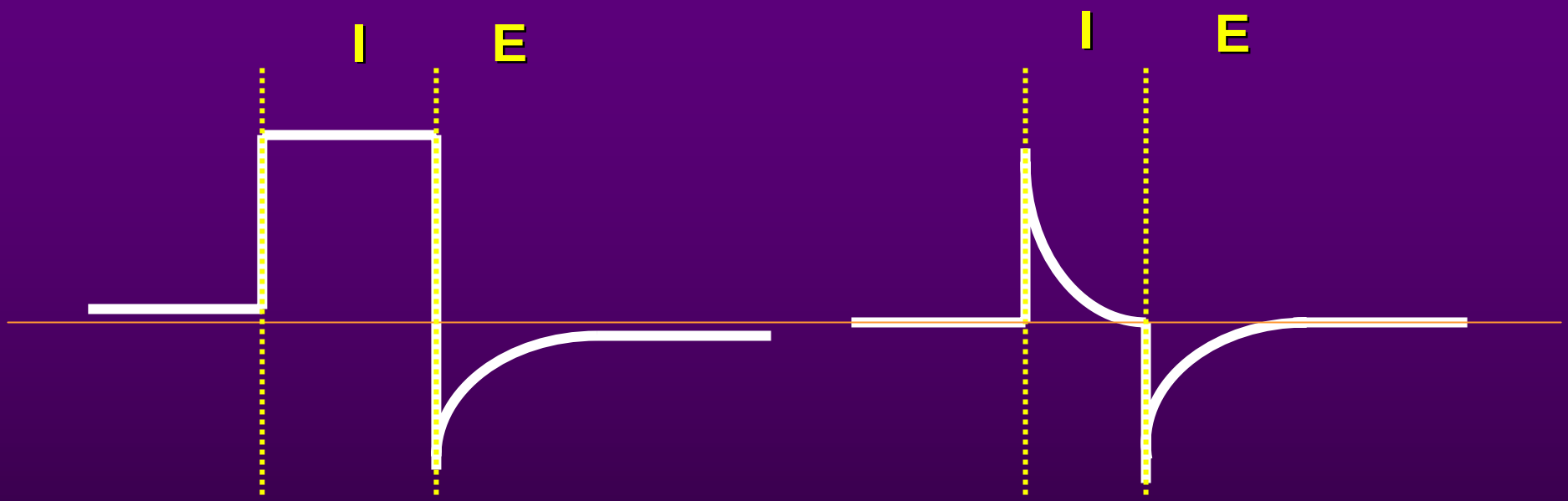
Pressure vs. Time



Volume controlled

Pressure controlled

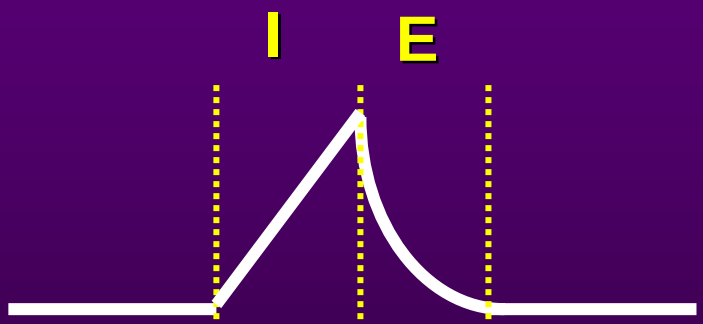
Flow vs. Time



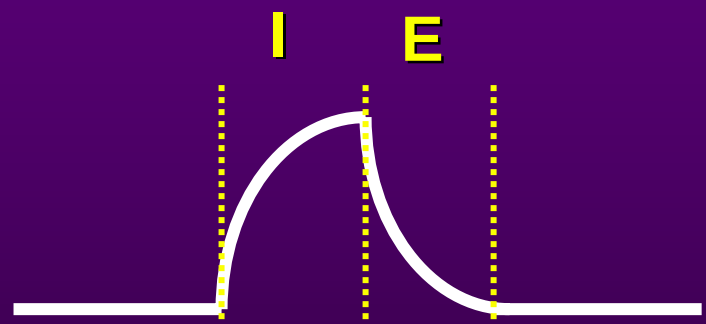
Volume controlled

Pressure controlled

Volume vs. Time

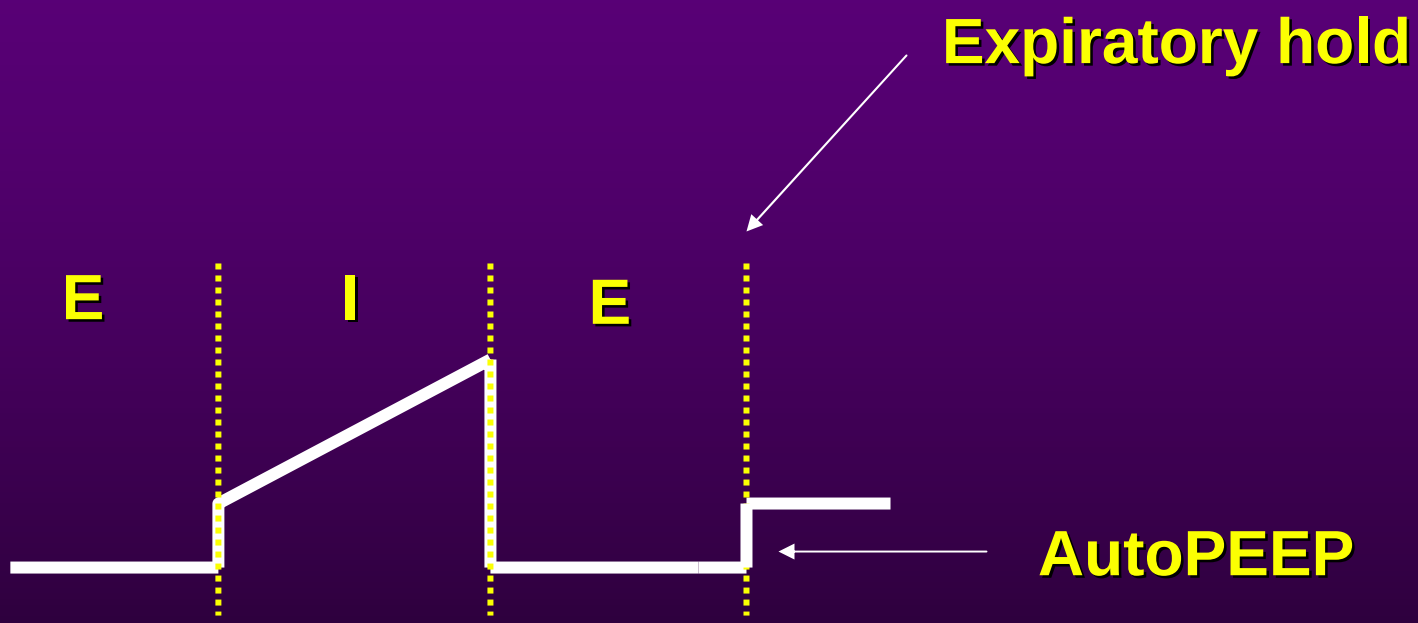


Volume controlled

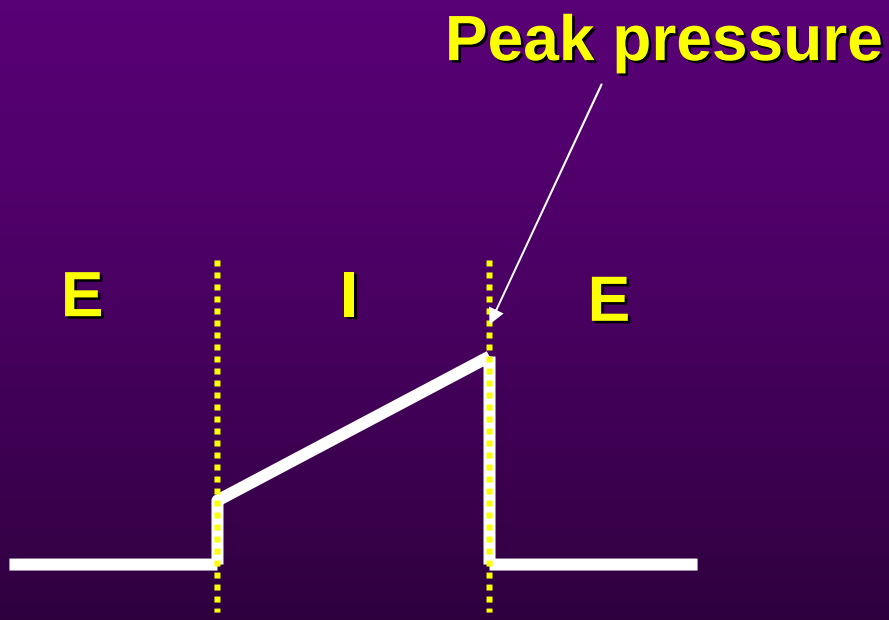


Pressure controlled

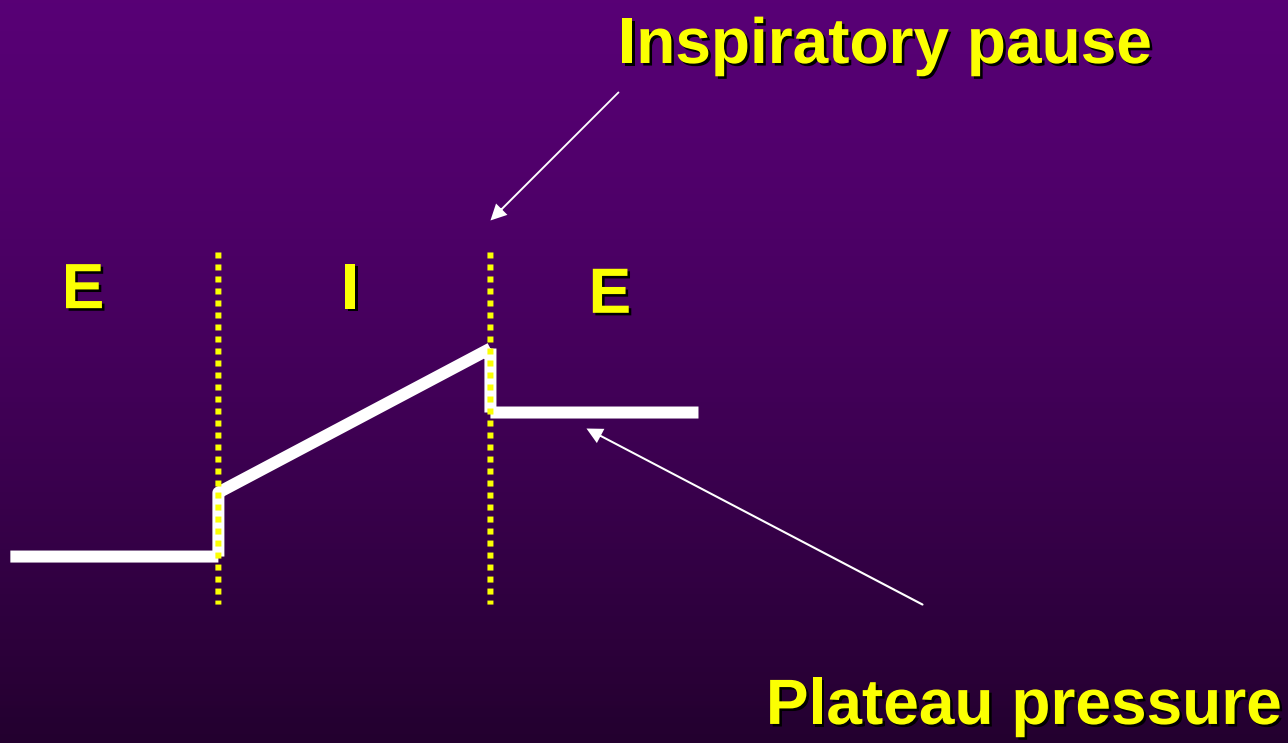
AutoPEEP



Peak pressure



Pressure vs. Time



Specific modes

Continuous Positive Airway Pressure
Bi-phasic Positive Airway Pressure
Controlled Mandatory Ventilation
Assist Control
Synchronized Intermittent Mandatory Ventilation
Pressure Regulated Volume Control
Pressure Support Ventilation
Pressure Control Ventilation
Volume Support

Airway Pressure Release Ventilation
High Frequency Ventilation

CPAP

Continuous Positive Airway Pressure

Control-P to set value

Trigger-F to set sensitivity (P/V)

