ARDSnet—A New Update on an Old Topic

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Learning Objectives

- Review the hazards of mechanical ventilation.
- *Describe the **evolution of ARDSnet***
- ***Examine the key aspects of ARDSnet***
- *Describe how **ARDSnet can and has been applied** at the bedside.*
- ***Examine Adjunctive Therapy** which can be combined with ARDSnet.*
- ***Review some cases & questions** of ARDSnet in action*.
- Describe where ***more work needs to be done***.
- Furnish additional resources.

DANGER

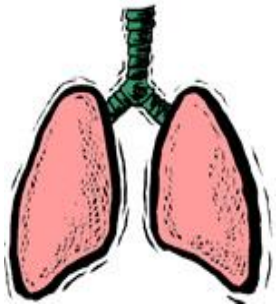
Mechanical Ventilators, ***and the People who operate them,*** can both save lives and cause harm or death!!!

Danger Zones in Mechanical Ventilation—Where the Hazards Lie

- Airways issues
  - Vocal cord injury
  - Micro-aspiration
  - Biofilm-related concerns
- Ventilator Associated Pneumonia (VAP)
- Other infection related issues:
  - Sepsis/Septic Shock
- The normal mechanics off breathing are reversed:
  - Normal: Negative pressure gradient vs Positive Pressure
  - Volume & Pressure Concerns
    - Overdistention
    - Sheering pressures

Initiating Mechanical Ventilation: Lung Protective Ventilation

- Brower, Mattay, Morris, et al., *NEJM*, 342 (18) 1301-1308 (2000)
  - Findings: Ventilation with Lower Tidal Volumes (6 mls/kg) as compared with Traditional Tidal Volumes results in less acute lung injury and acute respiratory distress syndrome.
- Multi-center, randomized trial.
  - Control Group: VT = 12 mls/ kg
  - Experimental Group: VT = 6 mls/kg
- Trial stopped: After 861 subjects enrolled, interim statistical analysis revealed large "between group" differences
- 28 Day Mortality: Controls=39.8% vs Exp. 31.0%: P Value = 0.007 (7 in 1000 likelihood that this was due to chance.)
- Example: 75 KG IBW X 6 mls = VT of 450 mls.



Recent Studies Have Confirmed these Results & Expanded Findings

- Hodson, H, et al: Permissive Hypercapnia, Alveolar Recruitment and Low Airway Pressure (PHARLAP): a protocol for a phase 2 trial in patients with acute respiratory distress syndrome, Crit Care Resusc, Jun;20(2):139-149 (2018).
- Khemani, RG, et al, Positive End-Expiratory Pressure Lower Than the ARDS Network Protocol Is Associated with Higher Pediatric Acute Respiratory Distress Syndrome Mortality, Am J Respir Crit Care Med, Jul 1;198(1):77-89, (2018).

