VENTILATOR STRATEGIES

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No Disclosures

DISCUSSION OBJECTIVES

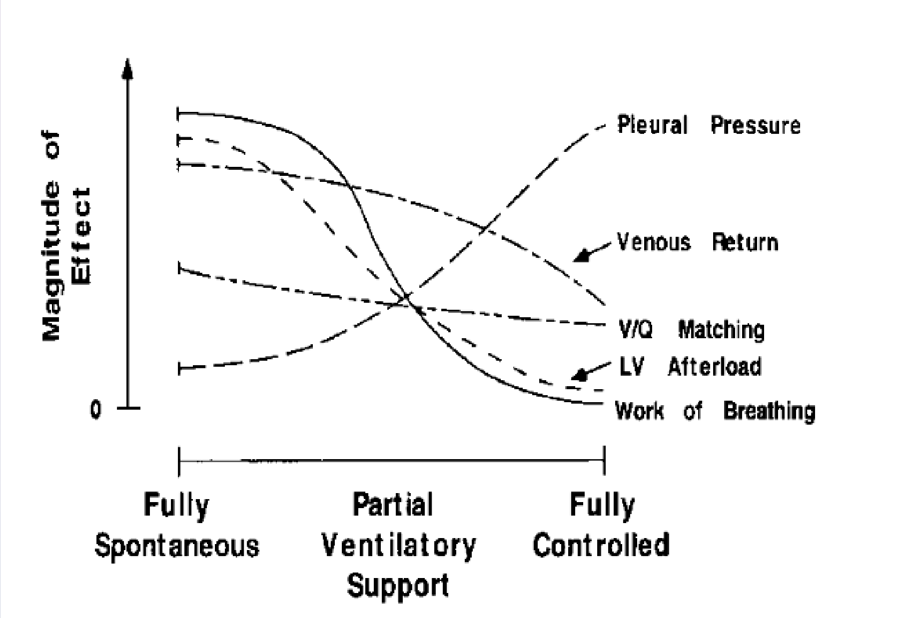
1. How Positive Pressure Ventilation (PPV) helps
    - Reduce work of breathing (WOB)
    - Restore adequate gas exchange
2. The essentials in PPV
    - Variables Involved
    - Modes of Ventilation
3. Clinical Considerations
    - Volume/Pressure Relationship (Time, Flow, Trigger)
4. Ventilator Liberation

WHY VENTILATE

- Unprotected and unstable airways (e.g., coma)
  - Intubation and IPPV allows to
    - Airway maintenance
    - Minimize risk of aspiration
    - Maintain adequate alveolar ventilation
- Hypercapnic respiratory acidosis
  - IPPV and NIPPV
    - ↓ WOB and prevent respiratory muscle fatigue (speeds recovery when fatigue is already present)
    - Maintain adequate alveolar ventilation (prevent or limit respiratory acidosis as needed)
- Hypoxic respiratory failure
  - Alveoli collapse or fluid filled alveoli
  - IPPV and NIPPV help correct hypoxemia as it allows to
    - Deliver a high FiO_2 (100% if needed during IPPV)
    - Reduce shunt by keeping alveoli open

PPV CONSIDERATIONS

- Positive and negative effects associated with PPV
  - Circulation
    - Reduced venous return and afterload
    - Hypotension
    - Cardiac output effect
  - Lungs
    - Increased thoracic pressure
    - Barotrauma
    - Ventilator-induced lung injury (VILI)
    - Air trapping / Auto-Peep
  - Gas exchange
    - Compression of capillaries - PEEP
    - May increase dead space V_D (compression of capillaires)
    - Shunt – peep manuever