Limit-P at set value

Cycle-F down to fixed number (5L/m) or %max (25%)

Think of this as PEEPx + Pressurex pressure support

Does not decrease WOB, and in fact may increase it

Designed for nasal mask delivery at home, can be used in-house

CPAP-Notes

Used for oxygenation support

NOT ventilation. Does not directly decrease the WOB

Best uses-Hypoxemia felt to be fairly quickly reversible (hours to a few days)

Risks-Pneumothorax, baro/oxygen toxicity, ASPIRATION, sphicter-tightening intubation if fails, facial necrosis, hemodynamic compromise

BiPAP

BiPhasic Positive Airway Pressure

- Control-P (set IPAP/EPAP)
- Trigger-F to set sensitivity (40mL/sec for 30 ms)
- Limit-P at set value
- Cycle-F down to fixed number (5L/m) or expiratory flow or 3 seconds

- Think of this as variable pressure support + PEEP in non-intubated patients
- Designed for nasal mask delivery at home, can be used in-house

BiPAP-Notes

Same as CPAP except

Does decrease the work of breathing

Can be nearly full mechancial support if pressures are high enough

Can set a backup rate

CMV

Continuous mandatory ventilation

Control-V to set value

Trigger-T to set interval

Limit-P at set value (F)

Cycle-V when set volume is hit. Can cycle using T (and thus I:E)

First mode developed, designed for use intra-op or in sedated/paralyzed patient

CMV-Notes

Patient effort is ignored, therefore best use is in OR or in STABLE sedated/paralyzed patients

WILL NOT CHANGE with changing physiology, especially dead space and need for increased V_A

Risks of VAP, barotrauma, oxygen toxicity, DVT, stress ulcers

AC

Assist control

Control-V to set value

Trigger-T to set interval or P to set value (F)

Limit-P at set value (F)

Cycle-V when set volume is hit. Can be set to T to give control of I:E ratio

Early mode, designed for use in ICU in awake, possibly unstable patients

AC-Notes

Best use is as an initial mode in unstable patients who are awake and controlling their own V_A

Risks-Same as CMV

Should probably be the mainstay of initial ventilation in most patients. I:E ratio can be controlled somewhat, but might be easier to adjust flow rate instead

Not a weaning mode-must use SBT from here

SIMV

Synchronized Intermittent Mandatory Ventilation

Control-V to set value

Trigger-T to set interval

Limit-P at set value (F)

Cycle-V when set volume is hit.

Designed as a weaning mode, only assists set number of breaths/min. Allows patient to gradually assume WOB as rate is decreased

SIMV-Notes

It’s a weaning mode… Get off of it if you’re not weaning

Don’t add pressure support to SIMV, it just confuses the picture and doesn’t really gain you anything

You don’t need this as a back-up rate on PSV «just in case they don’t breath » The vent has alarms, and what are you doing weaning someone who doesn’t breathe anyway?

