Wales Neonatal Network Guideline

Neonatal Ventilation: Ventilation Modes

Please refer to the longer version of this guideline (available on the network website) for further detailed information.

Commonly used ventilation modalities:

Continuous Mandatory Ventilation (CMV) – Time triggered, pressure limited, time cycled ventilation with no relation to the patient's respiratory effort – should not be used as a primary mode of ventilation. Although increasingly rare, this mode may be used by some neonatal transport teams due to technical limitation of the transport ventilators Synchronised modes in paralysed or deeply sedated apnoeic patients are equivalent to CMV but has the added advantage of spontaneous synchronisation when they wake up or improve. Therefore, such infants should not be converted to CMV mode on the neonatal unit. Synchronised modes of ventilation have been proven to reduce the length of time ventilated, therefore this mode cannot be recommended in routine practice.

Synchronised Intermittent Mandatory Ventilation (SIMV) – A set number of breaths are supported as determined by the back-up rate. The ventilator divides a minute into set windows based on the back up rate. If no spontaneous breath suitable for triggering is generated within that window, a mandatory breath is delivered. Any additional spontaneous patient breaths are unsupported.

Synchronised Intermittent Positive Pressure Ventilation (SIPPV)/Assist Control (AC)/ Patient Triggered Ventilation (PTV) - Flow /volume/pressure triggered, pressure limited, time cycled ventilation. All spontaneous patient breaths are supported should they satisfy set trigger threshold. Back up mandatory breaths kick in if the patient's spontaneous breaths are lower than the set back up rate.

Pressure Support Ventilation (PSV) – Flow /volume triggered, pressure limited, flow cycled ventilation. Variable inspiratory time and rate. Back up breaths kick in if patient's spontaneous breaths are lower than set back up rate.

SIMV + Pressure support – Often used during weaning to a low rate. Spontaneously triggered breaths are augmented by additional airway pressure by the ventilator up to a pre-set proportion of the PIP and are flow terminated. Periods of inactivity/ apnoea is supported by a pressure limited time-cycled breath up to the set PIP and back up rate.

Volume guarantee (VG) – Best used in situations where there is rapidly changing lung compliance. Volume limited by set tidal volume but the volume guarantee is overridden if maximum pressure setting is reached. (It is volume limited for some breaths and pressure limited for some – hybrid mode). Can be used in combination with SIMV, SIPPV/AC or PSV.

Choice of Ventilation Mode:

This varies significantly from one unit to another. There are theoretical advantages of one mode over another in a specific group of patient but it is important and far more beneficial to ventilate in the mode that the unit is most familiar with.
Many units prefer SIPPV in small ELBW babies to maximise support for every breath. However, vigilance for leak and water in the circuit is required to prevent autocycling; and appropriate setting modification is required in rapidly breathing babies to avoid hyperinflation and hypocarbia.
PSV is an excellent mode in babies with good respiratory drive, relatively mild lung disease and during weaning. It is not as efficient in babies with stiff lungs, such as significant chronic lung disease. Experience and close bedside observation required to set appropriate flow.
SIMV is a popular ventilation mode, and is more suitable for a bigger baby so is used often in stable babies and during weaning. There is less risk of hyperinflation from autocycling; but greater risk of lung atelectasis and work of breathing at lower rates.
A recent Cochrane review suggest that volume guarantee ventilation reduces the incidence of death and chronic lung disease, hypocarbia, pneumothorax, days of ventilation and a combined outcome of PVL or severe intraventricular haemorrhage. Consider volume guarantee if lung compliance is changing rapidly or if there is increased risk of atelectasis due to stiff lungs and increased airway resistance. It can be used in conjunction with other modalities of synchronised ventilation.
High Frequency Oscillation Ventilation (HFOV) is widely used in the UK as a rescue mode for both preterm and term infants with respiratory failure. Elective use of HFOV is less common. Despite widespread acceptance and use in tertiary units, the evidence for its usefulness is inconsistent. A recently updated Cochrane review failed to show benefit for either elective or rescue use in respiratory failure in neonates. Correct choice of patient, pathology and operator competence may be important factors in success.