PPV INITIATED BY FOUR VARIABLES

- Trigger

  Initiates the breath
- Control

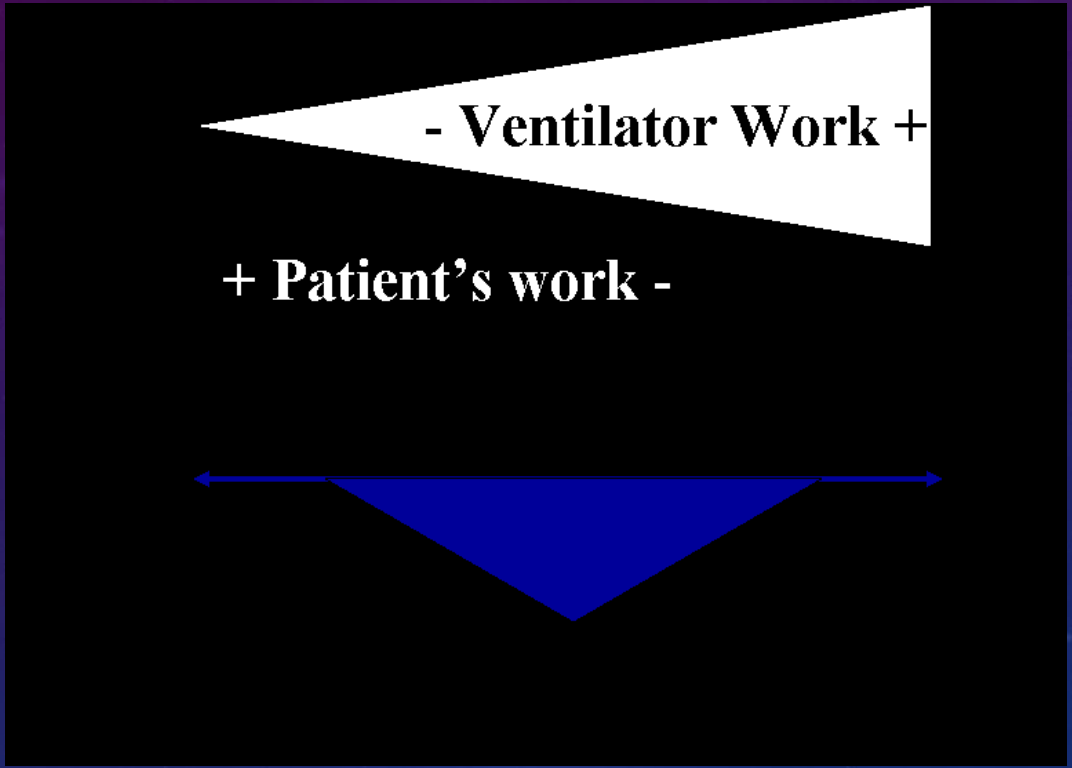
  Controls delivery
- Limit

  Terminates the breath
- Cycle

  Initiates the frequency

- Mandatory
  - A/C, SIMV
- Pressure
  - PC (Pressure Control, Time Cycled)
- Dual Control
  - PRVC (A/C, SIMV)
  - APRV
- Spontaneous
  - CPAP
  - Pressure Support

WORKLOAD BETWEEN PATIENT & VENTILATOR



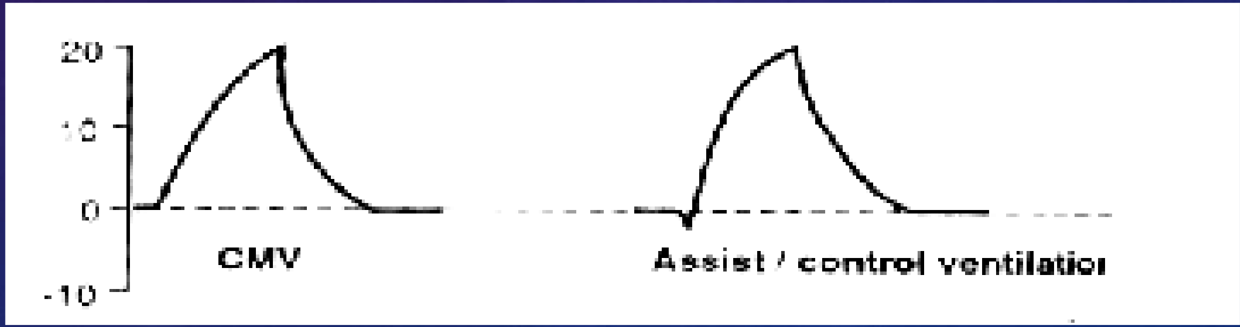
How the work of breathing partitions between the patient and the ventilator depends on:

1. Mode of ventilation (e.g., in A/C majority of work done by the ventilator)
2. Patient effort and synchrony with the mode of ventilation
3. Specific settings of a given mode (e.g., level of pressure in PS and set rate in SIMV)

Mandatory Ventilation

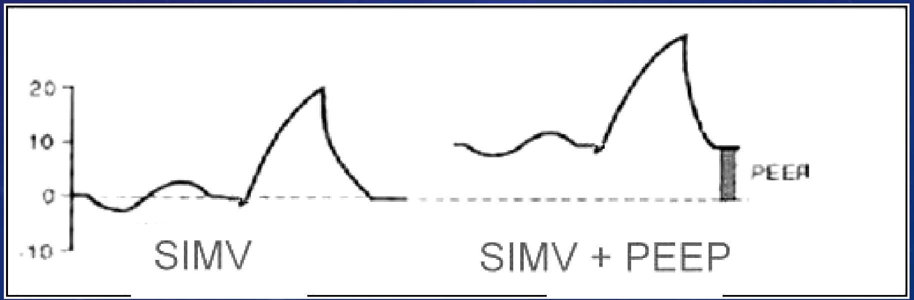
ASSIST CONTROL (A/C)

- A/C - Tidal volume (V_T) of each delivered breath is the same, regardless of whether it was triggered by the patient or the ventilator. At the start of a cycle, the ventilator senses a patient's attempt at inhalation by detecting negative airway pressure or inspiratory flow.



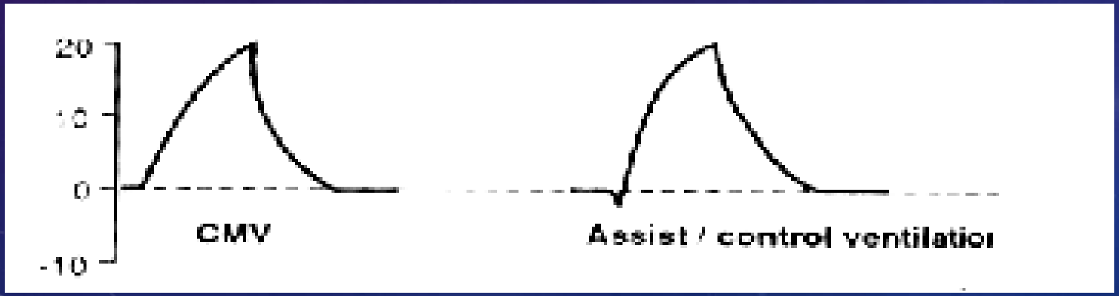
SYNCHRONIZED INTERMITTENT MANDATORY VENTILATION (SIMV)