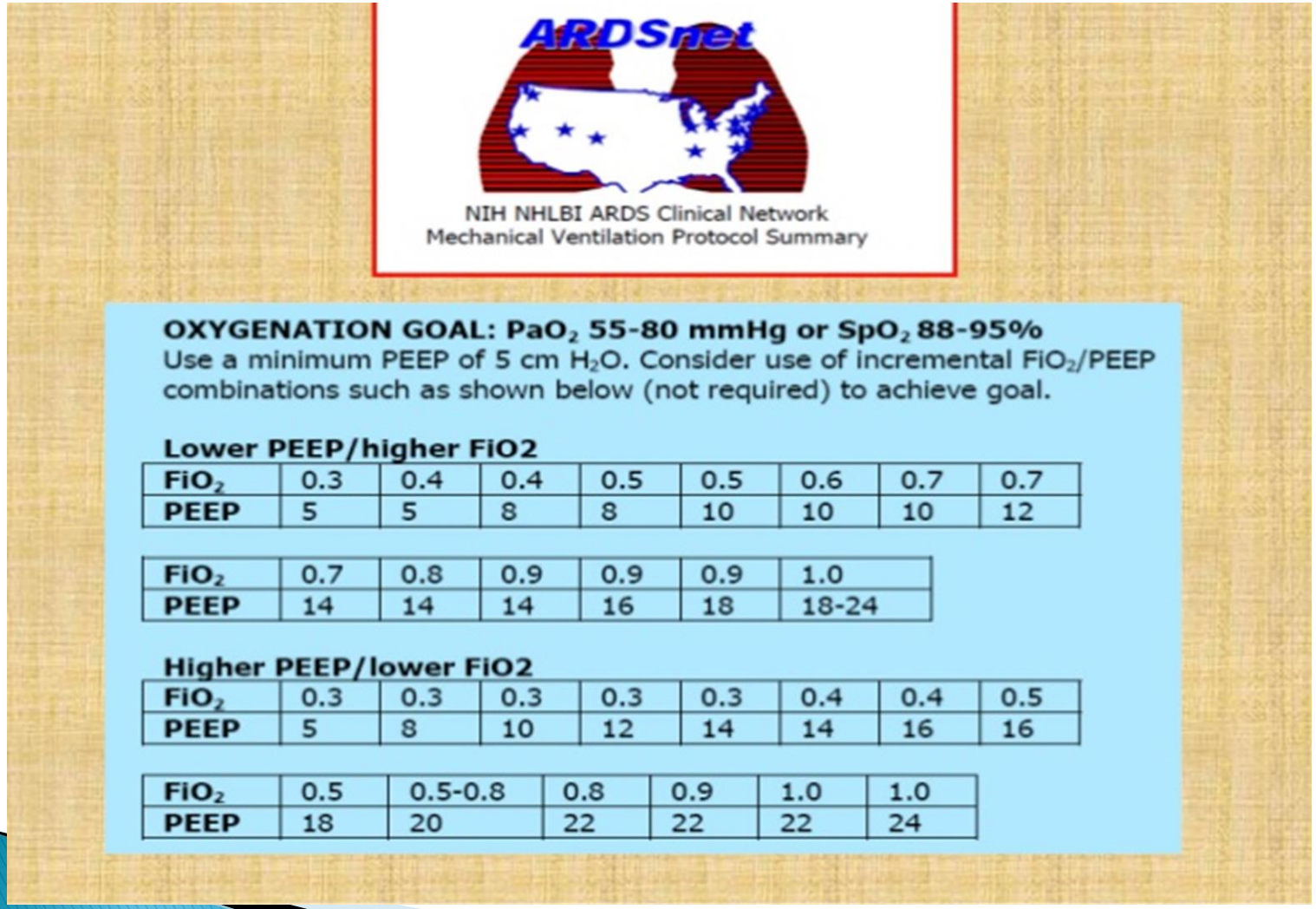
Four Main Tenants of Ardsnet

- Lower Tidal Volumes
- Liberal Use of PEEP
- Keep Plateau pressures $\leq$ 30 cm H_2O preferably $\leq$ 25 cm H2O.
- Keep Driving Pressures $<$ 15 cm H_2O