Synchronised Intermittent Mandatory Ventilation (SIMV)

- Flow triggered – pressure limited – time cycled ventilation.
- Only pre-set number of spontaneous breaths up to the set trigger threshold are supported. The ventilator divides a minute into set windows based on the back up rate. If no spontaneous breath suitable for triggering is generated within that window, a mandatory breath is delivered. Any additional spontaneous patient breaths are unsupported. For e.g. if the back up rate is set at 60 and the infant is breathing at 70, 10 breaths a minute will be unsupported).
- Set frequency will provide back up during periods of apnoea
- Can be used with Volume Guarantee
- Avoid in extremely small babies with narrow ETT

Parameters that require setting:

Flow – 5-8 litres is sufficient for most preterm infants**.** Higher flow may be required to maintain MAP in settings with very short inspiratory time, high PIP and fast rate. Very high flow can damage preterm lungs and increase airway resistance. Some ventilators have preset flows and do not need this to be set.

Trigger – For smaller babies keep trigger threshold close to the lowest setting to allow most breaths to be triggered. The most sensitive trigger threshold should be avoided as it increases the risk of auto cycling from water, leak and movement of circuit tubing. If pulmonary graphics are displayed, set the trigger threshold just below the flow generated during spontaneous patient breaths.

PEEP – Usual starting point is 4-5 cm. Higher PEEP may be useful in very stiff lungs, turgid lungs with large PDA and significant abdominal distension. Lower PEEP may be useful in air leak syndromes but be aware of atelectasis. Lung inflation on X-ray may provide a good guide to adjust PEEP. If PEEP >6 cm is necessary, ask for senior advice.

PIP - Usual starting point is 18cm. Adjust according to TV readings of 4-4.5 mls /Kg. Usual increments is by 2cm. Usual range 14-26cm. If PIP higher than 26 cm is required, ask senior advice and consider HFOV. If using with Volume Guarantee mode set PIP is the maximum PIP

I Time (T_I) – 0.3-0.4 sec – less likely to develop air trapping due to fast spontaneous rates.

Rate: Usually started @ 60/min to achieve better synchronisation. Thereafter, adjus as required to attain target minute volume. Only the set number of breaths will be supported.

Alarms – **Set alarm limits** as appropriate for your ventilator and your patient. Set so that a balance is struck between early warnings of deviation and alarm nuisance. Limits much easier to set compared to SIPPV as expected MV is easier to calculate (set rate × TV generated).

Additional pressure support mode is available in some ventilators to avoid lung atelectasis on slow back up rates. This ensures pre-set additional pressure support for every synchronised spontaneous patient effort (usually a few cm above PEEP but lower than the set PIP for mechanised breath). The amount of pressure support is then gradually reduced as patient approaches extubation.

Troubleshooting:

Similar to SIPPV, but autocycling unlikely and risk of hyperinflation is reduced.

Infant not triggering –

- sedated or unwell infant with poor central drive or overventilated infant with low PCO_2
- back up rate set too high leaving no window for spontaneous breathing – reduce back up rate and maintain minute volume by adjusting parameters that increase TV
- Infant too tired due to increased work of breathing against a small tube secondary to inadequate back up rate

Infant fighting the ventilator - Asynchrony **–** check if ETT patent, inspiratory time too long , water in circuit , inappropriate back up rate.