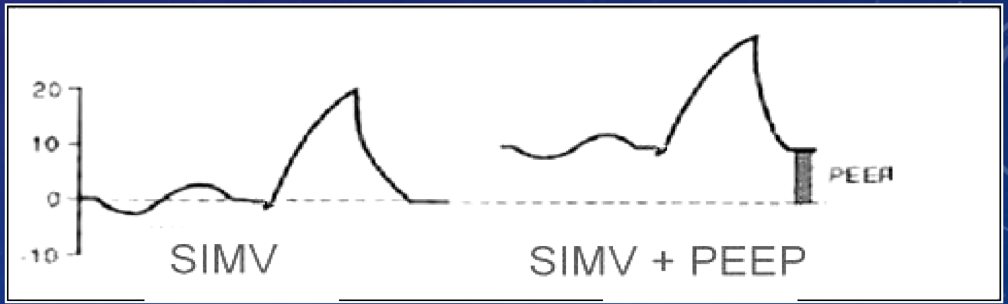
SIMV - Delivers a minimum number of fully assisted breaths per minute, synchronized with patient respiratory effort. Breaths are patient- or time-triggered, flow-limited, and volume-cycled. However, any breaths taken between volume-cycled breaths are not assisted; the volumes of these breaths are determined by the patient's strength, effort, and lung mechanics.



CLINICAL CONSIDERATIONS

- Volume Control Modes (A/C, SIMV)
  - Guaranteed V_T regardless of compliance
  - In non-variable flow modes (A/C, SIMV) PIFR demands may not be met
  - Can cause increased Paw leading to barotrauma, volutrauma and adverse hemodynamic effects
  - Ventilation Asynchrony ↑ WOB

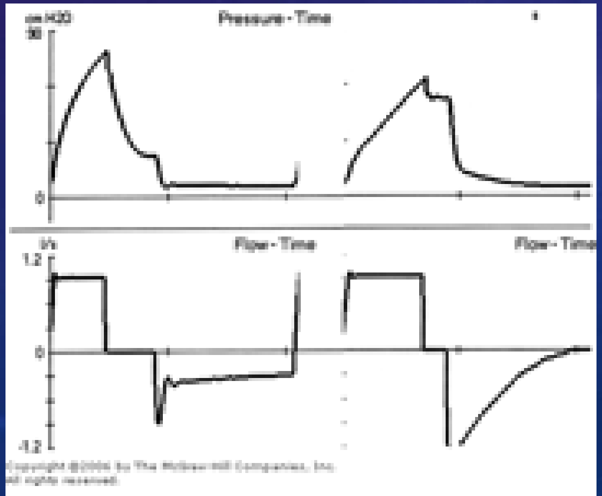




PRESSURE CONTROL

PRESSURE – TIME CYCLED

- Pressure
  - PC - ventilator delivers a flow to maintain the preset pressure at a preset respiratory rate over a preset inspiratory time (IT)

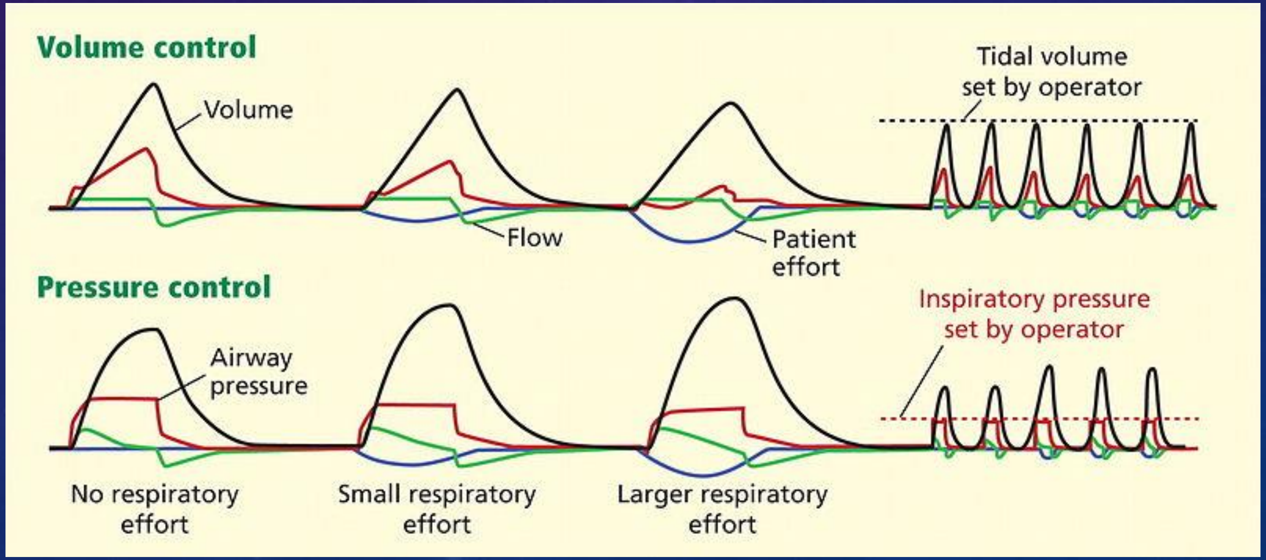


- Clinical Considerations
  - Ability to manage Paw
  - Variable V_T as pulmonary mechanics (compliance) change
  - Potential for excessive V_T as compliance improves

DUAL CONTROL MODES

PRESSURE REGULATED VOLUME CONTROL (PRVC/VC+)

- PRVC - Pressure modulates (up or down) to achieve a pre-set tidal volume. Breaths are controlled by pressure (inspiratory +PEEP) and volume, limited by pressure (inspiratory + PEEP) and cycled by time.

