

## Mechanical Ventilation

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## Indications for mechanical ventilation

- Respiratory Failure
  - Hypercarbia
  - Hypoxemia
  - Impending Failure

## Topics to Discuss

- Brief history
- Blood gas abnormalities
- Clinical findings
- Modes of ventilation
- Hazards of ventilation
- Novel techniques
- Future

## History

- Elisha - mouth to mouth
- Hippocrates - endotracheal intubation
- Paracelsus - 'Fire Bellows'
- Vesalius - tracheotomy (pig)
- Fathergill - mouth to mouth
- Hunter - double bellows

## Earliest Ventilators

- Negative pressure
  - 'Cuirass'
  - Iron lung
  - Philip Drinker
- Positive pressure
  - 1952-53 Denmark polio epidemic
  - 1 iron lung & 6 cuirass

## Denmark Polio Epidemic

- 31 patients, 3 weeks
- 90% mortality
- Dr Lassen Epidemiologist / Chief
- Dr Bjorn Ibsen / Anesthesiologist

### Positive Pressure Ventilation

- Convention
  - high carbon dioxide = alkalosis
- Ibsen
  - high carbon dioxide = retention
- Hand ventilated cuffed tracheotomy
  - 12 year old test subject
  - Measured exhaled carbon dioxide

### Measuring acid

- Dr Astrup - measured pH was acidotic
- Dr Lassen - assembled teams to Rx
- 50 new patients/day
- 2-3 months recovery
- Mortality 25 %

### Replacing man with machine

- Engstrom (Swedish)
  - Volume controlled, positive pressure vent
  - Literally a life saver in Sweden, as polio epidemic struck, ventilators were ready

### Lessons Learnt

- Clinical lab rapid, accurate, available
- Developed highly specialized units
- New concepts
  - standard bicarbonate/excess

### Blood Gas Basics

- Measure pH, PCO<sub>2</sub>, PO<sub>2</sub>
- Estimate Bicarbonate, Base deficit
- Henderson-Hasselbalch Equation
- Stewart Strong Ion Dissociation
- Oxygen Delivery Equation
- Alveolar Gas Equation

### Modes of Ventilation

- Pressure Targeted
- Volume Targeted
- Mixed Modes

### Controlled Mechanical Ventilation

- 1960s
  - Draeger
  - Bird
  - Bennett
- 1970s
  - Ohio 560
  - Bennett MA

### Assist Control Ventilation

- Rate & volume set
- Allows patient spontaneous effort
- Each effort delivers FULL volume
- Potential for 'breath stacking'
- Possible hyperventilation

### Synchronized IMV

- Set rate & volume
- Spontaneous breaths allowed
- These are synchronized by ventilator
- Depended on development of sensitive solenoid valves which detect small negative pressure indicating patients spontaneous effort

### Pressure Control Ventilation

- Set plateau & PEEP
- Set rate
- Set I:E ratio
- No spontaneous efforts
- Tidal volume is dependent on compliance
- Minute ventilation not guaranteed

### Caveats

- Hypercarbia may follow
- Neurosurgical condition may worsen
- Generally tolerated in the 'sicker' patient with requirement for heavier sedation to ensure no ventilator patient mismatch

### Pressure Support Ventilation

- Various terms used interchangeably
- Spontaneous effort **required**
- Reduces work of breathing
- Useful in weaning, slow or fast
- Convention
  - < 5 cm H<sub>2</sub>O = minimal PS
  - > 5 cm H<sub>2</sub>O = PSV

### Pressure Regulated Volume Control

- Ventilator or Patient initiated
- Constant inspiratory pressure, regardless of initiation
- Patient's lung compliance assessed by ventilator, which adjusts pressure to achieve desired volume
- Risk of intrinsic PEEP, especially obstructive lung diseases
- Decelerating inspiratory flow =  $\Delta$  Oxygenation

### Airway Pressure Release Ventilation Inverse Ratio

- Concept start at high baseline ~ plateau pressure, then release to lower limit PEEP
- Generates tidal volume by deflation
- Spontaneous efforts allowed any point
- 'New' 1987

### Concept APRV

- Confusion terminology "bi-level PEEP"
- Maintain alveoli inflated brief exhalation
- 'Inverse - Ratio'
- Normal is 1:3 - Inverse is anything less
- Typically 1:1 to 3:1
- Has been used at 13:1

### Any advantage?

Better oxygenation

No need to change mode to wean

**Improved cardiac performance**

**No paralysis**

50 studies and 18 discussion articles

### Modes & Manufacturers

- Pressure Augmentation Bear
- Volume Support Maquet
- Pressure Regulated Volume Control PB
- Adaptive Support Ventilation Hamilton
- Proportional Assist Ventilation Drager

### Adaptive Support

- Dongelman, DA, 2008, A & A
- CT surgery patients 362
- ASV vs. PC/PS
- Tassaux D, Anesthesiology 2002
- ASV vs. SIMV
- No difference

### High Frequency Oscillator

- Viasys
- Relatively little experience at UCH
- Probably used too late in course
- Trial ongoing for early use in ARDS
- Head to head LPS vs. HFOV
- Improves oxygenation

### Prone Ventilation

- Gattinoni L, Eur Resp Journal 2002
- Not replicated
- Temporary at best
- Hard to achieve in post surgical patient
- Risk of extubation

### Inhaled nitric oxide

- FDA only neonates for PPHTN
- Useful for adults
- Improves oxygenation
- Reduces pulmonary artery pressure
- Anti-inflammatory effect
- No difference in outcome

### Intravenous Prostaglandin

- 'Flolan' long track record
- Long term iv access/infections
- Rapid rebound on discontinuation
- Refrigeration required
- New interest in new mode of delivery

### Hazards

- Volutrauma
- Barotrauma
- Atelectotrauma
- Ventilator Induced Lung Injury
- Hypoxemia
- Hypercarbia
- Ventilator Associated Pneumonia

### Prevent Hazards

- Lung Protective
- Bundle
  - Head of bed
  - Oral hygiene
  - Minimizing length of ventilation
  - HiLo tubes?
  - Silver coated tubes?
  - No routine change of circuitry

### Future developments

- More effective inhaled agents
- Optimum lung protection
- Modified ECMO - ECCOR
- Partial Liquid Ventilation (PLV)
- Avoidance of neuromuscular blockers

### Inhaled Prostaglandin

- 'Avidan'
- FDA approved
- Lower cost than iNO
- Similar efficacy
- Probably trial patients acute RV failure

### ECMO for CPR

- 40% survival for myocarditis
- Abysmal for all else
- Worse still if 2 organs failed

### Lowest Tidal Volume

- Pig model, CCM 2007
- Extracorporeal CO2 removal by arterio-venous interventional lung assist
- 3 ml/kg with ECCOR vs 6 ml/kg

### Mechanical Ventilation Conclusions

- 'Routine'
  - Irrelevant which mode employed
  - If they are ready, they will wean
- 'Challenging'
  - Irrelevant which mode employed
  - If they are not ready, they will not wean