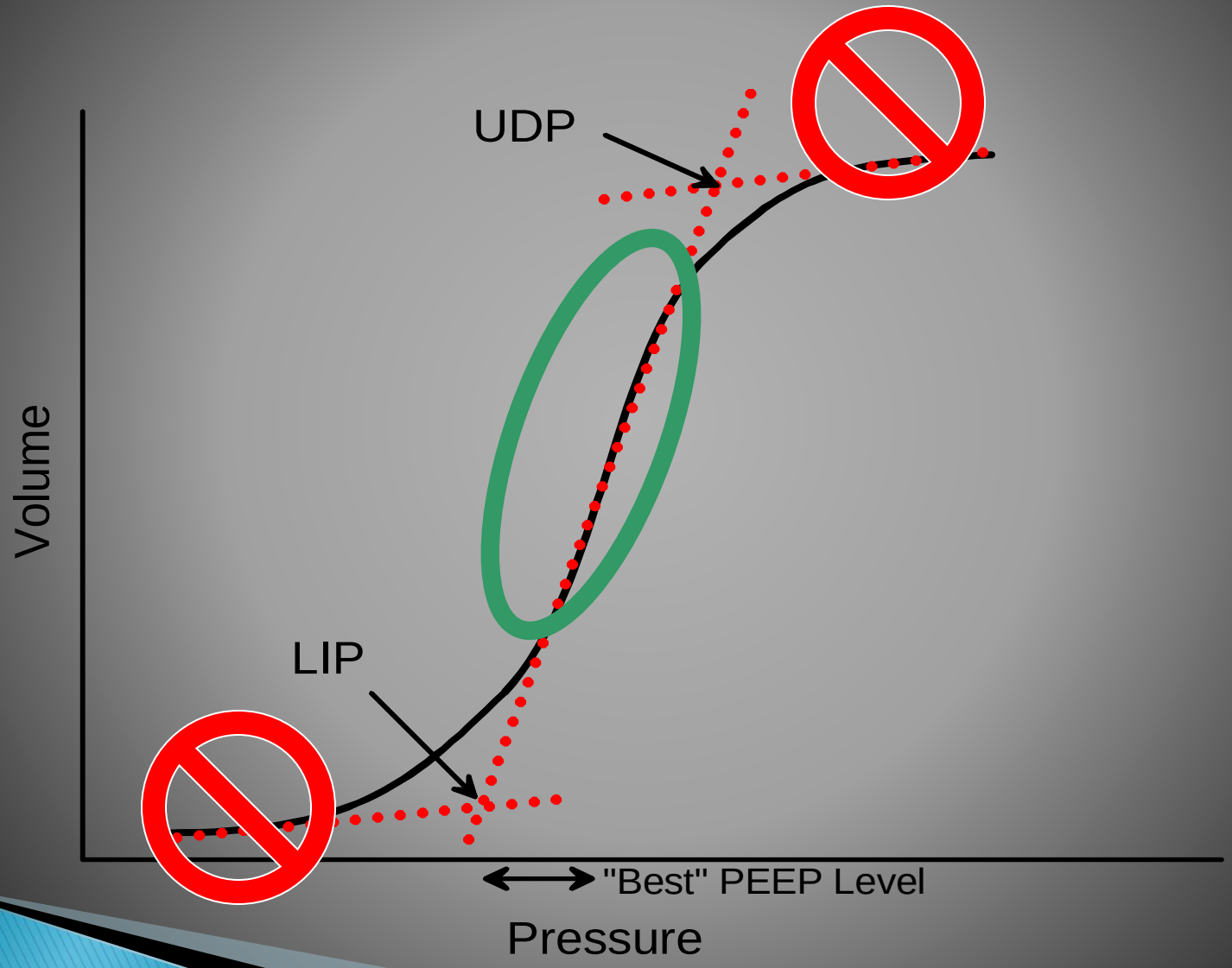
ARDSnet: Ventilator Setup and Adjustment

- Calculate predicted body weight (PBW)
  - Adult male: 50 + 0.91 (Height cm −152.4)
  - Adult female: 45 + 0.91 (Height cm −152.4)
- Select any ventilator mode and VT to 6mL/kg
- Set respiratory rate (RR) to maintain optimal minute ventilation (MV) (not RR > 35/min)
- Target SpO2 88-95% or PaO2 55-80mmHg
- Increase PEEP with increasing FiO2 (5-24 cmH2O) according to a sliding scale (see next slide)
- Aim for plateau pressure (Pplat) <30cmH2O
- Pplat >30 cmH20 allowed if TV 4 mL/kg IBW and pH <7.15
- VT could be increased up to 8 mL/kg PBW for patients with severe acidosis if Pplat maintained <30 cmH20
- pH goal = 7.30-7.45
  - if pH < 7.15 increase VT, give NaHCO3

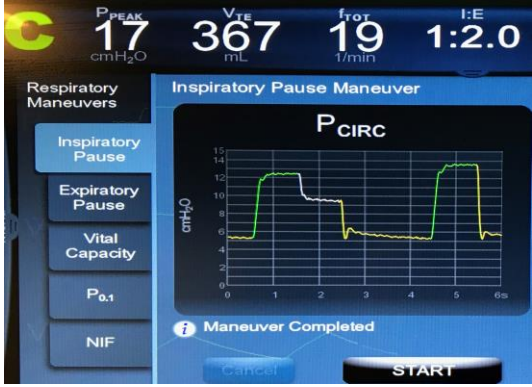
Setting PEEP: Positive End Expiratory Pressure (PEEP)



Adjusting PEEP Levels



Plateau Pressure (P_{PLAT}) & Static Compliance (C_L)



- ***Goal is to maintain a $P_{PLAT} \leq$ 30cmH2O, preferably $\leq$ 25 cm H2O***
- Implicated as a contributor to Vent Induced Lung Injury (VILI)
- It is measured by performing an ***inspiratory pause***
- Used to Calculate Static Compliance (C_L)
- $C_L = VT / P_{PLAT} - PEEP$
- Normal CL = 50-100 mL/cm H2O

Basic Strategies to Manage Plateau Pressures Include

- Reduce Tidal Volume (in volume ventilation) or Peak Inspiratory Pressure (in Pressure Control Ventilation)
- ***Per ARDSnet: If Pplat > 30 cm H2O: decrease VT by 1ml/kg steps (minimum = 4 ml/kg).***
- Increase Inspiratory Time or Reduce Flow Rate
- Address any Air Trapping or Auto-Peep

Driving Pressure

- The difference between the plateau pressure and PEEP **(Plateau minus PEEP).**
- Current suggestions are to maintain driving pressures *< 15cmH2O.*
- Management Strategies are similar to those for Plateau Pressures
  - ***Except***, where increases in PEEP result in lung recruitment without increasing driving pressure.

