Mechanical Ventilation

TF Loh

PHYSIOLOGY OF MECHANICAL VENTILATION

Modern day mechanical ventilators deliver a bolus of air using positive pressure. The positive forces not only overcome the lung compliance and resistive forces, but must also be adequate to *expand* the thoracic cage and overcome abdominal pressure forces. Therefore, altered mechanical properties of the thoracic cage and abdomen can impact significantly on positive pressure ventilation e.g. open chest wounds, abdominal compartment syndrome.

It is important to have an understanding on respiratory pathophysiology, anticipated timeline to reversibility and defined oxygenation/ventilation goals before deciding on detailed settings of mechanical ventilation.

NON INVASIVE VENTILATION (NIV)

NIV can be considered if the following criteria are present:

- Adequate spontaneous breathing
- Stable airway with adequate airway protective reflexes
- Ventilation and oxygenation needs are low (eg. FiO2 < 0.6)
- Haemodynamics are stable
- Child is able to co-operate with NIV application
- Low risk of instability if disconnection occurs
- Aspiration risk low
- Abdominal distension manageable
- No facial deformity or facial/base of skull trauma

Bear in mind that the patient may deteriorate transiently whilst he/she is getting used to NIV. Therefore, a patient who is unable to tolerate application of NIV is not a good candidate for non-invasive support. NIV is best used in early respiratory failure with when there are signs of progression. It should not be used in patients with late or very severe respiratory failure.

INITIAL SETTINGS FOR NIV SUPPORT

Mode	BiPAP (Timed, Spont/Timed, Spont) or PSV or CPAP
IPAP	8 - 10cmH_2O
EPAP	5 -6 cmH_2O
Respiratory rate (RR)	Match patient RR
FiO2	Match SaO_2

- Ensure expiratory /swivel valve is in place at the expiratory limb as close to patient as possible
- Humidification is essential
- Ensure proper mask size and fit
- Monitor set pressures with manometer or measured values

Monitoring of patient on NIV include vital signs, clinical assessments, mask fit/seal and blood gases. Patients should improve within the first 1-2 hours of NIV initiation.

Early intubation is advised if:
- Patient is deteriorating within the first 1-2 hours ie. failing NIV
- NIV settings escalate within the first 1 hour without improvement in patient condition or with deterioration of patient condition.
- Increasing oxygen needs ie 10-15L/min (with borderline saturations 90-95%).

Delays usually result in emergent intubation with a very unstable patient.

GOALS OF MECHANICAL VENTILATION

Apart from decreasing work of breathing, the commonest reason for starting mechanical ventilation is to either correct an oxygenation defect or remove carbon dioxide.

OXYGENATION

Oxygen delivery to the tissues is mediated by various factors such as:
- Inspired oxygen concentration
- Alveolar ventilation
- Amount of haemoglobin
- Abnormal oxygen-carrying capacity of haemoglobin
- Cardiac output

Arterial oxygen content (CaO2) is governed by the following equation:

$$CaO2= (1.36 \times HbO_2) + (0.0031 \times PaO_2)$$

Where HbO_2 is the amount of oxygenated haemoglobin, and PaO_2 is the partial pressure of arterial oxygen.

Oxygen defect at the level of the lungs is usually the result of:
- hypoventilation
- reduced functional residual volume (FRC)
- ventilation-perfusion imbalance (pathological dead space or shunts)

The easiest manner to improve oxygen is to increase the amount of inspired oxygen. Maneuvers that increase *mean airway pressure and/or minute ventilation* will also correct most oxygenation defects. Once oxygenation goals are met, the amount of inspired oxygen should be weaned accordingly.

Measures to reduce oxygen needs e.g. sedation, preventing hyperthermia and paralysis are also important considerations. When shunting is excessive, use of pulmonary vasodilator agents e.g. inhaled nitric oxide may be considered.

When FRC is reduced, recruitment measures to re-open and keep alveoli open will improve oxygenation. Examples of recruitment include:
- use of PEEP
- prone positioning
- sustained inflations or sequential increase in inspiratory pressures.

VENTILATION

Carbon dioxide level in the blood is a function of production and removal. Clearance of this gas is closely proportionate to alveolar minute ventilation (tidal volume x respiratory rate).

