Introduction to Conventional Ventilation

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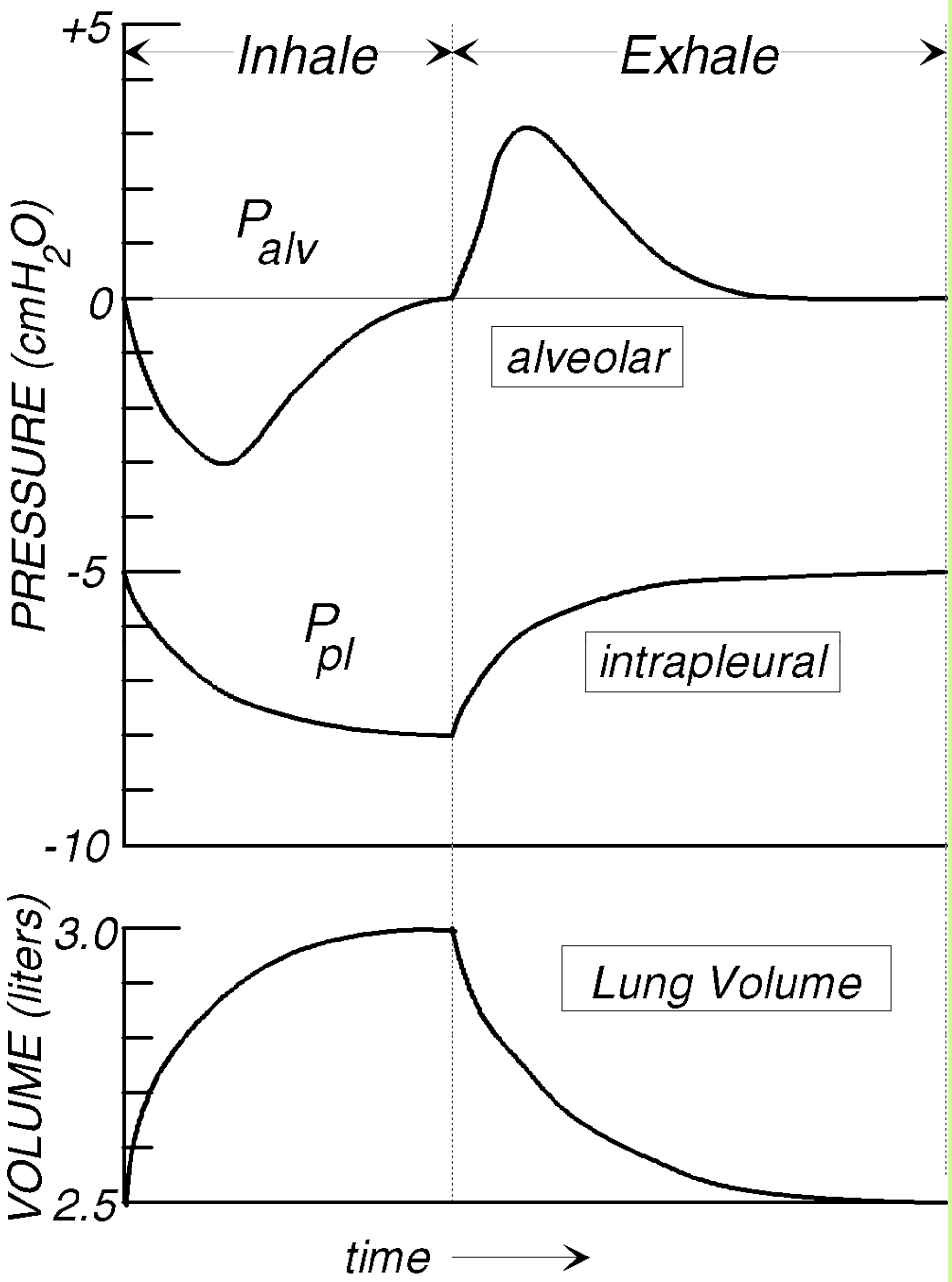
Mechanics

