MECHANICAL VENTILATION

IT IS AN ART MORE THE A SCIENCE !!!!!

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Objectives of Mechanical Ventilation

- Improve pulmonary gas exchange
  - Reverse hypoxemia and Relieve acute respiratory acidosis
- Relieve respiratory Distress
  - Decrease oxygen cost of breathing and reverse respiratory muscle fatigue
- Alter pressure-volume relations
  - Prevent and reverse atelectasis
  - Improve Compliance
  - Prevent further injury
- Permit lung and airway healing
- Avoid complications

Pulmonary mechanics

- **Compliance**
  - Property of distensibility of the lungs and chest wall
  - Change in volume per unit change in pressure
  - **C = Δ Volume**

    Δ Pressure
  - Neonatal lung
    - Normal 0.003-0.006 L/cm H_2O
    - with RDS 0.0005-0.001 L/cm H_2O

Pulmonary mechanics

- **Resistance:**
  - inherent capacity of the air conducting system (airways and ETT) and tissues to resist airflow
  - Change in pressure per unit change in flow
  - **R = $\frac{\Delta \text{ Pressure}}{\Delta \text{ Flow}}$**

Resistance →

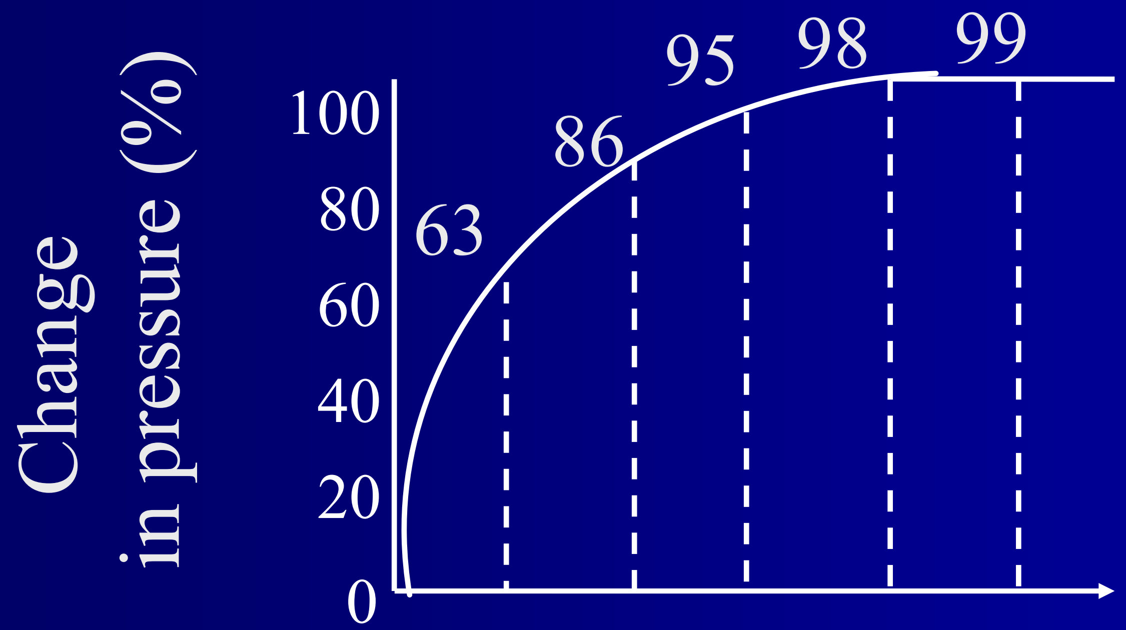
- **Total cross-sectional area** of airways
- **Length** of the airways
- **Flow** rate
- **Density** and **viscosity** of gas

Pulmonary mechanics

- **Time constant**
  - The time taken for the airway pressure (and volume) changes to equilibrate throughout the lung is proportional to the compliance and resistance of the respiratory system
  - **Time constant = Compliance x Resistance**

Pulmonary mechanics

- % change in pressure in relation to time



- Almost full equilibration: 3-5 time constants

Gas exchange

- Total minute ventilation = tidal vol x freq
  - $V_E = V_T \times f$

- Alveolar ventilation (VA) = Useful (fresh gas) portion of minute ventilation that reaches gas exchange units; excludes dead space (VD)
  - $V_A = (V_T - V_D) \times f$

Gas exchange

- **Causes of hypoxemia**
  - V/Q mismatch
  - Right to left shunt (venous admixture)
  - Hypoventilation (e.g. in apnea)
  - Diffusion abnormalities