Permissive hypercapnia refers to a state that accepts an arterial CO_2 that is above normal values (>55mmHg). In patients where the risk of ventilator associated lung injury is high, permissive hypercapnia may be acceptable so long as the pH is >7.2.

BASIC MODES OF INVASIVE MECHANICAL VENTILATION

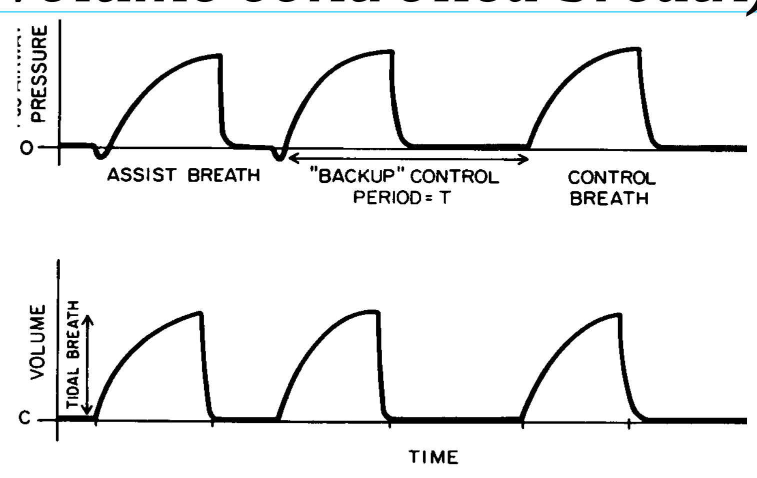
In general, an ICU ventilator provides 3 levels of basic respiratory support:

1. CONTROL-VENTILATED BREATHS

The highest level of support occurs when every respiratory cycle is a control-ventilated breath. This can either happen when the patient is paralysed and the ventilator takes over all work of breathing. Alternatively, the patient is able to breathe spontaneously and triggers the ventilator that provide full ventilated breaths with every trigger.

Common examples of such modes include controlled mechanical ventilation (CMV), spontaneous inspiratory positive pressure ventilation (SIPPV) or assist control ventilation (AC). This mode is usually used to reduce work of breathing (WOB) quickly and initiate ventilatory strategies to correct oxygenation or ventilation defects to stabilise the critically ill patient. Once the acute stabilisation phase is over, it is possible to switch over to a lower level of support.

Fig 8. Assist-control (volume controlled breath)



Ref: Ingento EP and Drazen J: Mechanical ventilators, in Hall JB, Scmidt GA, and Wood LDH(eds.): *Principles of Critical Care.* New York, McGraw-Hill, Inc., 1992, p.144.

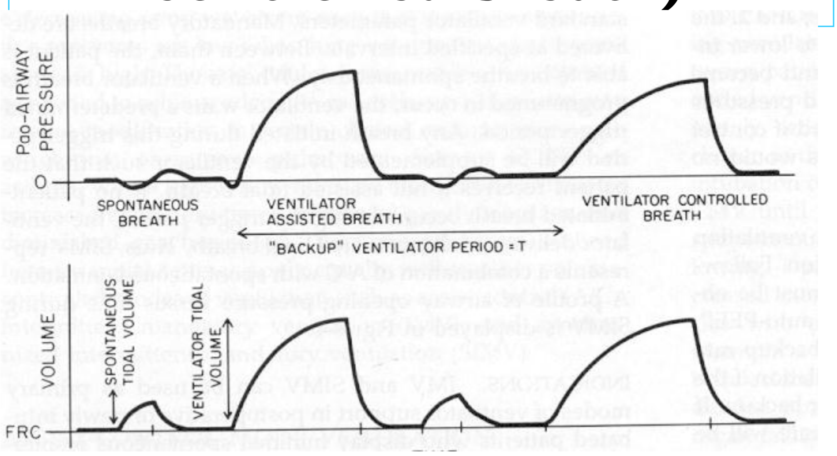
2. CONTROL AND SUPPORTED BREATHS

Modes like synchronized intermittent mandatory ventilation (SIMV), intermittent mandatory ventilation (IMV) provide an intermediate level of support. A preset back-up ventilator rate determines the minimum amount of ventilated breaths the patient receives. If the patient is able to trigger spontaneous breath above the ventilator set rate, these breaths may be supported with pressure, termed Pressure Support (PS). PS breaths should provide enough pressure to overcome airway resistance conferred by the endotracheal tube and circuit connections. It is usually set at 10cmH_2O.