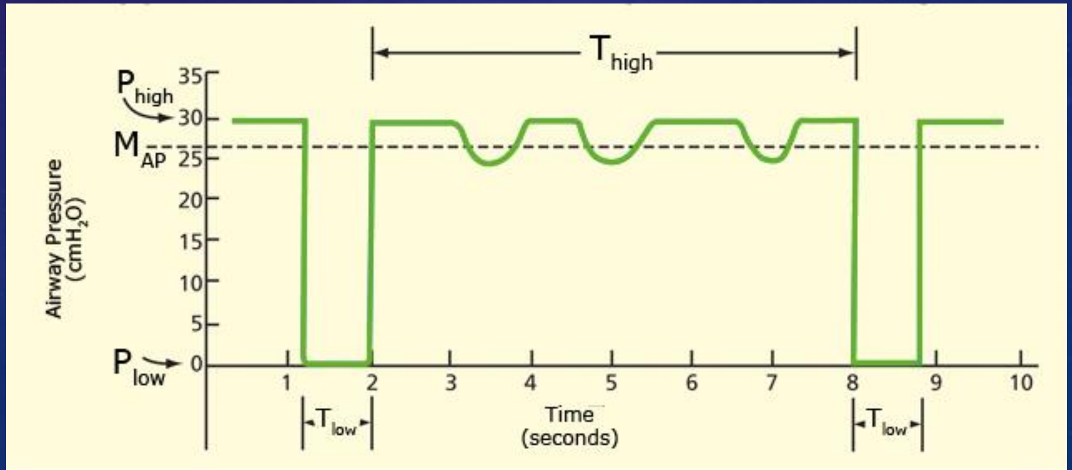


CLINICAL CONSIDERATIONS - PRVC

- Advantage of both V and P control – maintains minimum Paw to provide constant V_T
- Manages ventilation breath-to-breath (P ↑ or ↓ to maintain V_T based on V_T of previous breath)
- The pressure limit fluctuates between 0 cm H_2O above the PEEP level to 5 cm H_2O below the High-pressure alarm
- Improved patient-ventilator synchrony
- Variable PIFR
- If patient demand ↑'s pressure level may ↓ when support is most necessary resulting in ↓ Pmean leading to hypoxemia

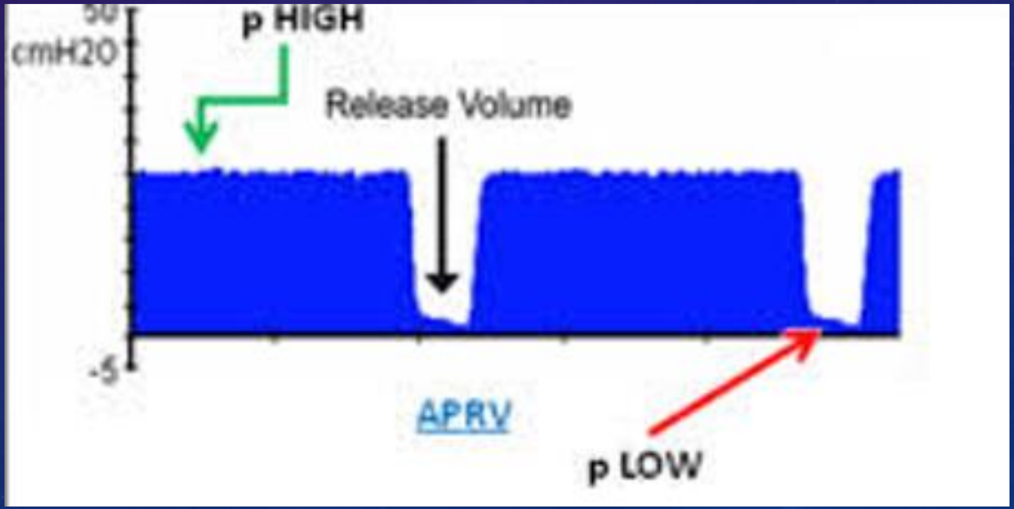
AIRWAY PRESSURE RELEASE VENTILATION (APRV)

- APRV - Time cycled pressure mode that cycles between two different baseline pressures (Hi/Lo) based on time that can by synchronized with patient effort. Controlled ventilation can be maintained by time cycling and occurs when pressures changes from high to low. PS can be added. Inverse Ratio.



CLINICAL CONSIDERATIONS - APRV

- Mandatory breaths occur when P changes from High to Low
- Variable Flow
- Preservation of spontaneous breathing at high CPAP
- ↓ WOB, ↓ barotrauma, ↓circulatory compromise, ↓ sedation
- V_T changes with alteration in compliance