Weaning:

- Both pressures (affecting TV) and rate can be reduced during weaning but generally best to wean pressure first.
- Do not wean to very low rates i.e. <30/minute. Lower rates should be used for the minimum duration possible. Lower ventilator rates for prolonged period forces the infant with higher spontaneous breathing rate to struggle to breathe against a narrow ETT thereby tiring the infant and promoting atelectasis and subsequent extubation failure.
- Consider additional pressure support over and above CPAP when slower rate is being used

Wales Neonatal Network Guideline

Synchronised Intermittent Positive Pressure Ventilation (SIPPV) also known as Assist Control (AC) or Patient Triggered Ventilation (PTV)

- Flow triggered – pressure limited – time cycled ventilation
- All spontaneous breaths over and up to the set trigger threshold are supported
- Set frequency provides back up during periods of apnoea
- Can be used with Volume Guarantee

Parameters that require setting:
Flow – 5-8 litres is sufficient for most preterm infants. Higher flow may be required to maintain MAP in settings with very short inspiratory time, high PIP and fast rate. Very high flow can damage preterm lungs and increase airway resistance. Some ventilators have preset flows and do not need this to be set
Set Trigger threshold – For smaller babies keep trigger threshold close to the lowest setting to allow most breaths to be triggered. The most sensitive trigger threshold should be avoided as it increases the risk of auto cycling from water, leak and movement of circuit tubing. If pulmonary graphics are displayed, set the trigger threshold just below the flow generated during spontaneous patient breaths.
PEEP – Usual starting point 4-5 cm**.** Higher PEEP may be useful in very stiff lungs, turgid lungs with large PDA and significant abdominal distension. Lower PEEP may be useful in air leak syndromes but be aware of atelectasis. Lung inflation on X-ray may provide a good guide to adjust PEEP. When PEEP >6 cm is necessary, ask for senior advice.
PIP – Usual starting point is 18cm. Adjust according to TV readings of 4-4.5 mls /Kg. Usual increments is by 2cm. Usual range 14-26cm. If PIP higher than 26 cm is required, ask senior advice and consider HFOV. If using with Volume Guarantee mode, set PIP to the 'Maximum pressure' allowed to deliver desired tidal volume.
I time- Usually set at 0.3-0.4 sec. Higher I time may be useful for babies with CLD and stiff lungs but be aware of air trapping in infants with higher spontaneous breath rates.
Back up rate – usually set at 40-50/min to allow back up during periods of tiredness and apnoea. Do not set too high as it reduces the triggering window for the baby.

Set alarm limits as appropriate for your ventilator and your patient. They should be set in such a manner that a balance is struck between early warnings of deviation and alarm nuisance. MV will vary a lot depending on patient's respiratory effort and therefore an initial wide MV alarm limit (±30%) may be required. Set a narrower limit when infant has settled in a rhythm.

Troubleshooting:
Remember adjusting or weaning the respiratory rate is unlikely to affect gas exchange as this is a patient controlled parameter, unless the patient is apnoeic or breathing slower than the back up rate.

Infant not triggering –
- sedated or unwell infant with poor central drive or overventilated infant with low PCO_2
- back up rate set too high leaving no window for spontaneous breathing – reduce back up rate and maintain minute volume by adjusting parameters that increase TV

Very high ventilator rate
- **Low tidal volume -** Ensure optimal TV of at least 4mls/Kg
- **Autocycling – ventilator senses artefacts as trigger for initiating ventilator breaths**
  - Check for water in the circuit and check for large leaks
  - If persisting despite assessing above consider increasing trigger threshold or light sedation

Infant fighting the ventilator - Asynchrony – check if ETT patent, inspiratory time too long , water in circuit, inappropriate back up rate

Weaning:
- Normally wean by reducing PIP by 1-2 cm (and / or PEEP) and **not by the rate** unless the patient has a slower spontaneous respiratory effort than the back up rate. Check that weaning is still iindicated
- Extubate when the patient is triggering steadily at PIP of 16 cm.
- Do not wean pressure too low in babies with significant Chronic lung disease as this promotes atelectasis and may lead to extubation failure.