SIMV modes can be used during the acute stabilisation period of ICU patients as long as the level of support is started at a high level e.g. high respiratory rate and/or high tidal volumes achieved.

These modes are also used when weaning the patient from mechanical ventilation or when patients are ventilated for non-respiratory pathology and lower ventilatory support is needed e.g. post operation care, status epilepticus.

Fig 9. SIMV (volume controlled breath)



Ref: Ingento EP and Drazen J: Mechanical ventilators, in Hall JB, Scmidt GA, and Wood LDH(eds.): *Principles of Critical Care.* New York, McGraw-Hill, Inc., 1992, p.146.

3. SUPPORTED BREATHS

The lowest level of support occurs when the patient is able to breathe spontaneously and and the ventilator provides triggered supported breaths only. This is usually a pre-extubation mode used to 'test' patients before liberation from the ventilator. Sometimes, it is used in acute setting when it is desirable to have the patient breathing spontaneously e.g. status asthmaticus.

It is also used to ventilate patients who need airway protection but have no/minimal respiratory pathology e.g. tracheal surgery. Usual modes include pressure support ventilation (PSV), continuous positive airway pressure with pressure support or assisted spontaneous breath (CPAP + PS/ASB). The trigger setting should be appropriate to avoid patient fatigue. In this mode, back up ventilation should be enabled to support patient should he turn apnoeic.

INSPIRED OXYGEN (FiO2)

Choosing an FIO2 is based on the patient's clinical condition and the reason for intubation. Blood gas measurements should be obtained in the first half hour after treatment, and adjustments made to keep the PaO2 between 60 and 90 mm Hg at the lowest FiO_2 possible.

TRIGGERING THE VENTILATOR

It is important to ensure that the trigger level/sensitivity is set optimally. If threshold is set too high, patient may fatigue due to failure to trigger support. Alternatively, if threshold is set too low, auto-triggering may occur and patient can be over-ventilated. Flow trigger levels are age dependent: adults about 4-5L/min; young child 2-3L/min, infants and younger <1L/min.

DETERMINANTS OF VENTILATED BREATHS

Each ventilated breath the patient receives can be configured as *pressure or volume* breaths. Traditionally, paediatric mechanical ventilation defaults to pressure controlled ventilation due to possible leak from uncuffed endotracheal tubes and concerns with barotrauma, especially in infants and neonates.

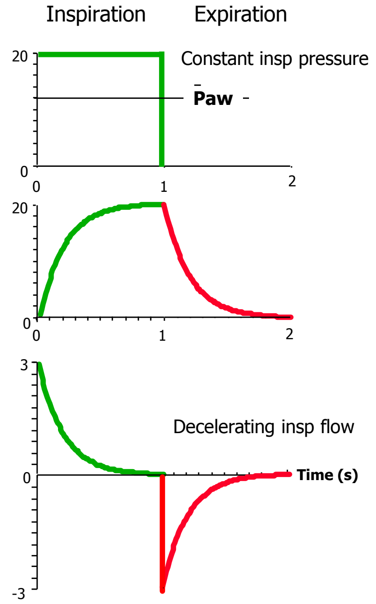
Volume controlled ventilation is ideal in situation when arterial carbon dioxide level needs to be keep constant e.g. neuroprotection, pulmonary hypertension and where air leak is not excessive. Pressured controlled breaths are preferable in managing acute lung injury or disease in which there is significant loss of potentially recruitable lung units.

PRESSURE CONTROL

In pressure controlled breaths, the peak inspiratory pressure (PIP) and inspiratory time (Ti) defines the amount of tidal volume to be delivered.

Tidal volume may vary depending on the airway resistance and lung compliance. (Fig. 11) Secretions or changes in lung pathology can alter tidal volume that is delivered to the alveoli. The driving pressure is the pressure difference between PIP and PEEP (ΔP). In healthy lungs, this is in the range of 8-10cmH_2O. This should achieve tidal volumes in region of 4.5-7 ml/kg.