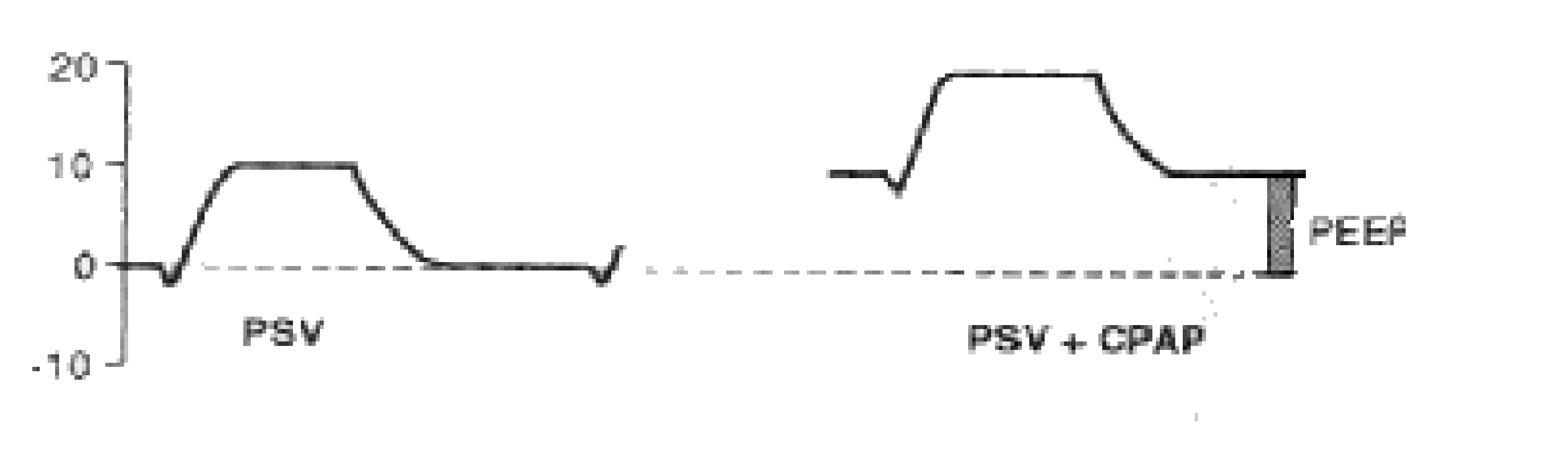


SPONTANEOUS

- Continuous positive airway pressure/Pressure Support ventilation (CPAP/PSV) – Flow Cycled
  - CPAP – demand breaths with the pressure level during inspiration equal to the preset-PS + PEEP and cycled by time or flow.
- Non-Invasive Positive Pressure Ventilation (NIPPV)
  - BiPAP - is a continuous positive airway pressure (CPAP) mode used during noninvasive positive pressure ventilation. It delivers a preset inspiratory positive airway pressure (IPAP) and expiratory positive airway pressure (EPAP). Rate can be set to guarantee bursts of IPAP.

CLINICAL CONSIDERATIONS

- Pressure Support
  - Always use in SIMV – preset RR
  - Patient generated breaths must overcome resistance - ↑ WOB



VENTILATOR-INDUCED LUNG INJURY

- Two primary mechanistic factors:
  - Overdistension of alveoli by high transpulmonary pressures: volutrauma (↑ V_T)
  - Shear-stress forces (**Atelectrauma**) produced by repetitive alveolar recruitment and derecruitment: collapse
  - Biotrauma (inflamatory mechanisims) and Barotrauma (ambient pressure changes)
- The degree of overinflation is dependent on:
  - V_T
  - Paw
  - Duration of mechanical ventilation

ADDITIONAL CONSIDERATIONS

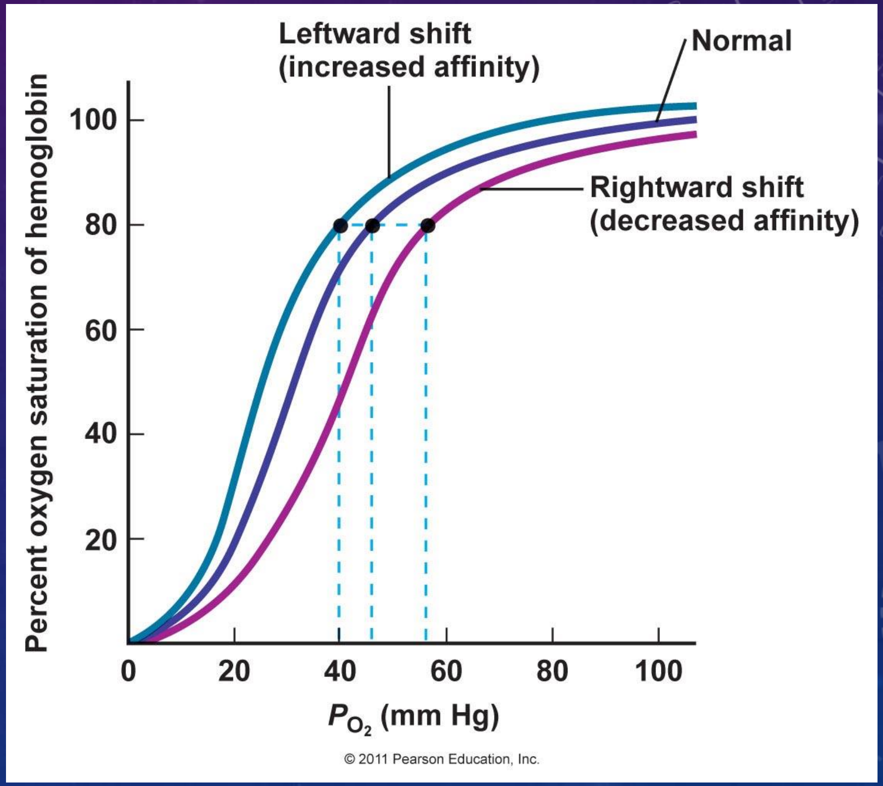
- Arterial Blood Gas
  - Assess pH (Acidotic, Alkalotic) (7.35 – 7.45)
  - Determine Respiratory Involvement (PaCO2) (35 – 45)
  - Determine Metabolic Involvement (HCO_3^-, BE) (22 – 26)
  - Assess for compensation (pH↑PaCO2 ↓ HCO_3^-)
  - Metabolic Considerations (Anion Gap, Lactate)

Normal ABG is not normal in Critically Ill patient

- Lactate (Prognostic Value)
- Hemodynamics
- Ventilation dysynchrony

OXYHEMOGLOBIN DISSOCIATION CURVE

- Describes the non-linear tendency for oxygen to bind to hemoglobin: below a SaO2 of 90%, small differences in hemoglobin saturation reflect large changes in PaO2.