- Inspiration – diaphragm lowers and thorax expands
  - Negative intrathoracic/intrapleural pressure so inc venous return
- Ventilation – applies positive pressure to airways
  - Positive intrathoracic/intrapleural pressure so dec venous return


Inhale
Exhale
+5
0
-5
-10
PRESSURE (cmH_2O)
P_{alv}
alveolar
P_{pl}
intrapleural
VOLUME (liters)
3.0
2.5
Lung Volume
time

Ventilator Set Up

- Patient
- Patient monitoring
- Gases
- Hoses
- Humidifier
- Ventilator
- Ventilator monitor/graphics
- Critical Power

Types of ventilator

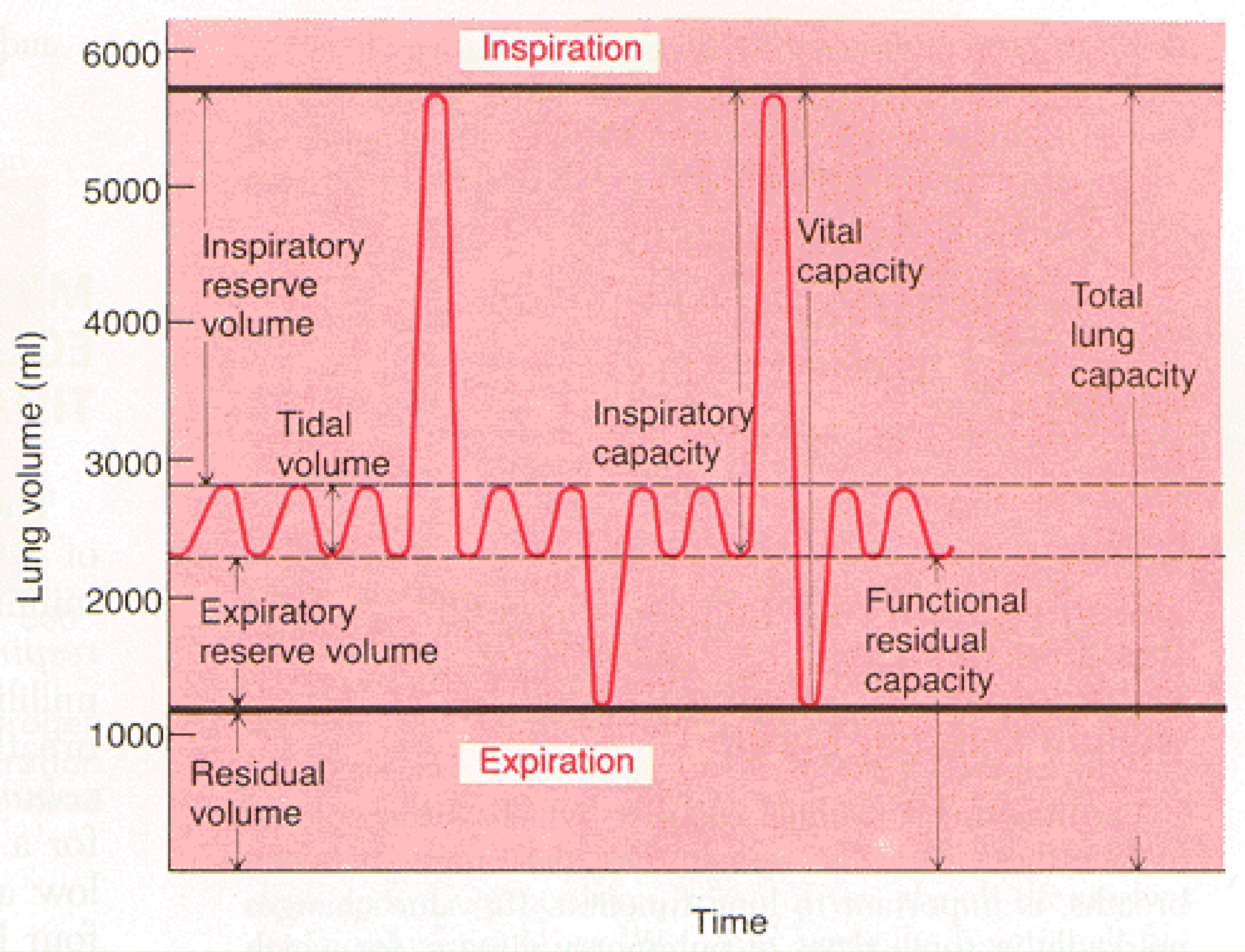
- Time cycling – switches from an inspiratory to expiratory mode after a preset time
- Flow control – switching mechanism detecting a fall in flow
- Volume control – inspiratory phase set by a preset volume
- Pressure control – inspiration terminated when preset pressure reached