- **Causes of hypercapnia**
  - Hypoventilation
  - Severe V/Q mismatch

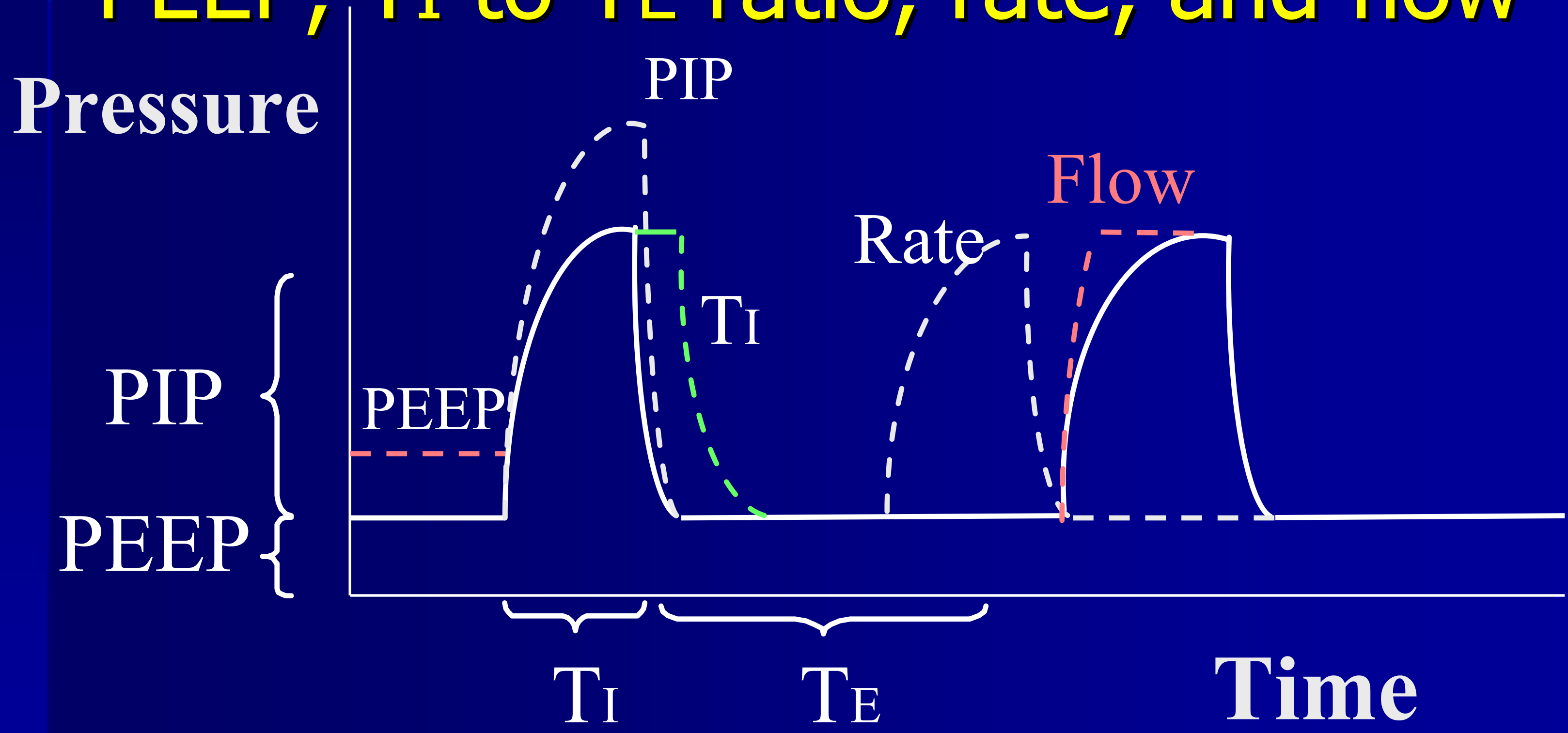
Gas exchange

- **Factors affecting oxygenation**
  - Mean airway pressure (MAP) : affects V/Q matching. MAP is the average airway pressure during respiratory cycle

    MAP = K (PIP-PEEP) [TI / (TI+TE)] + PEEP
  - Oxygen concentration of inspired gas (FI_{O2})

Gas exchange

- MAP increases with increasing PIP, PEEP, T_I to T_E ratio, rate, and flow



Gas exchange

- **Carbon dioxide elimination**
  - Proportional to alveolar ventilation (V_A) which depends on tidal volume (V_T) and frequency (rate)
  - V_T changes more effective (but more barotrauma) : dead space constant, so proportion of V_T that is alveolar ventilation increases to a greater degree with increases in V_T …. HOW ??