Fig 11. Pressure Control

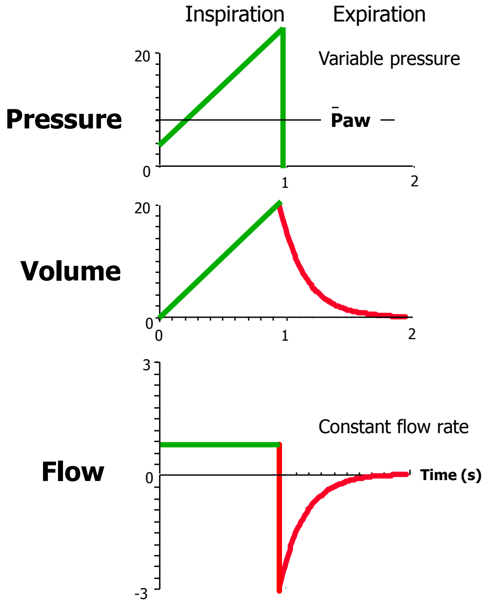


VOLUME CONTROL

Volume controlled breaths are defined by controlling tidal volume and airflow. Each breath starts with accelerating airflow till the set flow is reached and flow is maintained. When the preset tidal volume is reached, the ventilator cycles to expiration. Therefore, the duration of inspiration and peak pressures experienced by the patient is variable depending on airway resistance and lung compliance. Because of the initial accelerating flow, the patient may experience peak pressures above plateau pressure. (Fig. 12)

Most ICU ventilators now have an option that allows flow to be altered to a decelerating pattern by the ventilator to avoid the higher peak pressures (Autoflow mode). Set tidal volume is usually in the range of 6-7ml/kg.

Fig 12. Volume/Flow Control



Inspired oxygen concentration, ventilator set rate, PEEP and pressure support are other determinants common to both volume and pressure controlled ventilation.

INSPIRATORY TIME (Ti)

- Inspiratory and expiratory ratio (I:E ratio) should be preferably about 1:2 to 1:3
- Depending on the respiratory rate, Ti may have a significant impact on the expiratory time (Te). There is risk of incomplete expiration if the expiratory time is too short.
- Respiratory rate = 60/ (Ti + Te)

Age	Inspiratory time (sec)
Newborns, neonates and infants	0.5
Toddlers	0.6-0.8
Young Children	0.8-1.0
Adults	1.2-1.5

TIME CONSTANT

The time required for the lung to empty is known as *time constant*. It is a direct function of airway resistance and lung compliance. Time constant is also dependent on presence of air braking mechanisms (PEEP).

In obstructive lung disease (eg. Severe asthma, bronchopulmonary dysplasia), resistance is high while compliance is usually normal. Time constant will be long and so a long expiratory time (Te) is needed.

In patients with acute lung injury (eg.interstitial lung disease, acute respiratory distress syndrome (ARDS) and pulmonary edema/haemorrhage), resistance may be normal but compliance is low, therefore, time constant is low. Te can be short allowing higher ventilator rates to be set.

POSITIVE END EXPIRATORY PRESSURE (PEEP)

Positive effects of PEEP include:

- Open and keep airways and alveoli open
- maintain FRC
- minimises ventilation-perfusion imbalances
- decreases left ventricular transmural pressures

During spontaneous breathing, air-braking mechanisms can maintain physiological PEEP of about 5-8cmH_2O. After intubation and mechanical ventilation, the air-braking mechanism is lost and it is advisable to start PEEP on all intubated patients. In patients with ARDS, PEEP levels may reach over 20cmH_2O.

However, excessive positive thoracic pressures can lead to:

- decreased venous return
- loading of right heart function
- haemodynamic instability

Patients with severe obstructive airway disease are expected to have *intrinsic PEEP* (iPEEP) and may require high levels of PEEP on the ventilator to overcome iPEEP when intubated.

RESPIRATORY RATE

In the initial stabilisation phase, the respiratory rate is usually set at a high range or slightly beyond that of the normal breathing rate for the age.

When setting the respiratory rate, it is important to allow adequate time for expiration to occur. Failure to do so will result in air trapping and inadvertent increase in PEEP (*intrinsic PEEP*). This can lead to alveoli distension, barotrauma, and incrementally positive intrathoracic pressures.

TROUBLE SHOOTING

Patient can deteriorate while on mechanical ventilation resulting in hypoxia, CO_2 retention, discomfort and agitation.