Pressure Support Ventilation (PSV)

- Flow triggered – pressure limited – flow cycled ventilation
- Both inspiratory and expiratory synchronisation
- Variable inspiratory time and rate controlled by patient
- All spontaneous breaths over and up to the set trigger threshold are supported
- Set frequency will provide back up during periods of apnoea and can be used in conjunction with volume guarantee mode

The ventilator monitors flow across the flow sensor on the endotracheal tube. PSV is controlled by flow and/or inspiratory time. The maximal inspiratory flow is recorded; and when the actual flow into the patient reaches 5% of maximal inspiratory flow, inspiratory support is terminated and the pressure is dropped to expiratory pressure. If the actual flow exceeds the maximal inspiratory flow, the inspiratory flow is terminated when the upper limit of inspiratory time is reached. The patient is allowed to exhale immediately after the tidal volume is delivered.
The set T_I determines only the upper limit for inspiratory time. The real inspiratory time depends on the patient's spontaneous effort, lung mechanics, and maximum inspiratory flow. The inspiratory flow becomes a crucial parameter in controlling of duration of inspiratory pressure and inspiratory pattern.

Advantages:

- customised patient controlled inspiratory time avoids inspiratory plateau and reduces over-distension
- provides greater comfort
- works best for mild lung disease and during weaning

Disadvantages:

- Adjusting appropriate flow is a crucial element that requires meticulous clinical observation and experience. Avoid if not used to the principles.
- May not work in practice for very stiff, pressure /volume dependant lungs with significant V/Q mismatch and increased airway resistance i.e. significant CLD

Set up:

- ✓ Set PIP, PEEP, Trigger threshold, back up rate and $Fi0_2$ in the usual way
- ✓ **Set Ti is the maximum inspiratory time allowed. Set T_i to 0.4 second**
- ✓ Once PSV mode is on – observe patient for work of breathing and comfort
- ✓ Adjust inspiratory flow to minimise work of breathing
- ✓ Check spontaneous inspiratory times generated (Ti spo). Ti spo should be between 0.20 and 0.35 s.
- ✓ Re-evaluate work of breathing and set inspiratory flow if Ti spo outside this range
- ✓ When used in conjunction with VG – Set desired TV. Set PIP as the maximum allowed pressure

PSV+VG allow the infant to control almost all aspect of ventilation and allows auto-weaning
However, adjustments during PSV in practice require experience in clinical observation and a good understanding of changing lung mechanics in disease. Consult senior colleagues early.

Volume Guarantee Ventilation (VG)

- Flow triggered, volume guided (although actually pressure limited), flow or time cycled depending on modalities in use.
- Can be used with any modality – SIPPV, PSV, SIMV.

How does it work?

Prescribe a set tidal volume (TV) for the patient rather than a set PIP to be achieved for each breath. The ventilator aims to deliver this prescribed TV with the lowest possible pressure. This can be achieved on a breath-to-breath basis, by analysing how much volume was delivered with the previous breath and adjusting the PIP up or down to increase or decrease the TV accordingly for the next breath. Some ventilators do not achieve breath to breath manipulation but take an average value over a few breaths.

Advantages:

- Provides uniform lung volumes during varying lung compliance scenarios , eg RDS following surfactant adminstration
- If properly set - avoids barotrauma, volutrauma and atlectotrauma

Limitations:

- Does not work with big leaks If leak of >40% - as TV measurements are unreliable. Use with caution in leaks 25-40%.
- Awareness of the minimum volume that the ventilator can deliver reliably may be useful in extremely small babies.
- Be vigilant in small babies for hyperinflation as initial TV volume prescription is still a guesstimate and may need to be tailored to individual baby.

Set up:

- Set Flow, Trigger threshold, PEEP, Ti, $Fi0_2$ as appropriate (see SIPPV/SIMV/PSV guideline)
- Select an initial PIP that gives the desired TV on the conventional pressure limited mode (see below)
- Select VG , then set TV at 4-6 mls/kg. Aim to start with 4.5 mls/Kg in RDS and higher volumes of 5-6 mls /Kg in established CLD.
- In VG **'Set PIP' in essence is the maximum PIP allowed to deliver the desired TV.** This is essentially an alarm limit. Once VG is activated reset the PIP 20% higher (usually 4-6 mbar) than currently required to deliver the desired TV. If the PIP is set too low (too close) to the PIP setting delivering VG; the desired TV for every breath may not be reached and the ventilator will alarm frequently. In contrast if the PIP is set too high, the TV will be delivered, however, any imperceptible rise in delivered PIP(due to deteriorating clinical condition) will be unrecognised. Be prepared to allow higher pressures to achieve TV if the clinical assessment matches information provided by the ventilator.
- Set rate/Back up rate as appropriate to provide an estimated MV of 200-300 mls/Kg.
- Set MV alarm limit to ±30% of this value to prevent frequent alarms (common cause of inappropriate discontinuation of VG).

Monitoring:

- Monitor as normal.
- Chart the 'set PIP' AND 'measured PIP'.

Adjustments and Weaning:

- The PIP limit needs to be adjusted from time to time in response to changes in lung mechanics. Maintain the PIP limit sufficiently close to actual PIP, yet avoiding frequent alarms.
- If TV needs to be increased, the PIP may well need to be increased to deliver the increases set TV.
- If persistent high O_2 requirement- if set TV thought to be adequate, increase PEEP.
- If the infant is persistently tachypnoiec (RR>80) and has a
  - normal pH and pCO_2 – consider increasing the volume target TV as this suggests increased work of breathing.
  - low pCO_2 - consider sedation
- Wean by decreasing the TV. If over-ventilated, reduce the prescribed TV, usually by 0.5mls/Kg decrements. Avoid going below 4mls/Kg.
- There is **no point** reducing the rate if the baby is breathing above the ventilator on PSV or SIPPV as each spontaneous breath is assisted. On SIMV, reducing the rate will reduce the number of assisted breaths but this may increase the work of breathing as it will increase the time spent receiving ET CPAP.
- There is **no point** reducing the pressures without reducing the set TV – this will make the ventilator alarm because it is less likely to be able to deliver the volume prescribed with lower pressures.
- Extubate when VT maintained at set levels
  - PIP 14-18
  - FiO_2 <0.35
  - Good spontaneous respiratory effort

Troubleshooting:
Frequent low TV alarms

- Check for leak – is it too high?
- Is the ETT blocked
- Check the set TV – is it still what it was supposed to be?
- Check the maximum set PIP – is it still the same as set?
- Confirm adequate Ti and flow rate – may need to increase either or both
- Check the alarm delay limit and adjust if too short

If all ok – increase the PIP limit and investigate the cause of changes in lung mechanics e.g. atelectasis, pneumothorax or pulmonary oedema.
If pressure limit needs substantial or repeated increases verify that TV measurements are accurate (assess chest rise, obtain a blood gas and if required a CXR)

Frequent MV alarms:

Set limits to ±30% of desired TV. Do not use the automatic alarm limit reset when the minute volume is too low or too high (e.g. just before or after suction or during a splinting episode), as it will alarm again when the problem has been resolved.

Wales Neonatal Network Guideline

High Frequency Oscillation Ventilation (HFOV)

HFOV is a type of mechanical ventilation that uses a constant distending pressure (MAP) to keep the lungs open throughout the respoiratory cycle. Small pressure swings or 'oscillations' are generated around the MAP (Delta P) to produce small tidal volumes. These oscillations are applied at very high rates (up to 900 cycles per minute).
HFOV aids recruitment of alveoli and enhances uniform gas distribution thereby V/Q mismatch. It improves molecular gas diffusion in the proximal airways and creates a continuous two-way traffic for inward and outward gas flow.
HFOV is regarded as a less aggressive ventilator mode due to the minimal pressure/volume swings. Theoretically, it reduces atlectotrauma, barotrauma and volutrauma.

Indications:

- 'Rescue' in infants with refractory respiratory failure on conventional ventilation
- Lung protection in 'air leak syndromes' (PIE changes, Pneumothorax)
- Conditions where assured uniform lung inflation may be beneficial (PPHN, severe RDS). It works best in homogenous lung disease.