Ventilation parameters

Peak inspiratory pressure

Changes in PIP affect both PaO_2 (by altering MAP)
$PaCO_2$ (by its effects on tidal volume)

Use of a high PIP may increase the risk of volutrauma with resultant air leaks and BPD

A useful clinical indicator of adequate PIP is gentle chest rise with every breat

Always use the minimum effective PIP

Making frequent changes in PIP in the presence of changing pulmonary mechanics, such as after the administration of surfactant in the management of RDS, may be necessary.

Positive end-expiratory pressure

Adequate PEEP helps to prevent alveolar collapse

lung volume at end-expiration, and improves V/Q matching.

increasing PEEP usually increase oxygenation associated with increases in MAP

a very elevated PEEP (>5-6 cm H20) may not improve oxygenation further and, in fact, may decrease venous return, cardiac output .

an elevation of PEEP may decrease tidal volume and increase PaCO2.

older infants with chronic lung disease tolerate higher levels of PEEP without carbon dioxide retention and with improvements in oxygenation

Rate

Changes in frequency alter alveolar minute ventilation and, thus, $PaCO_2$

Frequency changes alone (with a constant I/E ratio) usually do not alter MAP nor substantially alter PaO_2

Any changes in inspiratory time that accompany frequency adjustments may change the airway pressure waveform and thus alter MAP and oxygenation.

Generally, a high-rate, low-tidal volume strategy is preferred

However, if a very short expiratory time is employed, expiration may be incomplete. The gas trapped in the lungs can increase FRC, thus decreasing lung compliance

Inspiratory and expiratory times

An inspiratory time 3-5 times longer than the time constant of the respiratory system allows relatively complete inspiration.

A long inspiratory time increases the risk of pneumothorax

Shortening inspiratory time is advantageous during weaning

patients with chronic lung disease may have a prolonged time constant.
In these patients, a longer inspiratory time (near 0.8 s) may result in improved tidal volume and better carbon dioxide elimination

Inspiratory-to-expiratory ratio

The major effect of an increase in the I/E ratio is to increase MAP thus improve oxygenation
changes in the I/E ratio are not as effective in increasing oxygenation as are changes in PIP or PEEP

Fraction of inspired oxygen

Changes in FiO2 alter alveolar oxygen pressure and thus, oxygenation

FLOW ??

MODES OF VENTILATION

Basic Principles and Guidelines for Conventional Ventilation

Ventilation practices vary between (and within) NICUs and neonatologists

There are limited randomised trial data which establish that any one ventilation strategy or mode is superior

Basic Principles of Ventilation :

There are two goals of ventilation:

- Appropriate oxygenation
- Appropriate ventilation

So, when you set about changing the settings, you need to think about what you are trying to achieve

Change Oxygenation
PaO2

Alter the FiO2
(turn the knob!)

Alter the mean
airway pressure

Change Ventilation
PaCO2

Increase the minute ventilation

Change the tidal volume (by changing the pressure, primarily)

Change the frequency of breaths

Target Blood Gas Values and saturation values

PH	7.22-7.4
PCO2	45 -55 (60 in the chronic phase)
P02	45-60 art
	35 60 cap
HCO3	17-30 (higher in the chronic phase)
Base excess	up to -7 (+ve deficit in the chronic phase)

Chronic phase settings

Targets in PPHN

Before you Touch the Ventilator .....

1) <u>Look at the blood gas result :</u>

Do you believe it?
Does it fit with the clinical picture the baby is giving you?
Does it fit with the expected course for the baby

If it is vastly different than you expect, is there some reason for it?
Was there an air bubble in the specimen?
If a capillary gas, is the perfusion awful? Did the baby bleed easily?

Don't change anything on the basis of a venous gas ?
Venous gas is useless for ventilation purposes !!

2) Look at the baby.

Is the chest moving?
What's the air-entry like?
Is the baby struggling on the ventilator?
Is the baby very tachypnoeic or is the baby apnoeic?

3) Look at the ventilator.

Is it cycling?
Are you giving the baby the ventilator settings you thought you were?
What tidal volume (VT) is the baby getting?
Is there a significant leak?
Is it set up properly with an appropriate inspiratory time and with appropriate pressures?

4. **Look at the nursing flow chart.**

How stable has the baby been over the past few hours or days?
Are there lots of secretions?
How is the baby handling?
How old is the endotracheal tube ?