Endotracheal tube factors:

- dislodgement/disconnection
- blockage
- ventilator-patient dsynchrony
- fault with ventilator and/or circuit.

Patient factors include:

- further deterioration in respiratory status
- pneumothorax

- lung collapse
- infection.

Respond by initially disconnecting the patient from the ventilator while bagging with secured intact oxygen source. This allows the ventilator and circuit to be assessed. While bagging, examine the patient next for complications relating to mechanical ventilation or new developments of disease state. At the same time, determine if there are excessive secretions or if the endotracheal tube is blocked or dislodged. Consider patient-ventilator dsynchrony only if there is no causative factor can be found. Before deepening sedation, check that the ventilator has the appropriate trigger setting; and pressure support and ventilatory support is adequate.

WEANING FROM INVASIVE MECHNICAL VENTILATION

Attempts to wean can begin once the patient has stabilized and shows signs of improvement.

Considerations during the weaning process include:

- Demonstration of good spontaneous respiration on minimal ventilator rate
- The patient should be able to maintain good tidal volume without need for high ΔP.
- Presence of ETT leak as a gauge of possible glottic edema. This is important when airway disease was the cause of respiratory failure, period of mechanical ventilation is prolonged (>5 days), significant patient-ventilator dsynchrony, initial intubation was difficult, problematic airways and previous failed extubation.

Other important considerations before extubation include:

- haemodynamic state
- conscious level
- nutritional state
- anemia
- presence of abdominal pathology

A spontaneous breathing trial (SBT) on CPAP with PS or using low SIMV rates is usually performed before extubation. Some signs that may indicate extubation failure during SBT include tachycardia, rapid shallow breaths, diaphoresis, haemodynamic instability and increased oxygen needs.

Patients are usually extubated to supplementary oxygen but NIV can also provide a suitable transition for patients who have residual respiratory disease or were on NIV before the period of invasive mechanical ventilation.

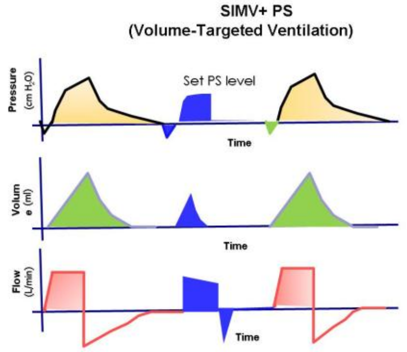
ADVANCED MODES OF VENTILATION IN PAEDIATRICS

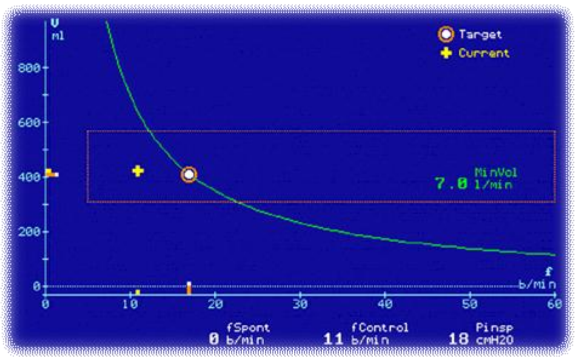
ADAPTIVE SUPPORT VENTILATION (ASV)

ASV is a form of volume targeted pressure ventilation with pressure support. The ventilator cycles between pressure supported breaths and volume-targeted breaths according to the target set by physician and parameters detected by the ventilator whilst ensuring the least work of breathing by the patient.

In ASV, the controls are set according to ideal body weight (IDW) and gender-based height/weight. Based on the patient's condition, the physician will set the minimum percentage minute ventilation (%MV) for the ventilator to meet and the Pmax within which each breath should not exceed.

Parameters to set in ASV mode:

- Patient's IDW
- %MV
- PEEP
- Pressure Support (PS)
- FiO2
- 



Based on every 10 breaths measured closed loop mechanics, the ventilator will calculate to determine the ideal tidal volume-Frequency for the next 10 breaths. The algorithms are set based on lung protective strategies and calculated respiratory mechanics to ensure the patient requires the least work of breathing.

There are limits also set to avoid intrinsic PEEP, hypoventilation and excessive dead space. Once initiated, the interface screen will show the current ventilatory pattern of the patient (indicated by cross) and counter posed with the target as depicted by a regression graph with the ideal pattern indicated by bold dot.