PSV

Pressure Support Ventilation

Control-P to set value

Trigger-P to set value (F but NOT T)

Limit-P at set value

Cycle-F when set flow (or %max flow) is reached

Designed as a weaning mode, assists every breath. Allows patient to gradually assume WOB as pressure is decreased

PSV-Notes

Wean mode

Don’t add SIMV

Is mechanical ventilation. You can almost fully support someone’s breathing with this mode on enough pressure. Pressures in normal lungs are around 5-10 cm water

PCV

Pressure Control Ventilation

Control-P to set value

Trigger-T to set value or P at set value

Limit-P at set value

Cycle-T at set I:E/rate

Think of this as pressure regulated (controlled) CMV. Purpose is really OXYGENATION through inverse I:E ratio

PCV-Notes

PCV-IMV makes no sense (allows them to breath on their own). Breaks the pressure you're using to try to open them up, and if you're struggling with oxygenation, why a wean mode?

Best use of this is when getting up to higher levels of PEEP and still not oxygenating.

Uncomfortable in general, may need higher levels of sedation/paralysis

PRVC

Pressure Regulated Volume Control

Control-P/V-to set V with minimum pressure

Trigger-T to set value

Limit-P but variable, to lowest possible value

Cycle-V

Functions similarly to AC, but eliminates the peak pressure, making us, and more importantly, RT, feel better.

PRVC-Notes

Does adjust for changing compliance, but not for changing Mv requirement.

No scientific literature to support

Probably over-used in our unit

Considerations

- Goals
- Mode and settings
  - Physiology
    - COPD, Asthma
    - ARDS
    - etc.
- Monitoring
- Trouble shooting

Early goals

- PaO2 >60 or 65
- Normal pH
- Peak pressure <30-35

- Avoid barotrauma (volutrauma) and autoPEEP
- Avoid oxygen toxicity
- Patient comfort

Initial settings

- Usually start vent. at 100% FIO_2
- Minute ventilation around 8-10 L/m. Lower in COPD, higher if floridly septic
- Peak/plateau pressure <30-35
- Typical tidal volumes are 8 mL/kg (in ARDS 6 mL/kg) with a rate of 10-20

First night

- Wean FIO2 to 50-60%
- Minute ventilation for pH around 7.40 if possible. Permissive hypercapnea OK of pH adequately conrolled
- Peak pressure <30-35