Adjuncts to ARDSnet

- Avoid Delays in Weaning & Extubating
- Prone positioning
- Other form of positioning
  - Good lung Down: In unilateral disease
  - Reverse Trendelenburg-Severe Morbid obesity & Ascites
  - Rotating beds
- Boutique ventilatory modes
  - APRV
  - Oscillatory ventilation no longer recommended in Adults
- Inhaled Nitric Oxide & Prostacyclin
- Extubation to HFNC or NIPPV
- Early mobility

Weaning & Liberation -- Predictors of Successful Weaning

- Kallet, Zhuo, Yip, et al 2018. Cochrane Systematic Rev.
  - *Findings:* **SBT's combined with conservative sedation** practices were associated with both reduced ventilator days and ICU LOS.
- Burns, Lellouche, Nisenbaum, (2014).
  - *Findings:* **Automated Weaning: Weaning with SmartCare™ significantly decreased weaning time**, ventilator days and ICU stay.
- Baptistella, Sarmento, da Silva (2018) Systematic Review:
  - *Findings: **RSBI was the most frequently studied*** and an important measurement tool in deciding whether to wean/extubate a patient.
- Kutchak, Rieder, Victorino, (2017)
  - *Findings: Inability to follow commands (hand grasping) independently predict extubation failure* in critically ill neurological patients.

“Optimizing” to Facilitate Weaning

- At least daily SBT/SAT!!!
- Sedation: Lighten and consider switching to “kinder” form of sedation e.g., Precedex
- Appropriate fluid balance
- Proper Nutrition (macro and micro nutrients).
- Permit adequate recovery time from prior failed weaning attempts. (min 24 hours of rest on AC).
- Adjunctive respiratory care: Bronchodilators, bronchial hygiene, sx’ing
- Airway optimization: Mucous shavers.
- Adequate staffing/resources.

Prone Positioning in Mechanical Ventilation

- Much Recent Research in this Area!
- Munshi, Del Sorbo, Adhikari, et al, *Prone Position for Acute Respiratory Distress Syndrome. A Systematic Review and Meta-Analysis*, Ann Am Thorac Soc. 2017.
- ***Findings: Prone positioning is likely to reduce mortality*** among patients with ***severe ARDS*** when applied for at least 12 hours daily.
- Qualifications:
  - Do it early: within 48 hours on ARDS onset
  - Devise a protocol in advance. ETT dislodgment is a risk!

Oscillatory Ventilation--Adult

- Nguyen, AP. Et al, (2016)
  - ***Findings:*** Two recent large multi-center trials of **HFOV failed to show benefits** in this patient population.

- Sud, S. et al: (2016) Cochrane Database Syst Rev.
  - ***Findings:*** HFO **does not reduce hospital and 30-day mortality due to ARDS**; the quality of evidence was very low. Our findings **do not support the use of HFOV as a first-line strategy** in people undergoing mechanical ventilation for ARDS.

Airways Pressure Release Ventilation (APRV)

Strong Support:

- Jane, SV, et al. (2016) Systematic Review:
  - ***Findings:*** Multiple studies demonstrated that APRV stabilizes alveoli and reduces the incidence of ARDS. **APRV has shown great promise as a highly lung-protective ventilation strategy.**

Weak Support:

- Arshad, Z. et al, (2016)
- Findings: **APRV is the not recommended as primary mode of ventilation in COPD** but in resistant cases it may be helpful…

No Support:

- Mireles-Cabodevila E & Kacmarek RM, (2016) **Expert Opinion**: For APRV to become the primary mode of ventilation for ARDS, it will require development of sound protocols and technological enhancements to ensure its performance and safety.
  - For now, ***APRV does have a greater potential for adversely affecting patient outcome than improving it.***
  - Unless definitive data are forthcoming for use of APRV in ARDS, ***there is no reason to consider this approach to ventilatory support***.