ASV tends to cycle spontaneous pressure-supported breaths in active patients but is able to regain control when the patient becomes fatigued or apnoeic. ASV is usually thought of as a weaning mode as the ventilator is able to respond to the patient's breathing pattern and effort as his/her respiratory disease improves.

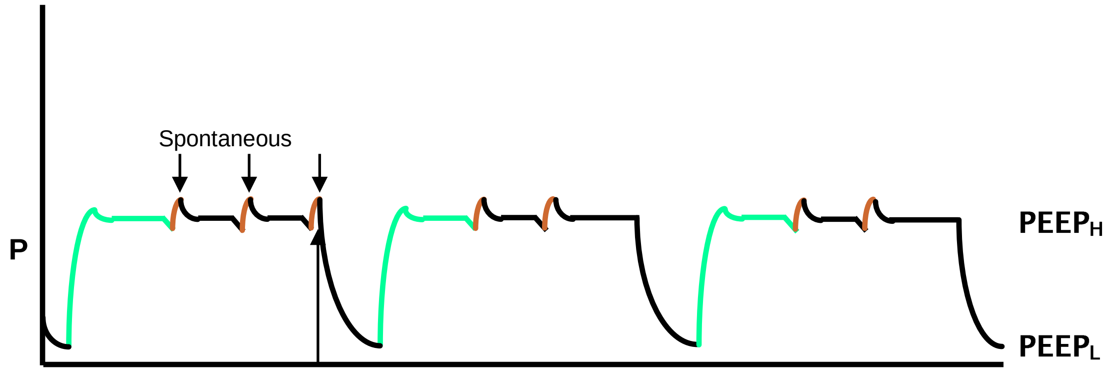
AIRWAY PRESSURE RELEASE VENTILATION (APRV)

APRV is a form of time-triggered, pressure-limited, time-cycled ventilation. This mode allows spontaneous breathing throughout its breathing cycle which comprises breathing at both a high level of continuous airway pressure (CPAP) termed P_{High} and a low level P_{Low}.

Duration of P_{High} (T_{High}) exceeds duration at P_{Low} (T_{Low}) resulting in higher overall mean airway pressures for the same Peak plateau pressures when compared with conventional ventilation. This helps to recruit lung units/ airways and improve oxygenation.

Carbon dioxide clearance is achieved through release ventilation during T_{Low} as the chest and lung recoil from high tension due to the sustained inflation during T_{High}. Furthermore, expiration can occur throughout entire ventilation cycle.

Apart from prolonged sustained inflations, preservation of spontaneous breathing allows for better ventilator-patient synchrony (lesser sedation) and encourages diaphragmatic contractions (preferential ventilation of dependent part of lungs). Other effects include reduction in pleural pressures as spontaneous breathing is maintained and lower mean pressures in APRV as compared with pressure controlled ventilation. These result in better haemodynamics.

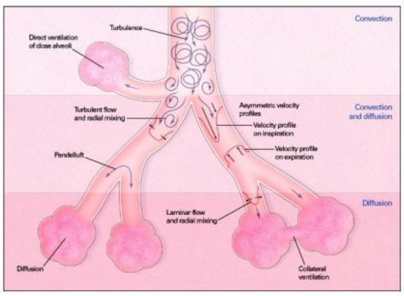


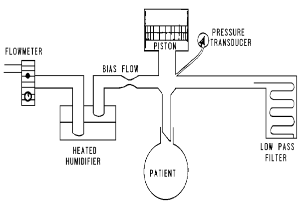
T_{Low} is usually set to terminate when flow during P_{Low} decrease to about half to third of peak flow at the initial phase of P_{Low}. This result in an end-expiratory lung volume. In cases of acute lung injury, P_{High} recruits diseased lung units and short T_{Low} during P_{Low} avoids de-recruitment. High peak flows during the release phase assist expiration in patients with airway disease.

APRV can be used early in patients with oxygenation deficit as indicated by increased FiO_2 >60% and PEEP>8cmH_2O or oxygenation index >0.15.

HIGH FREQUENCY OSCILLATION VENTILATION (HFOV)

High frequency ventilator strategies involve technique using much higher respiratory cycle and much lower low Vt than conventional ventilation. In that case of high frequency oscillatory ventilation (HFOV) tidal volume is actually sub dead space. By using a constant distending air pressure, HFOV is the archetypal open lung concept ventilation improving oxygenation. Ventilation is achieved through a piston that delivers energy pulses which potentially activates various gas transport mechanism which cause facilitated diffusion of gases.