This modality of ventilation is very powerful and requires judgment and expertise to use properly. Always seek senior guidance when starting HFOV.

Strategies:

- High volume strategy (optimal lung inflation) – 1st Choice and most commonly used for homogenous lung disease
- Low volume strategy, reserved for air leak syndromes and possibly in pulmonary hypoplasia to minimise further lung injury.

Controls and adjustments:

Mean Airway Pressure (MAP or Paw) – This primarily determines lung inflation and oxygenation. Higher MAP improves oxygenation provided it has not caused hyperinflation. Usual magnitude of change 1-2 cm / step.
Delta P or Amplitude or Power– This is a measure of pressure swing around the MAP and creates the small TV. This primarily determines CO_2 elimination. Higher the amplitude the greater the CO_2 elimination. It is most effective when there is optimum lung inflation or MAP.
Be aware the set delta P is often attenuated by small ET tube, compliant circuit etc. Therefore the correct delata P setting on the ventilator is the one that provides adequate chest oscillation. Start at twice the set MAP as guide and then adjust according to chest oscillation and pCO_2. Usually the delta P will vary between twice and three times that of the MAP. Usual magnitude of change is 4-6 / step.
Frequency – This determines the frequency of the pressure swings and usually varies from 7-15 Hz (1 Hz = 60 cycles/min).
This is a very powerful tool for CO_2 elimination and should only be altered after careful consideration and discussion with seniors. Usual magnitude of change 1 Hz / step.
The lower the frequency the greater the CO_2 elimination. A high frequency reduces the TV which has a greater cumulative effect on the final MV or DCO_2. (DCO_2 = Frequency × $TV^{2)}$
Remember this is the opposite of Conventional Ventilation.
Inspiratory time - often expressed as a percentage of time there is forward oscillation or as an I/E ratio. Usual setting is 33% (1:2) with a maximum of 50% (1:1). The latter has a greater risk of gas trapping. In some ventilators this is preset and cannot be altered.
Bias flow: This is the rate of replacement fresh gas flow used while maintaining MAP. Usually set at 12 L/min. This is preset in some ventilators.

Preparation before starting HFOV:

- Ensure appropriate ETT size and position
- Suction airways. Insert a close suction mechanism
- Apply and calibrate Transcutaneous oxygen and CO_2 monitoring
- Ensure appropriate sedation (paralysis not always required)
- Review existing lung inflation, if available on a recent chest X-ray
- Baseline record of heart rate, invasive blood pressure, blood gases including lactate and urine output

Initial Set Up (High volume strategy):

- Bias flow – 12 litres/min on Sensormedics, not set in other ventilators
- I time - 33% sensor medics, other ventilators where option available set I/E ratio as 1:2 or 1:1
- Fi02 as required to maintain saturations – usually high by this time e.g. 0.7-1.0
- Frequency – 12- 15 Hz for babies less than 1 Kg, 10Hz for others including near term and term babies
- MAP/ PaW – Start 2 cm above that on conventional ventilation
- Delta P / Amplitude – Initially set as twice the MAP and adjust up and down according to chest wobble. The chest wobble should be assessed by bending down at the level of patient's chest. The wobble should extend up to the umbilicus but not beyond. Adjust the provisionally set delta P to achieve this.

Adjustments and further monitoring:

- Increase MAP by 1 cm every 5 minutes until the patients responds - a rise in oxygen saturations and a fall in FiO_2
- Observe trends on $TcC0_2$ and fine tune Delta P.
- Blood gas at 20-30 minutes. Continue to monitor $TcCO_2$ (if reliable) or pCO_2 on gases frequently and adjust Delta P accordingly until the nadir pCO_2 is seen. This is very important to avoid hypocarbia.
- Obtain a CXR within 30-60 minutes to assess lung inflation – optimum is 8-9th posterior ribs. Adjust MAP to ensure optimum inflation if not already achieved.
- Adjust delta P by 2-4 units to obtain desired CO_2. Increasing delta P = Increases CO_2 elimination.
- Do not wean MAP until FiO_2 0.3-0.4 L/min in homogenous lung disease such as RDS. This may not be achievable in CLD and Oxygen levels below 0.6 L/min may be acceptable.
- Once the above goals are achieved wean the MAP to the minimum tolerated i.e. where the saturations start dropping again. Reset MAP 1cm higher than this.**This step is very important, to avoid hyperinflation**. An open lung can be maintained with lower pressures than that required to open the lung in the first instance.
- Avoid routine suctioning. However, if necessary re-recruit lungs by resetting MAP 1-2 cm above current setting for 10 minutes and then reduce back to baseline.
- Always monitor for signs of cardiovascular compromise related to hyperinflation
  - Drop in systemic blood pressure and rise in HR, reduced urine output and rising lactate
  - Rise in FiO_2 and pCO_2 after an initial improvement
  - If in doubt see clinical response by dropping MAP by 2 cm or confirm on CXR

Chest X-ray appearance in hyperinflation **-** lung inflation >9th posterior ribs, narrow cardiac silhouette, flat diaphragm, bulging intercostal spaces.

Troubleshooting:

Acute rise in $TcCO_2$/pCO_2

- Loss of wobble - commonest (blocked or kinked tube)
- Rule out pneumothorax (Cold light / Chest X-ray)
- Ensure optimum lung inflation – Does the MAP require adjustment –If in doubt get a chest X-ray
- If the above optimum – Reduce frequency after discussing with consultant

Gradual rise in FiO_2 and pCO_2

- Hyperinflation – reduce MAP
- De-recruitment following suction – manage as described above
- Worsening of lung disease – escalate settings
- Associated unresolved PPHN
- Alternative diagnosis (e.g. cardiac)

Recognised complications and prevention:

- Hypocarbia – $TcCO_2$ monitoring and fine tuning of delta P
- Hyperinflation – Early CXR and reduction of MAP to the minimum tolerated after the initial response. Awareness of features of hyperinflation
- End organ manifestation of poor cardiac output
  - Hypotension
  - Poor urine output / renal failure
  - Rising lactate]
  - Rarely intraventricular haemorrhage

These complications are rare provided cardiovascular compromise is avoided.

Low volume strategy: Used in air leak syndrome and pulmonary hypoplasia as a lung protective strategy.

- Start with MAP equal to that on conventional ventilation
- Consider starting on higher frequency 12-15 Hz
- Accept higher pCO_2 and perhaps lower oxygen saturations
- Rib count of 9th rib for lung inflation unrealistic and unreliable in pulmonary hypoplasia – aim for lower values.

References:

Assisted Ventilation of the Neonate – 5th Edition, 2010 – Ed. Jay P Goldsmith, Edward Karotkin, Saunders Elsevier
Manual of Neonatal Respiratory Care –3rd Edition, 2012 Ed. Donn SM, Sinha SK, Springer, New York
Greenough A, Milner AD. Synchronized mechanical ventilation for respiratory support in newborn infants. *Cochrane Database of Systematic Reviews* 2008, Issue 1. Art. No: CD000456. DOI: 10.1002/14651858.CD000456.pub3.
Baumer JH. International randomised controlled trial of patient triggered ventilation in neonatal respiratory distress syndrome. Archives of Disease in Childhood 2000; 82: F5–F10.
Wheeler K, Davis PG. Volume-targeted versus pressure-limited ventilation in the neonate. Cochrane Database of Systematic Reviews 2010, Issue 11. Art. No.: CD003666. DOI: 10.1002/14651858.CD003666.pub3
De Paoli AG, Henderson-Smart DJ. High frequency oscillatory ventilation versus conventional ventilation for infants with severe pulmonary dysfunction born at or near term. Cochrane Database of Systematic Reviews 2009, Issue 3. Art. No.: CD002974. DOI: 10.1002/14651858.CD002974.pub2