INFANT VENTILATOR


Cub


CRESTLINE
Medical LLC


SECHRIST


Inspiration
6000
5000
4000
3000
2000
1000
Lung volume (ml)
Inspiratory reserve volume
Tidal volume
Expiratory reserve volume
Residual volume
Inspiratory capacity
Vital capacity
Total lung capacity
Functional residual capacity
Expiration
Time

Definitions

- Minute volumes – Tidal Volume x resp rate in 1 minute

- Compliance – Distensibility of chest (volume change from PIP to PEEP)

- Resistance – Pressure necessary to generate airflow
- (change in pressure/change in flow)

Ventilator Lung Induced Injury

Not just prems: well recognised in adults (Dreyfuss D 1988)

Injurious ventilation → ↑ pro-inflammatory cytokine, neutrophils and ECM in lung parenchyma (Suguira M 1994; Berg JT 1997; Takata M 1997; Tremblay L 1997).

Rapid: within first few inflations after birth (Bjorklund LL 1997)

Even gentle ventilation of animal preterm lung (Coalson JJ 1999) → histological changes consistent with 'new' BPD in humans (Hislop AA 1987).

Indications for Ventilation

- Absolute
  - Apnoea
- Relative
  - hypoxia
  - hypercarbia
  - control of an unsafe airway
  - stabilisation
  - -cardiac disease
  - -metabolic disease
  - -elective surgery
  - transport

Ventilatory Requirements

- For adequate CO_2 exchange
  - Tidal volumes (VT) above effective dead space
  - An adequate respiratory rate
  - Maintenance of a CO_2 gradient across an exchange surface

Ventilatory Requirements

- CO_2 exchange $\propto$ minute ventilation
- Minute ventilation $\propto$ tidal vol x resp rate
- Tidal volume $\propto$ Driving pressure (PIP-PEEP)
- Chest wall movement approx = tidal volume

Oxygenation

1. Oxygenation $\propto$ lung volume

2. Lung volume $\propto$ Mean Airway Pressure

3. Therefore, Oxygenation $\propto$ Mean Airway Pressure

4. MAP is the average area under the curve of the pressure wave form

$$MAP = \frac{(PIP \times Ti) + (PEEP \times Te)}{(Ti + Te)}$$

5. The higher the MAP, the more alveoli that will be recruited to take part in gas exchange

Terminology

- **Controlled – no synchronisation**
  - **IPPV/CMV/PCV**
- **Assisted and synchronised – combination of ventilation and spontaneous breathing**
  - **SIPPV/SIMV/MMV/BIPAP**
- **Supported spontaneous – easier to breath by providing a flow**
  - **ASB/PS/PPS/ATC**
- **Volume Ventilation**
  - **VG/TTV**
- **Positive End Expiratory Pressure – enlarges FRC**
  - **PEEP/CPAP/HFNC**

Conventional Ventilation

- IMV/IPPV
  - Set – Rate (Ti/Te) PIP, PEEP, Flow
  - Baby control – Own rate

  - Exhaling during ventilators inspiratory cycle may impair ventilation

Octave 1991

- Multicentre randomised controlled trial of high against low frequency positive pressure ventilation
  - **Arch Dis Child 1991;66:770-775**

- 346 infants

- HFPPV 60/min v LFPPV < 40/min
- If have RDS then HFPPV had less pneumothoraces
- 18% v 33%

Synchronisation – why?