Pulmonary Vasodilators: Epropostenol (Flolan) & Inhaled Nitric Oxide (INO)

INO Vent- Inhaled Use & Change Expiratory Filters Q 2-4 hrs

Flolan via Syringe pump--Aerogen goes on Dry Side of Humidifier

Extubating High Risk Patient- Using NIPPV & NFNC

- **HFNC:**
  - Ni, Lou, Yu, BMC Pul. Med (2017): HFNC is a reliable alternative of NIPPV to *reduce rate of reintubation* compared with conventional O2 therapy.
  - Dhillon NK, Smith EJT, Ko A, J Surg. Res (2017): Ventilated patients at risk for recurrent respiratory failure have *reduced reintubation rates when extubated to HFNC*.
- **NIPPV:**
  - Zhu, et al (2013): **NIPPV can reduce the need of re-intubation** and improve clinical outcome as compared with invasive ventilation.

Early Mobility (EM)

- Much supportive research on the positive impact of early mobility on ICU patients.
  - Needham (2008) *Mobilizing patients in the intensive care unit…*
  - ***Findings:*** Supports the ***safety, feasibility, and potential benefits of EM in combating ICU-acquired muscular weakness*** critical care medicine.
- However, it is very, very resource intensive and has Risks.
  - Schmidt, Knecht & MacIntyre (2016).
    - ***Findings****: Early mobilization decreases the negative consequences of ICU-acquired weakness*.
    - However, it has drawbacks:
      - May entail risks (falls) to the patient
      - Additional staffing needs might have a negative financial impact

Case 1

A physician orders intubation and volume control A/C ventilation for a 6 foot 3 inch tall 190 lb (86 kg) adult male patient with ARDS. Which of the following ventilator settings would you aim for to support this patient?

	Rate/min	VT (mL)
A.	10	800
B.	8	1200
C.	20	900
D.	15	500

Answer: D. Rate of 15 and a VT of 500

General Feedback: In adult patients with ARDS, the goal is to achieve a tidal volume of 6 mL/kg of predicted body weight, with a plateau pressure (Pplat) $\leq$ 30 cm H2O. If Pplat > 30 cm H2O at 6 mL/kg, the VT can be reduced to as low as 4 mL/kg. The respiratory rate should be set to approximate the baseline minute ventilation, with the goal to achieve a pH between 7.20 and 7.45. For a six foot 3 inch tall patient with a predicted body weight of 85 kg, the goal would be a VT of about 500 mL with a rate between 10-20/min. In some cases rates as high as 35/min may be needed to maintain the pH above 7.30.

Case 2

You note in the medical record of a patient's who is receiving volume control ventilation that the plateau pressure has been increasing over the last 6 hours, while the PIP levels remains constant. Which of the following would be the most likely cause of this change?

- A. development of pulmonary edema
- B. water accumulation in the ventilator circuit
- C. partial obstruction of the endotracheal tube
- D. development of bronchospasm

Answer: A. development of pulmonary edema

General Feedback: An increase in the plateau pressure relative to baseline (Pplat-PEEP) indicates a decrease in the patient's lung and/or thoracic compliance. Common causes of a decrease in lung compliance are pneumothorax, pulmonary edema, atelectasis and ARDS. Partial obstruction of the ET tube and development of bronchospasm would increase airway resistance and thus increase PIP and the PIP-Pplat pressure difference, but not affect Pplat.

Case 3

A 36-year-old woman who has just undergone intestinal bypass surgery is brought to the recovery room intubated. She has normal pulmonary function, weighs 136 kg (300 lbs), and is 159 cm. (5 ft 2 in) tall. In this situation, you should recommend which of the following ventilator settings?

	Rate/min	VT (mL)
A.	8	300
B.	12	500
C.	15	700
D.	8	1000

- Answer: B. 12 500

- General Feedback: This patient's actual weight should not be used to establish an initial tidal volume. Rather, her initial tidal volumes should be set using a formula of 6 to 10 mL/kg PREDICTED (or ideal) body weight (PDW), which is probably about 50 kg. It is also recommended that the initial respiratory rate be set between 10-16/min.

Case 4

A doctor institutes volume control ventilation for an 80 kg ARDS patient. Which of the following is the maximum pressure you would aim to achieve in this patient?

