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Volume targeted ventilation- A Framework of Practice

Principles of ventilation

- Every effort should be undertaken to support spontaneously breathing stable preterm infants on non-invasive modes of ventilation like CPAP or HFNC to minimise lung injury.
- Criterion for intubation in delivery room can be a quality improvement initiative to minimise mechanical ventilation.
- **When invasively ventilated, volume targeted ventilation (VTV) should be the preferred mode in the early respiratory support** phase unless there are strong contraindications.

Why there is an emphasis on lung protection

- The UK has reported an increasing trend in the incidence of Bronchopulmonary dysplasia (BPD) as reported by NNAP and recent articles (1, 2) over the last decade.
- NNAP also reports network level variation in incidence of BPD and the NWNODN has incidence above the national average.
- Early respiratory strategies like non-invasive ventilation, LISA and volume targeted ventilation have been significantly associated with reduction in BPD.

The basic principles of lung protection

The basic goal of lung-protective ventilation is to establish an acceptable level of gas exchange while minimising Ventilation Induced Lung Injury (VILI) as much as possible.

The cornerstones of a lung-protective ventilation strategy are:

1. Minimising End-inspiratory (alveolar) over distention (volutrauma).
2. Optimising End expiratory lung volume (EELV) by reversing atelectasis (recruitment) and stabilising lung units throughout the ventilatory cycle (avoiding atelectrauma). This is achieved through optimal PEEP.
3. Maintaining compliance to accepted saturation targets - current evidence suggests this should be between 91%-95% according to the NeoPROM meta-analysis (3) (less oxygen toxicity).

A lung-protective ventilation strategy based on these principles is often referred to as an optimal lung volume strategy or open lung ventilation strategy. Although a lung-protective ventilation strategy can attenuate lung injury, it can never totally prevent it. For this reason, infants should be weaned from invasive support as soon as possible and transferred back to non- invasive modes of respiratory support.

The evidence base:

- **VTV as opposed to Pressure controlled ventilation modes reduces death or BPD by 27%, NNT 8 and Intraventricular haemorrhage (grades 3–4) by 47%, NNT 11**

  ***(1 out of every 8 preterm infants treated with VTV will not have an outcome of death or BPD and 1 out of every 11 babies treated with VTV will not have severe IVH)* (4)**

- **VTV reduces rates of pneumothorax, mean days of ventilation, hypocarbia and combined outcome of PVL with/without IVH (4)**

Professional recommendations on VTV

NICE Guideline [NG124]-Specialist neonatal respiratory care for babies born preterm (4):

For preterm babies who need invasive ventilation, use VTV in combination with synchronised ventilation as the primary mode of respiratory support.

European Consensus Guidelines on the Management of Respiratory Distress Syndrome: 2022 Update (5)

Lung-protective modes such as VTV or HFOV should be the first choice for babies with RDS who require MV.

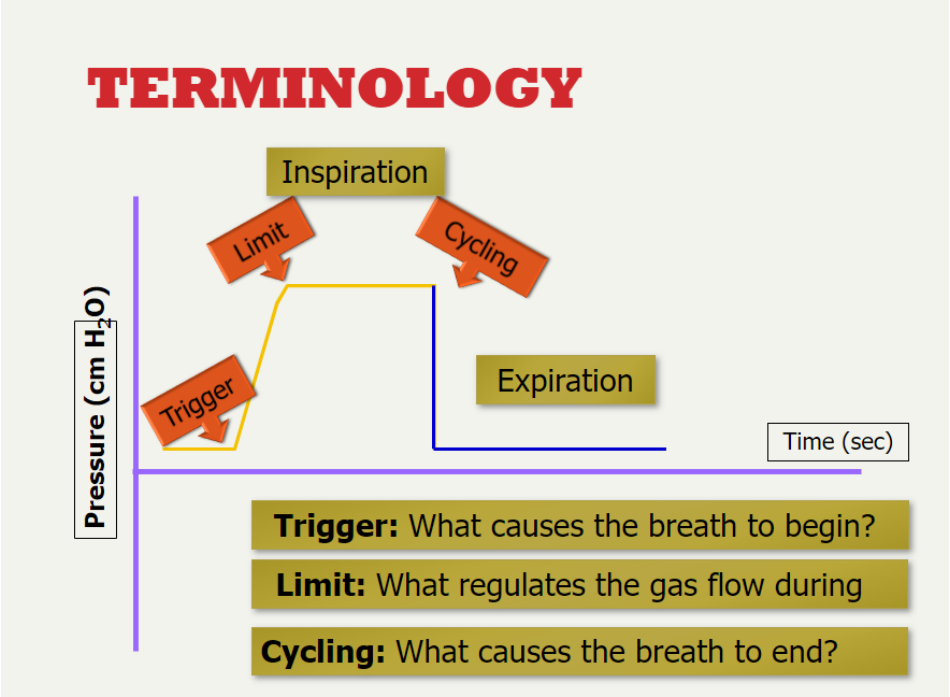
BAPM Quality Improvement Toolkit – Reducing the incidence of Bronchopulmonary Dysplasia (BPD) (6)

Volume targeted ventilation (VTV) should be the preferred mode of invasive ventilation when using conventional MV in the neonatal unit as a lung protective strategy. A volume range of 4-6ml/kg is the optimal operational range for the first 2 weeks. Every effort should be made to maintain babies on this lung protective mode where possible- High quality evidence, strongly recommended.