- Most neonates breathe during mechanical ventilation
- Actively exhaling against positive pressure causes pneumothoraces
- Synchrony improves oxygenation and CO_2 elimination
- Therefore achieve adequate gas exchange at lower pressures
- Active expiration more common with long inspiratory times
- Increasing ventilator rate and lowering inspiratory time mimicks more closely the infants respiratory pattern

So……..

- Theoretically trigger modes should:

  - Improve tidal volume exchange
  - Reduce blood pressure
  - Reduce cerebral blood flow fluctuations
  - Reduce air leaks and associated
    - Intracranial Haemorrhage
    - Chronic Lung Disease

Randomised multicentre trial comparing synchronised and intermittent mandatory ventilation in neonates

- **Bernstein et al J Pediatr 1996;128:453-463**

- 327 infants RDS Pneumonia Mec asp

- SIMV group lower MAP
- SIMV decreased duration of ventilation >2000g
- SIMV decreased oxygen dependency @36 wks <1000g
- SIMV regained birthweight earlier <2000g

- SIMV at least as efficacious as IMV possibly some better outcomes

Randomised controlled trial of patient triggered and conventional fast rate ventilation in neonatal RDS

- **Beresford et al Arch Dis Child 2000;82:F14-F18**

- 386 Infants RDS 1000-2000g
- Conventional or SIMV (SLE 2000)

- No difference in
  - **CLD both definitions**
  - **Pneumothorax**
  - **Intraventricular Haemorrhage**
  - **Ventilator**
  - **NB Babies not immediately put on Trigger ventilation**

SIMV

- Like IMV but some of the infants own breaths are synchronised.

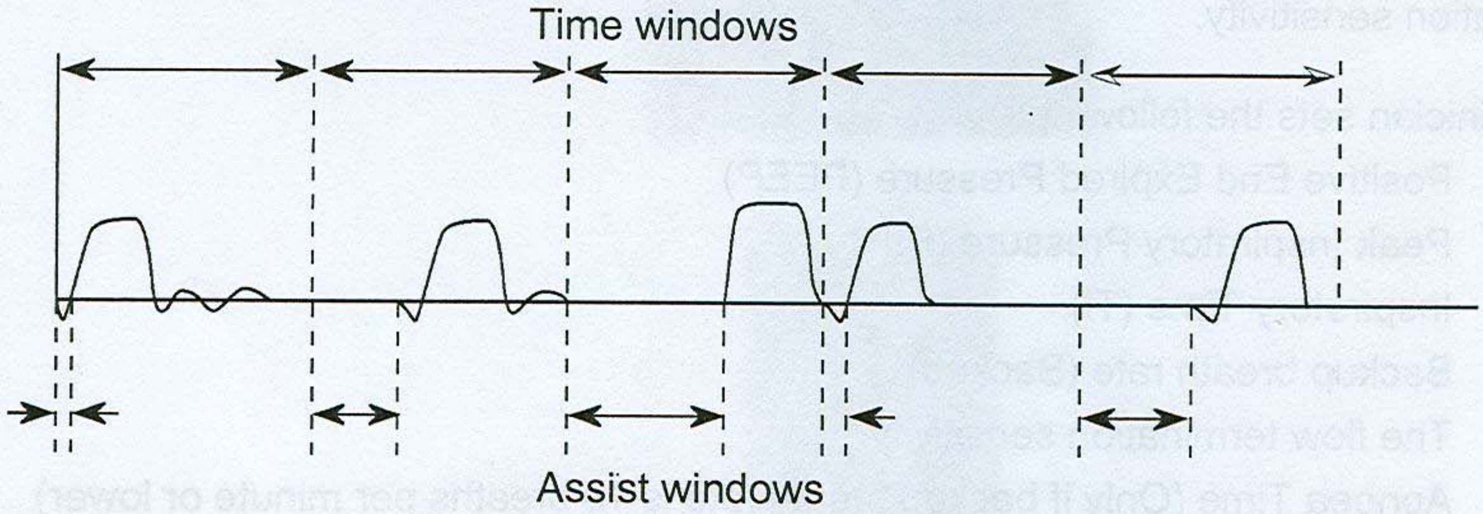
- You set
  - Desired rate (Ti/Te), PIP, PEEP, Flow