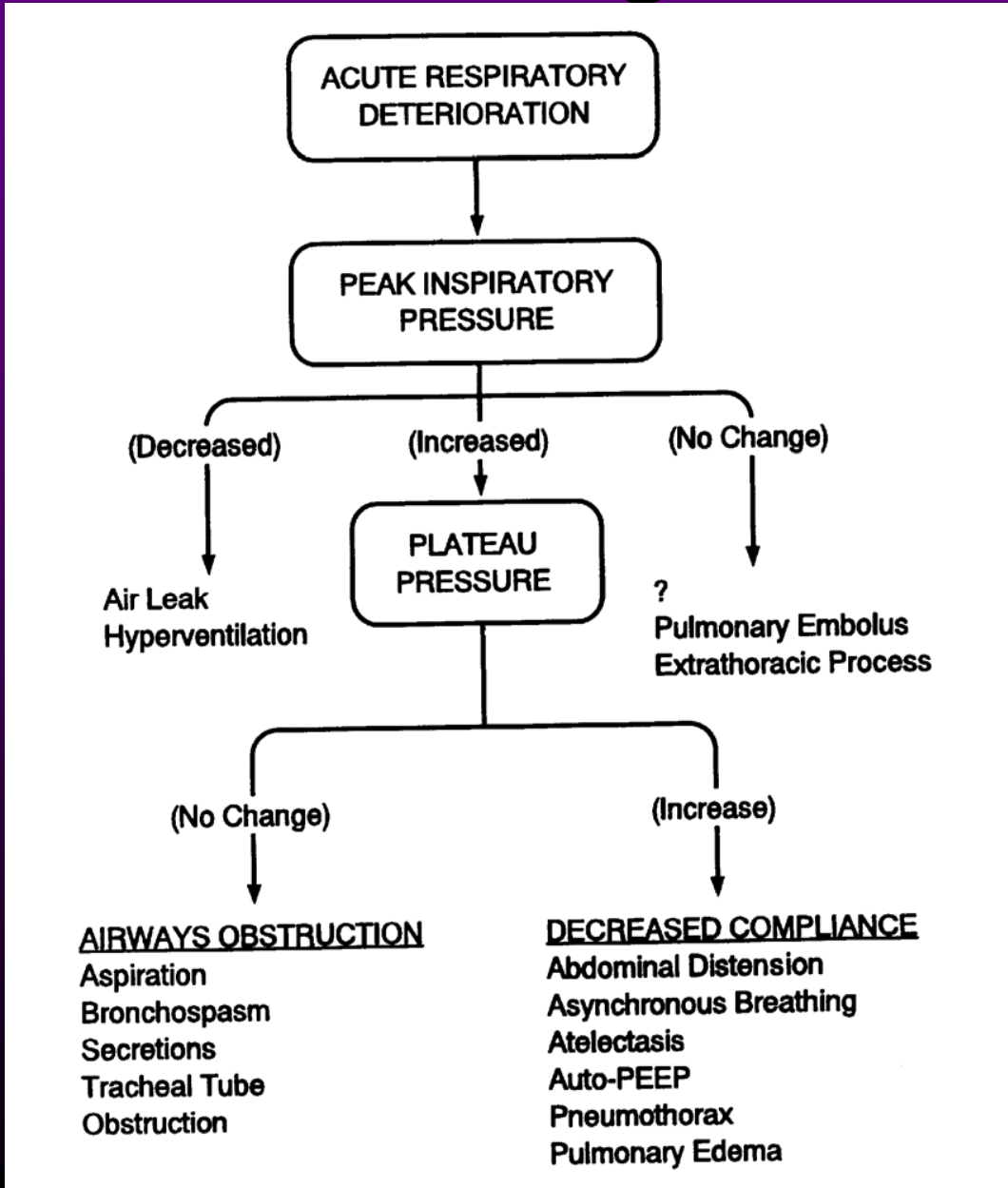
Trouble Shooting

- Ppeak is up
  - Look at your Pplat

Trouble Shooting

- If your Pplat is high, you are faced with a COMPLIANCE problem
- If your Pplat is normal, you are faced with a RESISTANCE problem

Trouble Shooting



Trouble Shooting

- At the time of intubation, fighting is largely due to anxiety
- But what do you do if the patient is stable and then becomes agitated?

Trouble Shooting

1. Remove patient from ventilator
2. Initiate manual ventilation
3. Perform brief P/E and assess monitoring indices
4. Check patency of airway
5. If death is imminent, consider and treat most likely causes
6. Once pt is stabilized, undertake more detailed assessement and management

Trouble Shooting

- Patient-related causes
  - Artificial airway problems
  - Secretions
  - Pneumothorax
  - Bronchospasm
  - Pulmonary edema
  - Pulmonary embolism
  - Dynamic hyperinflation
  - Abnormal respiratory drive
  - Alteration in body posture
  - Drug-induced problems
  - Abdominal distension
  - Agitation
- Ventilator-related causes
  - System leak
  - Circuit malfunction
  - Inadequate F_{IO_2}
  - Inadequate ventilator support
- Patient-ventilator asynchrony

Tracheal Decannulation

- Successful weaning is not synonymous with tracheal decannulation
- If weaned and not fully awake or unable to clear secretions, leave ETT in place
- Contrary to popular belief, tracheal decannulation increases the work of breathing due to laryngeal edema and secretions
- Do not perform tracheal decannulation to reduce work of breathing

Inspiratory Stridor

- Post extubation inspiratory stridor is a sign of severe obstruction and should prompt reintubation
- Laryngeal edema (post-ext) may respond to aerosolized epinephrine in children
- Steroids have no role
- Most need reintubation followed by tracheotomy