Paw=CPAP

In HFOV, gas exchange control is de-coupled; oxygenation is affected by mean airway pressure (MAP). Ventilation is determined by amplitude (delta power) that determines the power of piston and speed with which the piston cycles in 1 second (frequency).

HFOV can be consider when oxygenation index reaches >0.2 or FiO_2 reaches >80% with PEEP > $10cmH_2O$.

Adjusting ventilator settings

Acute stabilization phase

Basic conventional ventilation

Mode of ventilation is usually synchronized intermittent mandatory ventilation with pressure support. The choice of pressure or volume ventilation depends on the patient and disease time. In younger patients, pressure ventilation is preferred especially if air leak is a concern. PCV is also standard in patients with acute lung injury of any etiology, pneumonia, bronchiolitis, pulmonary edema/ haemorrhage and pleural effusions. Volume controlled ventilation maybe used in older patients especially if close control of minute ventilation is ideal to maintain carbon dioxide level constant e.g. pulmonary hypertension, traumatic brain injury.

Preset tidal volume in VCV is about 5-7ml/g. Peak pressures in PCV are set to achieve adequate tidal volumes. Injurious pressures peak above $35cmH_2O$ or plateau pressures above $30cmH_2O$ is to be avoided. If oxygenation defect is significant despite using of high PEEP in conventional ventilation, advanced mode of ventilation maybe considered. Respiratory set is set in the high range of normal respiratory rate range of the patient if there is lung pathology. In patients intubated for non pulmonary pathology, the rate maybe set in the lower range of normal for age group. Inspired oxygen (FiO_2) maybe set at 100% initially for patients with pulmonary pathology and 50% if there is no pulmonary pathology. Subsequent FiO_2 maybe titrated to saturations >95%. Inspiratory time should be set to avoid prolonged I:E ration and autoPEEP. PEEP should be set at minimum of $5cmH_2O$ and increased if there is need for recruitment with increasing oxygen needed. PEEP up to 12-13cmH2O may be needed. Trigger is set at 1-4l/min depending on age group and pressure support of at least $10cmH_2O$ is indicated.

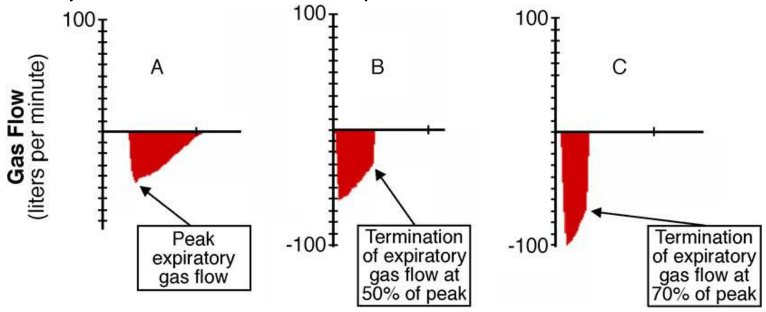
Goals of blood oxygen and carbon dioxide depends on the pathophysiology of disease and reasons for mechanical ventilation. It is balanced with the tidal volume and pressures required to achieve gas exchange and whether there is pre-existing lung pathology. In the latter situation or when injurious tidal volume or pressures are needed, it is reasonable to accept lower targets of oxygen >60mmHg and carbon dioxide >50mmHg (permissive hypercapnia). If mechanical ventilation is needed for neuroprotection or pulmonary hypertension, targets for carbon dioxide and oxygen is about 35mmHg or 100mmHg respectively. When oxygenation or ventilator goals cannot be achieved or injurious settings are needed on convectional ventilation, advanced modes of ventilation should be considered.

Oxygenation index = [(mean airway pressure X FiO_2)/PaO_2] maybe used to gauge oxygenation.

Advanced modes of ventilation

A. APRV

$FiO_2$is set at 100% and P_H is set to match the mean airway pressure achieved whilst on conventional ventilation. P_L is set to zero. T_H is set at 2-3 with T_L set at 0.2-0.6 depending on age of patient to achieve flow termination at half to a third of highest peak flow during release ventilation. It is preferable to allow spontaneous breathing using adequate sedation. Paralysis should be avoided if possible.