  Weaning
  - PIP and rate

- Baby controls
  - Onset or timing of set no. mechanical breaths

2.5 SIMV (Synchronised Intermittent Mandatory Ventilation)

The frequency of mandatory breaths is determined by the BPM control. When a mandatory breath is due an assist window opens and waits for a patient's inspiratory effort. When this occurs the ventilator delivers a synchronised breath. Once the breath has been delivered the assist window closes until the next set breath is due.



SIMV

- **Advantages**
- Choose no. breaths synchronised
- Understood well
- Weaning pressure and rate

- **Disadvantages**
- Patients own breath through ET tube
- At worst like IMV

International randomised controlled trial of patient triggered ventilation in neonatal RDS

- **Baumer JH. Arch Dis Child 2000;82:F5-F10**

- 924 Babies 22NICU's

- No observed benefit of PTV
- PTV more often abandoned (27% v 15%)
- Trend towards more pneumothorax in <28 weeks (18.8% v 11.8%)

SIPPV/AC/PTV

- With a minimum set rate the ventilator senses the infant's spontaneous breaths and gives full assisted ventilator breaths.

- Weaning is therefore with Ti and PIP.

- You set
  - Back up rate, PIP, PEEP, Ti (<0.4s), Flow

- Baby controls
  - Rate

PTV

- **Advantages**
- Every breath in sync
- Quicker weaning
- Shorter inspiration times
- Weaning pressure

- **Disadvantages**
- Overventilation
- ?inc pneumothorax
- Apnoea (back up)

SIMV vs PTV during weaning

Dimitriou et al Arch Dis Child 1995;72:F188-F190

Two randomised trials looking at weaning of infants.

Duration of weaning

Failure of weaning

No difference between pressure and rate reduction (SIMV) than pressure reduction alone (PTV)

PSV

- With a minimum set rate the ventilator senses the infant's spontaneous breaths and gives full assisted ventilator breaths.

- You set
  - Back up rate, PIP, PEEP, Flow

- Weaning is therefore with and PIP.

- Baby controls
  - Rate and Ti

What to do when CO_2 goes up

- 1. Look at chest wall movement

  Is it adequate?

  If not why not?

  ETTube blocked/out/RMB etc

  Airleak

  CDH

  If there is an airway problem…………………….fix it

What to do when CO_2 goes up

2. If ET Tube OK and no chest wall movement then increase the driving pressure until the chest begins to move

Increase PIP

Decrease PEEP

Increase flow

A pneumothorax is preferable to death!!

What to do when CO_2 goes up

If 3. ET Tube OK and adequate chest wall movement then increase rate

Remember for some conditions, e.g. MAS, increasing Te (even if rate falls a little) may improve CO_2 clearance

How to Improve Oxygenation

Six ways on the ventilator

- 1. increase FiO_2
- 2. increase PEEP (best when lungs small & stiff)
- 3. increase PIP (not when CO_2 normal or low)
- 4. increase Ti (keeping Te same or shorter)
- 5. decrease Te (keeping Ti same or longer)
- 6. increase flow (esp large leak, large baby, old ventilator)

All of these except increasing FiO_2 increase MAP and therefore increase effective lung volume

What are we trying to achieve?

- Shorter Ventilation Times
- Smaller Tidal Volumes
- Less Volu/Baro/Atelectotrauma
- Less Oxygen toxicity
- Less Chronic Lung Disease
- Less Morbidity
- Greater Survival

Questions?