LUNG PROTECTIVE STRATEGIES

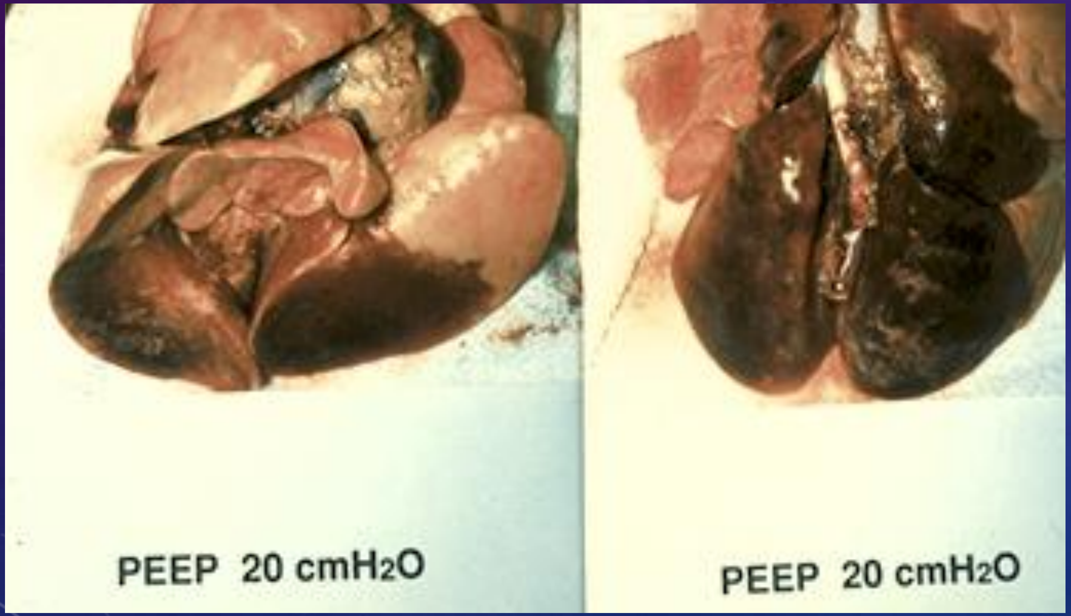
Ventilate at Ideal Body Weight (IBW)

Males (kg): 50 kg + 2.3 kg for each inch over 5 ft

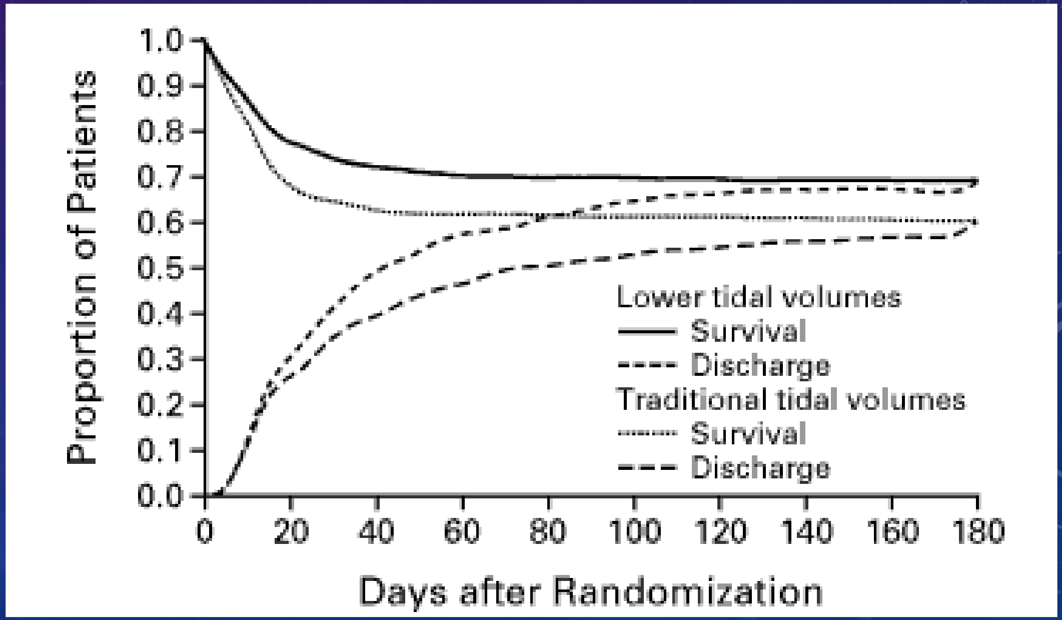
(lb): 105 lbs + 6 lbs for each inch over 5ft.

Females (kg): 45.5 kg + 2.3 kg for each inch over 5 ft

(lb): 100 lbs + 5 lbs for each inch over 5ft



Lungs of dogs ventilated for a few hours with ↑V_T demonstrates extensive hemorrhagic injury.



The Acute Respiratory Distress Syndrome Network. N Engl J Med. 2000;342:1301-1308

ARDS 2012 NETWORK

Lower PEEP/higher FiO2

FiO_2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7
PEEP	5	5	8	8	10	10	10	12

FiO_2	0.7	0.8	0.9	0.9	0.9	1.0
PEEP	14	14	14	16	18	18-24

Higher PEEP/lower FiO2

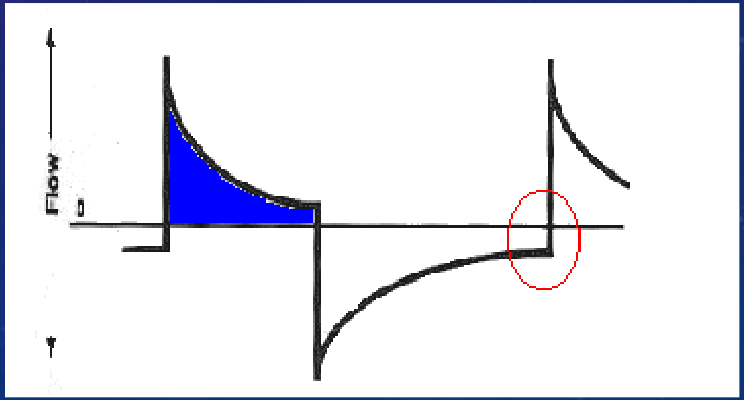
FiO_2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.5
PEEP	5	8	10	12	14	14	16	16

