Mechanical Ventilation: A Basic Introduction

- John Denny MD
  Director Section of Critical Care
- Professor
  Department of Anesthesia
  Rutgers Robert Wood Johnson Medical School

Historical Features

- Ventilator Origins

Origins

- "…an opening must be attempted in the trunk of the trachea, into which a tube of reed or cane should be put; you will then blow into this, so that the lung may rise again…and the heart becomes strong…"

Andreas Vesalius (1555)

Origins

- Polio epidemic of 1955
- Sweden
- Emerson Company, Boston

Early ventilators

- Pressure Cycled

Early ventilators

- Pressure Cycled
- Volume Cycled

Indications for Mechanical Ventilation

- Useful aphorisms from Marino ICU Book:
- "Thinking of it"
-

Indications for Mechanical Ventilation

- Thinking of it
- Intubation is not an act of weakness

Indications for Mechanical Ventilation

- Thinking of it
- Intubation is not an act of weakness
- ET tubes are not a disease, and ventilators are not an addiction

Strategies for Mechanical Ventilation

- Tidal Volume:

  Old settings 10 ml/kg….

Strategies for Mechanical Ventilation

- Tidal Volume:

  Old settings 10 ml/kg

- After ARDSnet study:

  Lung Protective 5-8 ml/kg

Ventilator Induced Lung Injury

- ARDS, pneumonia-pathology not uniformly distributed. However, ventilator volumes are distributed preferentially to NORMAL lung areas, overdistending normal areas and producing stress fractures in alveolar walls and adjacent pulmonary capillaries.

Ventilator Induced Lung Injury

- Can lead to pneumomediastinum, PTX
  -damage to pulmonary capillaries can result in leaky capillary type of pulmonary edema

Ventilator Induced Lung Injury

- May be due to

  barotrauma (pressure injury) or

  volutrauma (volume distention injury)

Strategies for Mechanical Ventilation

- End Inspiratory Pressure:

  Old setting: Peak < 50 cm H20

  Lung Protective: Plateau < 30 cm H20

Strategies for Mechanical Ventilation

- Positive End Expiratory Pressure (PEEP):

  Old setting: Use PEEP to keep FIO2 < 60%

  Lung Protective: 5-15 cm H20

Strategies for Mechanical Ventilation

- ABGs:

  Traditional setting: Usual pCO2, pH 7.36-7.44

  Lung Protective: Hypercapnia Ok IF needed, pH 7.20-7.44

Adjusting the Ventilator

- How to increase the pO2?:

Adjusting the Ventilator

- Increasing the pO2:

  Increase FIO2

Adjusting the Ventilator

- Increasing the pO2:

  Increase FIO2

  Increase PEEP

Adjusting the Ventilator

- Increasing the pO2:

  Increase FIO2

  Increase PEEP

  Try different mode of ventilation

Adjusting the Ventilator

- To decrease pCO2?:

Adjusting the Ventilator

- To decrease pCO2:

  Manipulate Minute Ventilation

Adjusting the Ventilator

- To decrease pCO2:

  Manipulate Minute Ventilation (T.V. X Rate)

  Either increase TV or increase rate

When making changes

- Change one variable at a time
  (unless patient is *in extremis*)

Auto PEEP

- Results from incomplete alveolar emptying at end expiration
- Aka intrinsic PEEP
- Measure by occluding expiratory tubing at end of expiration
- Newer vents, simply hit button to measure

Auto PEEP, consequences:

- Decreased Venous Return
- Decreased CO
- Alveolar Rupture
- Artificial > in PIP
- Increase in Work of Breathing

Auto PEEP

- Predisposing Factors:
- Patient:
  - COPD
  - Reactive airway disease

Auto PEEP

- Predisposing Factors:
- Patient:
  - COPD
  - Reactive airway disease
- Ventilator:
  - High TV
  - Rapid Rates

Auto PEEP

- Management:
- Avoid excessive TV
- Allow for adequate exhalation, avoid rapid RR

Weaning: Factors to consider

- Inspiratory Loading due to Auto PEEP: Normal vent trigger threshold ex: –1cm H2O

Auto PEEP-Can Increase WOB

- Normally, pts spontaneous breaths create neg. pleural pressure which triggers pressure support assistance from vent
- Need NIF of -1 min. to trigger
- Auto Peep increases needed NIF to trigger

Weaning: Factors to consider

- Inspiratory Loading due to Auto PEEP: Normal vent trigger threshold ex: –1cm H2O
- If Auto PEEP present, pt must overcome both it and trigger….