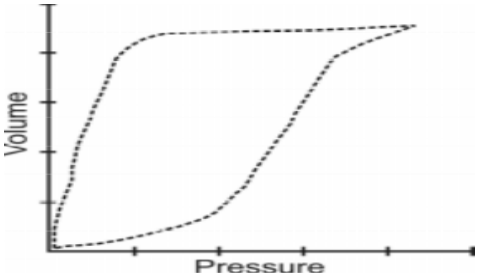
- A. 50 cm H2O peak pressure
- B. 30 cm H2O plateau pressure
- C. 40 cm H2O peak pressure
- D. 50 cm H2O plateau pressure

- Answer: B. 30 cm H2O plateau pressure

- General Feedback: According to the NHLBI Protocol, the target volume for ARDS patients is 4-6 mL/kg, with a maximum plateau (alveolar) pressure of 30 cm H2O. The ventilator rate should initially be set to match the prior VE, but can be increased as needed up to a maximum of 35/min. In addition, a slightly hypercapnic state (pH 7.25- 7.35 and PCO2 45-50 torr) known as ***permissive hypercapnia*** may be tolerated in order to maintain lower a VT needed to keep plateau pressures $\leq$ 30 cm H2O.

Case 5

You observe the following pressure-volume loop display on a patient receiving volume-control ventilation. Which of the following actions would be appropriate?



- A. Decrease the delivered volume
- B. Increase the inspiratory flow
- C. Decrease the I:E ratio
- D. Increase the PEEP level

- Answer: A. Decrease the delivered volume

- General Feedback: This pressure-volume loop exhibits significant flattening beyond its upper inflection point, indicating overdistention of the lungs. Due to its resemblance to a bird, this is sometimes called a “beaked” pressure-volume loop. When you observe this problem, you generally can resolve it by either reducing the volume (in volume ventilation) or the pressure setting.

Case 6

A patient under your care has X-ray and clinical evidence of severe unilateral right lung infiltrates. His PO2 on a non-rebreathing mask is 55 torr. The attending physician asks your advice as to how best to improve this patient's oxygenation without committing to ventilatory support. Which of the following would you recommend?

- A. place the patient on his left side (left lung down)
- B. place the patient on his right side (right lung down)
- C. turn the patient from the supine to prone position
- D. institute a regimen of inspiratory resistive breathing

Answer: A. place the patient on his left side (left lung down)

General Feedback: Dependent positioning can improve the distribution of ventilation in patients with V/Q imbalances, especially those with local conditions such as unilateral pneumonias. Placing the good lung in the dependent or down position (in this case the left lung) can significantly improve oxygenation without a change in FIO2, since the 'down' lung will receive the best ventilation and blood flow. Another plausible option is to initiate high-flow nala cannula therapy. However, this is not an answer choice.

More Work to Be Done

- **Dedicating Appropriate Resources: Staffing, Supplies & Equipment**
  - Vent-Patient management & weaning is resource intensive.
    - SBT
    - Prone positioning
    - Nitric Oxide
  - Hence, vent-patient management depends on appropriate staffing and other resources, as well as supportive and informed leadership.

- **Other Supported Practices May Not be Practical**
  - Early Mobility for Mechanical Ventilation Patients
  - Other Boutique Vent Modes (e.g., VDR, APRV) require extensive training and (re)education

- **ARDSnet did not work especially well in Covid-19 induced-ARDS.**

- **Inconsistencies in Practice**
  - **Use of HFNC and NIV to avoid intubation/reintubation**
  - **Inter-prescriber variation (variation in physician practice)**

Take Home Points

- Advances in, and complexities of mechanical ventilation have helped elevate our profession.
- Mechanical ventilation saves lives…but can be harmful.
- An abundance research and resulting protocols has helped guide safer and more effective practice.
- However, the research is constantly changing so we must keep abreast and adapt.

Selected Resources

- Apfelbaum, et al, 2022 American Society of Anesthesiologists Practice Guidelines for Management of the Difficult Airway, (2021)
- ARDSnet: http://www.ardsnet.org/
- Brower, Mattay, Morris, et al. Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome *NEJM*, 342 (18) 1301-1308 (2000)
- Kacmarek, RM, Stoller, J & Heuer AJ, *Egan's Fundamentals of Respiratory Care*, ed 12th ed, 2021.
- Munshi, Del Sorbo, Adhikari, et al, *Prone Position for Acute Respiratory Distress Syndrome. A Systematic Review and Meta-Analysis*, Ann Am Thorac Soc. 2017.
- Oxford Medical Education : https://www.oxfordmedicaleducation.com/clinical-skills/procedures/endotracheal-tube/
- US Nat'l Library of Medicine: https://medlineplus.gov/ency/article/003449.htm .

Thank You!!!

Questions?