FiO_2	0.5	0.5-0.8	0.8	0.9	1.0	1.0
PEEP	18	20	22	22	22	24

- Oxygenation Goal: PaO_2 55-80 mmHg or SpO^2 88-95%
  - PEEP-FIO_2 Combination
  - Permissive Hypercapnia
  - O_2 Index = $\frac{FIO2 \times MAP}{PaO2}$
- P_{plat} Goal: ≤ 30 cm H^2O
  - Check P_{plat} (0.5 second inspiratory pause), at least q 4h and after each change in PEEP or V_T
- pH GOAL: 7.30-7.45
- I: E Ratio Goal: Recommend that duration of inspiration be ≤ duration of expiration

IMPORTANT PRINCIPLES

- Intrinsic PEEP
  - ↑ WOB and can be offset by applying external PEEP
  - ↑ Expiratory resistance
  - ↑ Respiratory rate
- Δ in Pmean
  - Measure of the pressure applied across the lung and chest wall
    - Arterial oxygenation
    - Cardiac output
- V/Q
  - V without Q – Dead space
  - Q without V – Shunt



VENTILATOR LIBERATION

- Spontaneous Breathing Trial (SBT)
  - $FiO_2 \leq 40\%$ and PEEP ≤ 8 OR $FiO_2 \leq 50\%$ and PEEP ≤ 5
  - PEEP and $FiO_2 \leq$ values of previous day
  - Systolic BP ≥ 90 mmHg without vasopressor support
  - No neuromuscular blocking agents
- Mechanics
  - RSBI (f/V_T) < 105/min/L
  - Monitor Compliance ($\Delta V/\Delta P$, *Cstat, Cdyn*)
    - *Cstat* = V_T / P*plat* – PEEP (inspiratory pause)
    - *Cdyn* = V_T / PIP– PEEP (active inspiration)

QUESTION #1

1) Which of the following is NOT a ventilator goal during management of ARDS

a) PaO2 55-80

b) pH < 7.2

c) Plateau pressure < 30

d) Vt 6 ml/kg of ideal body weight

QUESTION #2

2) Which of the following is a potentially deleterious effect of mechanical ventilation