Auto Peep in Weaning

- If trigger requires 1 cm H2O NIF

  and if Auto Peep is 14,

pt must generate NIF of 15 EVERY breath to trigger vent

Counteracting Auto Peep:

- By adding external PEEP to the inspiratory circuit , you reset the sensitivity level. SO in this ex, with auto PEEP of 14, by adding 14 of external PEEP the vent circuit sensitivity will be reset to –1 cm H2O for this patient's inspiratory muscles

Auto PEEP in Weaning

- RX:
  - Aggressive tx of underlying airway obstruction
  - Add external PEEP equal to auto PEEP

Indications for Mechanical Ventilation

- Hypoventilation

Indications for Mechanical Ventilation

- Hypoventilation

  Arterial pH < 7.30

Indications for Mechanical Ventilation

- Hypoxia

Indications for Mechanical Ventilation

- Hypoxia

  Face Mask CPAP

Indications for Mechanical Ventilation

- Hypoxia unresponsive to more conservative measures warrants intubation

Indications for Mechanical Ventilation

- Respiratory Fatigue

Indications for Mechanical Ventilation

- Respiratory Fatigue:

  Excessive (WOB) Work of Breathing (tachypnea, dyspnea, use of accessory muscles, nasal flaring,diaphoresis, tachycardia)

Indications for Mechanical Ventilation

- Airway Protection

Indications for Mechanical Ventilation

- Airway Protection:
  - Decreased mental status
  - Increased aspiration risk

Goals of Mechanical Ventilation

- Provide adequate alveolar ventilation (pH, pCO2)
- Provide adequate oxygenation

Goals of Mechanical Ventilation

- Use lowest possible FIO2
- Histological signs of O2 Toxicity:
  - 100%-12 Hours
  - 80%-24 hours
  - 60%-36 hours

Goals of Mechanical Ventilation

- Promote pt.-ventilator synchrony
- Avoid alveolar overdistention
- PEEP to maintain alveolar recruitment

Modes of Mechanical Ventilation

- AC or Assist Control
- Pre-set volume is delivered
- Patient can initiate (“assisted”)
- Else machine initiates (“controlled”)

Modes of Mechanical Ventilation

- Problems with AC:
- Rapid breathing produces respiratory alkalosis
- Decreased exhalation time produces auto-PEEP

Modes of Mechanical Ventilation

- IMV or Intermittent Mandatory Ventilation
- IMV delivers preset volume cycled breaths at a preset rate
- But also allows for spontaneous patient breathing

Modes of Mechanical Ventilation

- IMV or Intermittent Mandatory Ventilation
- Synchronized IMV= machine breaths are synchronized to coincide with patients spontaneous lung inflations

Modes of Mechanical Ventilation

- Pressure Support (PS)
- Analogous to "lift assist" for doing pullups in a gym. I.E., in gym, you must initiate effort to do pullup, then "lift assist" helps you complete pullup (breath)

Lift assist gym device for pullups

Modes of Mechanical Ventilation

- Pressure Support (PS)
- In pure PS mode, patient MUST have intrinsic rate!!

Modes of Mechanical Ventilation

- Pressure Controlled Ventilation (PCV)
- Pressure Cycled

Modes of Mechanical Ventilation

- Pressure Controlled Ventilation (PCV)

- Pressure Cycled
- Inspiratory flow rate decreases exponentially during lung inflation to keep airway pressure at the chosen value
- Inflation volumes vary with mechanical properties of lungs

PCV

- In pure PCV, you don’t set a TV.
- TV is dependent on lung compliance!

PCV

- Therefore, you must follow-up what the resultant TV is
- And adjust PC accordingly
- Especially to maintain a lung protective strategy!

Pressure Regulated Volume Control (PRVC)

- Volume Ventilation with limitation on pressure
- Automatically adjusts PC so achieve desired TV without over-distending lung!

Variables in Mechanical Ventilation

- Inverse Ratio Ventilation (IRV)

- Usual I:E 1:2 to 1:4
- Reverses I:E to 2:1
- Thought to prevent alveolar collapse
- Tends to produce auto-peep and decrease C.O.

HFOV

- High Flow Oscillatory Ventilator

HFOV

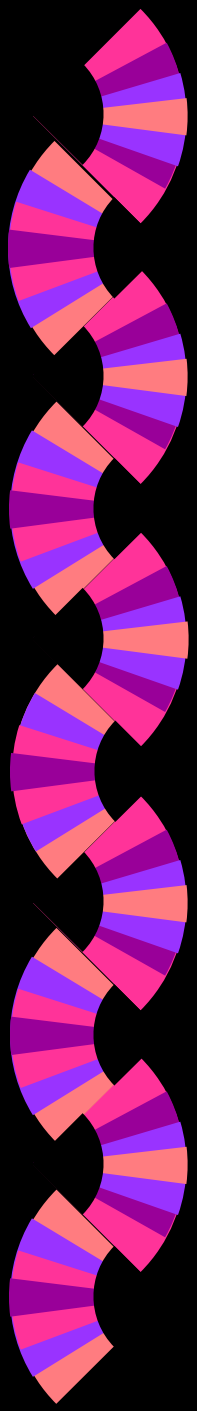
- High Flow Oscillatory Ventilator
- Initial Settings:
  - Rate 5 Hz (300 bpm)
  - MAP 3-5 cm > previous PC
  - Delta P (amplitude) 65 cm H2O
  - FIO2 100
  - I time 33%

HFOV

- Unfortunately, recent adult trials have not shown clear benefit in ARDS

Modes of Mechanical Ventilation

- Jet Ventilation
- Rarely, beneficial when other modes not effective



BiVent

- Covered in a separate lecture.

THE END