B. HFOV

FiO_2 is set to 100% and MAP is set to 4cmH_2O above the mean airway pressure achieved whilst on conventional ventilation. Prepare bag and mask and extra oxygen tank to help with transition. Amplitude is set to achieve "chest wiggle" that can be observed clearly from the chest till it is barely perceptible at the groin. Frequency is set according to age from neonates (15 Hz), infants (10-12 Hz), child (6-10Hz) and older child (2-5Hz). Inspiratory time is set to 33% and seldom adjusted.

Saturations maybe acceptable if >88% and permissive hypercapnia is reasonable. A chest film is obtained after 4 hours initiation to assess posterior rib space to target about 9 intercostals space. Suction is judicious and tube disconnection should be avoided.

Convalescent phase

After initiation of mechanical ventilation and empiric treatment of the cause of respiratory failure, monitoring (blood gases, chest film) is performed to assess response. In open lung concept, chest film should more aeration and increase lung size. As oxygenation and/or ventilation goals are met, ventilation settings can be adjusted to so that these goals are achieved with lowest possible ventilator support.

Signs of improvement would be resolution of respiratory distress, improving chest film, reduction in oxygen supplementation and improvement in oxygen and ventilator indices.

Once FiO_2 is reduced to <50%, peak pressures, PEEP maybe gradually reduced. Reduction in tidal volume and preset respiratory rate would decrease minute ventilation needed to maintain adequate ventilation.

In APRV or HFOV, P_H and MAP can be reduced by 1-2cmH_2O increments as oxygenation needs requires. As CO_2 is cleared T_H is increase or amplitude reduced by 5-10.

Patients on advanced mode of ventilation can be transitioned to conventional ventilation once FiO_2 is below 50% with P_H and MAP of 10-13 cmH_2O.

Weaning and extubation

Once the cause of respiratory failure is largely treated/ improved, the patient can be weaned off respiratory support with aim towards liberation from endotracheal tube.

Weaning is usually performed on conventional ventilation by reducing inspiratory pressures, PEEP whilst maintaining oxygenation. Respiratory rate is reduced to allow increased spontaneous efforts. The patient should be able to sustain spontaneous breathes, be alert and able to protect airway. Sedation is usually reduced in tandem.
Once FiO_2 is <50%, adequate tidal volume (>5ml/kg) achieved with peak pressures 10-12cmH_2) above PEEP and PEEP <8cmH_2O, extubation can be considered. A weaning trial on spontaneous mode of ventilation for a short period (2-4 hours) is implemented.

Signs of failure to wean and/or failure of extubation trial include respiratory distress, worsening oxygenation/ ventilation indices and increased work of breathing. In absence of these signs, extubation can be considered. Before extubation, considerations should be given to use of NIV as a form of post-extubation respiratory support.

Patients should be closely monitored after extubation and kept nil by mouth for 4-6 hours. Chest film maybe performed if clinically warranted.

REFERENCES

1. Nicolai T. The physiological basis of respiratory support. Paediatric Respiratory Reviews 2006: 7; 97-102.
2. Lands LC. Applying physiology to conventional mechanical ventilation. Paediatric Respiratory Reviews 2006: 7S; S33-S36.
3. Acosta P et al. The use of PEEP in Mechanical Ventilation. Critical Care Clinics 2007; 23: 251-261.
4. Greenough A et al. Matching Ventilatory Support Strategies to Respiratory Pathophysiology. Clinics in Perinatology 2007; 34: 35-53.
5. Eskandar N et al. Weaning from Mechanical Ventilation. Critical Care Clinics 2007; 23: 263-274.
6. Haitsma J J. Physiology of Mechanical Ventilation. Critical Care Clinics 2007; 23: 117-134.
7. Magnay A R. Recent Advances in intubation and mechanical ventilation. Paediatric Respiratory Reviews 2001; 2: 184-194.
8. Koh S O. Mode of Mechanical Ventilation: Volume Controlled Mode. Critical Care Clinics 2007; 23: 161-167.
9. Nichols D, Haranath S. Mode of Mechanical Ventilation: Pressure Controlled Mode. Critical Care Clinics 2007; 23:183-199.