a) Respiratory muscle hypertrophy

b) Increased mucociliary motility

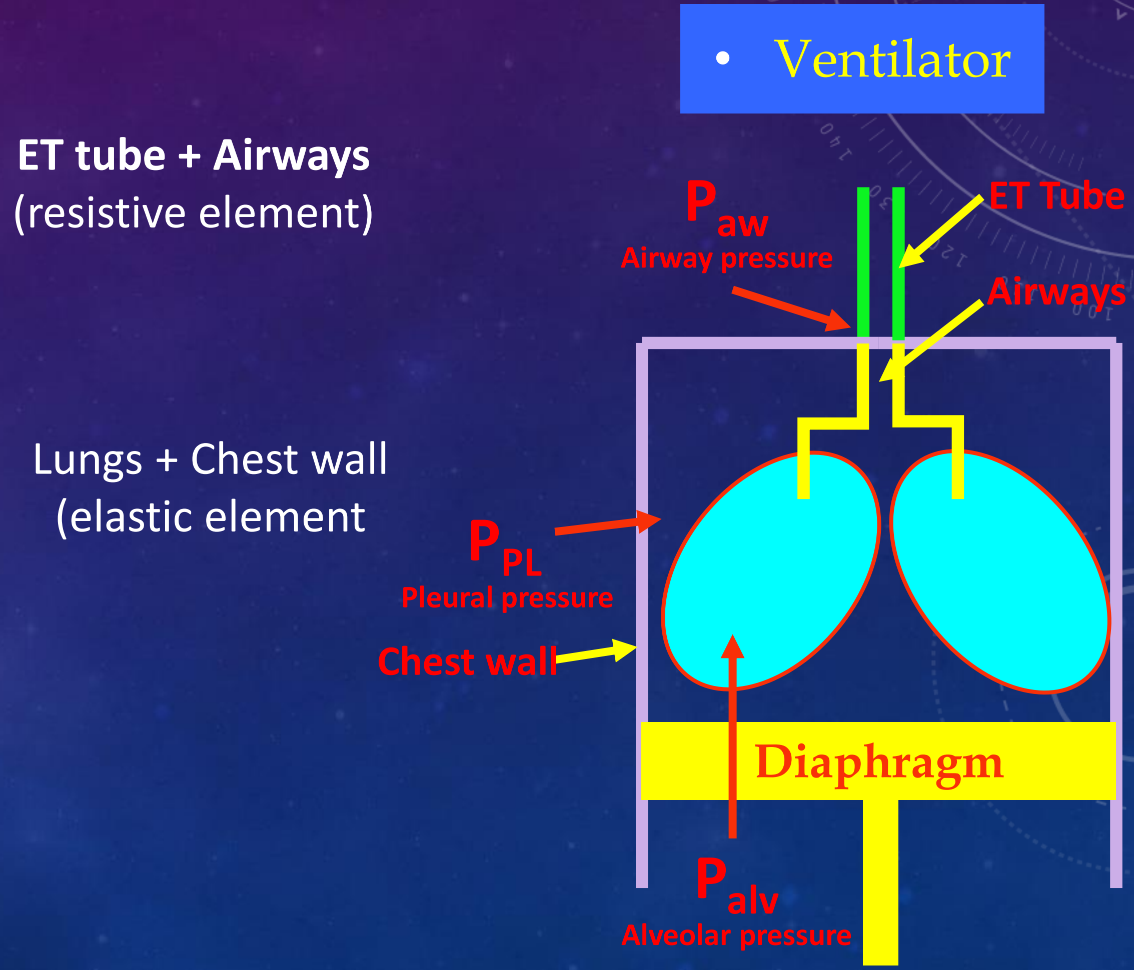
c) Decreased intracranial pressure

d) Reduced cardiac output

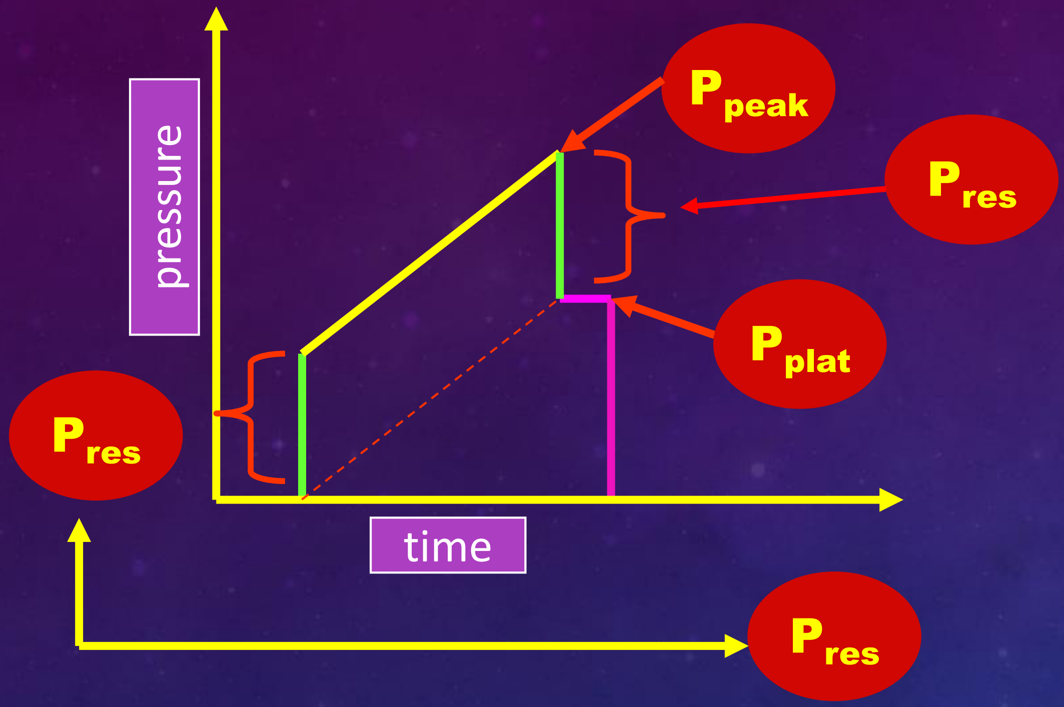
UNDERSTANDING AIRWAY PRESSURES

The respiratory system can be thought of as a mechanical system consisting of

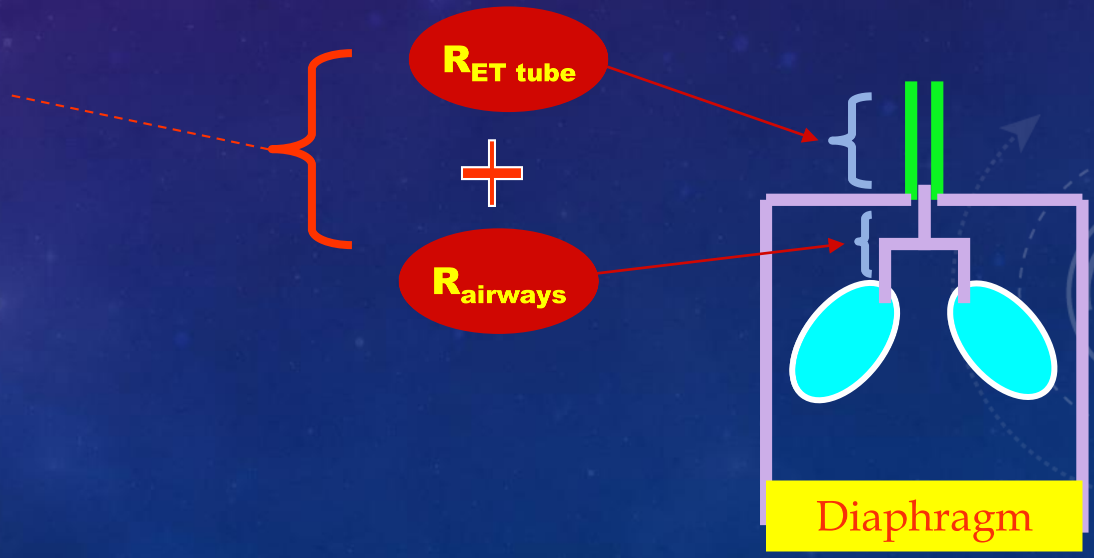
- resistive (airways + ETT)
- elastic (lungs and chest wall) elements in series



Understanding Pressure-Time Waveforms



1. At the beginning of the inspiratory cycle, ventilator has to generate a pressure P_{res} to overcome the airway resistance.
2. Next pressure rises in a linearly to reach P_{peak}
3. At end inspiration, air flow is zero and the pressure drops by an amount equal to P_{res} to reach P_{plat}. Pressure returns to baseline during passive expiration.



Pressure-time waveform is a reflection of the pressures generated within the airways during each phase of the ventilatory cycle.