Changing the Ventilation Settings

Low Oxygenation
Low PaO2
or
Saturations

→

Increase the FiO2

OR

Increase the Mean Airway Pressure (MAP)

Increase the Mean Airway Pressure (MAP) :

Increase the PIP (but this may also affect ventilation)
Increase the inspiratory time
Increase the PEEP

Changing the Ventilation Settings

High Oxygenation
High PaO2
or
Saturations

→

decrease the FiO2
OR
decrease the Mean Airway Pressure (MAP)

Decrease the FiO2 :

The easiest solution (unless the baby is already in room air
If in room air … accept higher saturations or PO2

Decrease the MAP :

If the PEEP is higher than 5, then you can drop this down (caution with pulm hg
Decrease the PIP (but this may adversely affect ventilation)
Decrease the inspiratory time

Changing the Ventilation Settings

Overventilation
High pH
with a Low $PaCO_2$

→

Decrease the tidal volume
OR
Decrease the frequency

Decrease the tidal volume :

Decrease the difference between the PIP and PEEP
In general, dropping the PIP by 2mbar (or more if significantly overventilated) is about the right amount. But look at the tidal volume!

Decrease the frequency :
drop by 5. If really alkalotic, you might want to drop it by 10 or more.
Note that for modes where every breath is assisted !!!!!! The rate change is uselesssss

Changing the Ventilation Settings

Underventilation
Low pH
with a High $PaCO_2$

→

increase the tidal volume
OR
increase the frequency

Increase the tidal volume :

Increase the PIP till you get some chest movement but look at the tidal volume too ..

Remember that if you are having to put the PIP up a lot to get the same tidal volume in that you were giving previously, compliance is going down (consider radiographs +assessment)

Increase the frequency :

For fast rates, it is really important that the expiratory time is longer than the inspiratory time.

If you find you need to give more than 70 breaths per minute, think about HFOV

Balance is Important

Don't forget to balance your ventilator settings

<u>For example,</u>
if a baby is in 100% oxygen but with low pressures settings
it may be preferrable to reduce the FiO_2 but increase the pressures.

Similarly, if the baby is on high pressure settings but a low rate,
it may be better to give a faster rate and lower pressures

When Do I Do the Next Blood Gas?

An easy answer at last : "It depends ....". So what does it depend on?

How abnormal the gas is :

If it is really outside the normal range you are targetting
you probably want to check it quite soon
15-30 minutes

How stable the baby is :

If the baby is stable and you're not doing too much with the ventilation,
you don't need to check it too soon after the change.
Some babies who are chronically ventilated may only need a gas once a day.
If you have given surfactant, you might want to check a gas within
an hour to see what effect any change in compliance is having on gas exchang

When Do I Do the Next Blood Gas?

How confident you are :

If new , you may need reassurance with a gas soon after you make your change
However, try to avoid too many tests just to reassure yourself

When the nurses tell you :

If they are worried, they **will** tell you (...and you should listen).

I'm really worried that I will be told off on the ward round if I get it all wrong .....

Believe it or not, all the consultants had to learn by trial and error, and they don't always get it "right".

And if you are not sure what to do, **ask someone**

Assist Control Ventilation

Volume-cycled lung inflation
Patient can initiate each mechanical breath or Ventilator provides machine breaths at a preselected rate
Maintain I:E ratio to 1:2 to 1:4. An increase in Peak flow decreases the time for lung inflation and increases the I:E Ratio
I:E ratio of <1:2 can cause hyperinflation by air trapping
Diaphragmatic contraction continues during ACV and increases the work of breathing.

Assist Control Ventilation

Adverse effects:

In a tachypneic patient>>Lead to overventilation and

severe respiratory alkalosis>> Hyperinflation and

Auto-PEEP>> Lead to Electromechanical

dissociation

Intermittent Mandatory Ventilation

- Delivers volume cycled breaths at a preselected rate with spontaneous breathing between machine breaths
- Less Alkalosis and Hyperinflation
- Synchronized IMV

Intermittent Mandatory Ventilation

Disadvantages:

<u>Increased work of Breathing:</u>

Spontaneous breathing through a high resistance circuit

Solution: Add Pressure support

<u>Cardiac Output Changes:</u>

C O decreased by decreasing ventricular filling

C O increased by reducing ventricular afterload

More significant decrease in patients with LV dysfunction

Pressure Controlled Ventilation

- Pressure cycled breathing, fully ventilator controlled
- Inspiratory flow rate decreases exponentially during lung inflation
- (+)Reduces peak airway pressure and improves gas exchange
- (-)Inflation volume varies with changes in mechanical properties of the lungs.
- Suited for patients with neuromuscular diseases and normal lung mechanics

Pressure Support Ventilation

- Pressure augmented breathing
- Allows patient to determine the inflation volume and respiratory cycle duration
- Uses: augment inflation during spontaneous breathing or overcome resistance of breathing through ventilator circuits (during weaning)
- Popular an a non-invasive mode of ventilation via nasal or face masks