Key messages:

1. **Early "lung protective" strategies are required to minimise incidence of BPD and they can be achieved through LISA, early NIV, Volume targeted ventilation and optimal PEEP.**
2. **Volume targeting should be the preferred mode of invasive ventilation (when conventional ventilation is used) and has significant positive impact on BPD, IVH etc.**
3. **VTV is recommended by national and international professional expert task groups.**

Basic understanding of the terminologies describing ventilation modes



Assist Control (AC) vs SIMV:

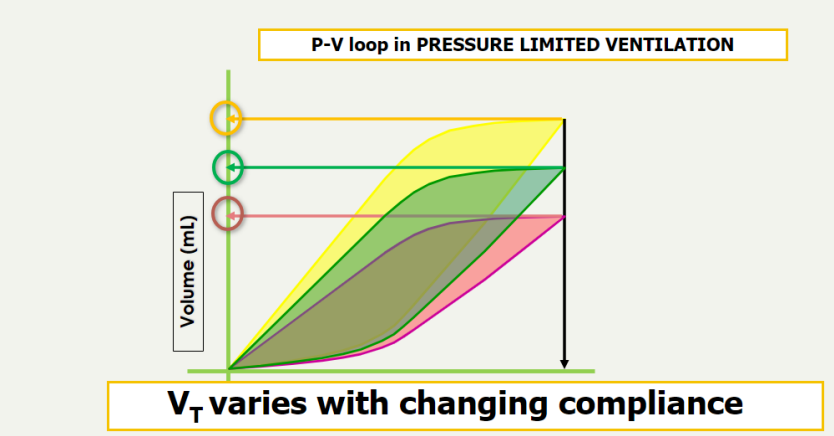
AC: Patient triggered, Time Cycled Pressure Limited (TCPL) with secondary controls such as volume:

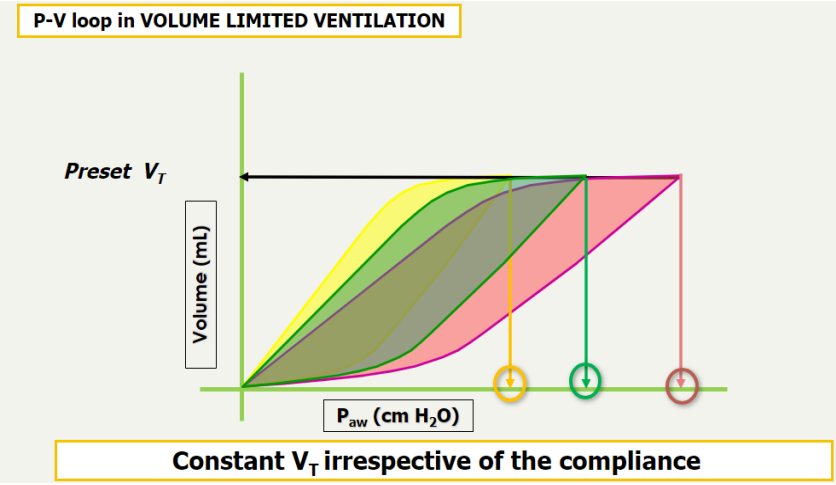
- All breaths taken by the baby will be supported.
- If the infant is apnoeic, the ventilator delivers the mandatory back up breaths as per the set 'back-up' rate.
- Level of support defined by the user.

SIMV: Not patient triggered, Time Cycled Pressure Limited (TCPL) with secondary controls such as volume:

- Only the 'mandated' number of breaths will be supported (according to the 'back up' rate)
- If the infant is apnoeic, the ventilator delivers the mandatory breaths as per the set 'back-up' rate.
- Any spontaneous breaths taken by the infant more than this rate will be unassisted.
- Level of support defined by the user.

Volume targeted ventilation: Physiology





In conventional pressure-controlled ventilation (Fig 1) delivery of volume varies with changing compliance of lung (risk of overdistention or atelectasis)
However, in VTV (Fig 2), the volume delivery is constant with auto-titration of delivered Pressure according to compliance.

Points to note:

1. **Volume guarantee (VG) is a hybrid mode and different to Volume control .**
2. **When we refer to VTV in this framework we will consider Volume targeted pressure. limited time cycled mode and NOT volume control mode.**
3. **VTV or VG Has to be combined with SIMV or A/C or PSV.**
4. **The physician sets the tidal volume.**
5. **No PIP is set, only Pmax is set to limit the peak pressure.**
6. **Other parameters are the same as pressure-controlled ventilation.**

Initiating Ventilation

Is the ETT leak < 65%

NO → **Start PC-AC without VG**

YES

Start PC-AC VG
Is there pulmonary hypoplasia?

See appendix no 2 for "Alternative strategies for different pathologies/scenarios"

NO

Settings (See appendix 1 for recommended settings for different scenarios)

PEEP 5cmH_2O
VT* 5ml/kg (default setting if weight entered into ventilator)
Pmax 25 cmH_2O
RR (back up) 40-50 breaths / minute
Ti (preset)- 0.3- 0.4 depending on gestational age/weight

YES

Settings (low volume low PEEP high-rate strategy) (consider early HFO)

PEEP 4cmH_2O
VT* 4ml/kg
Pmax 22 cmH_2O
RR (back up) 60 breaths / minute
Ti (preset)

***TV needs to be entered in mls (not mls/kg) i.e. you will have to calculate the number required**

What is the Minute Volume (MVe)?

Below 0.24 L/kg/min
1. If on "back-up"** increase rate.
2. Increase VT by 0.5ml/kg (max 6ml/kg) until MVe is 0.24-0.36 L/kg/min.

0.24 – 0.36 L/kg/min
Leave ventilator as set

Above 0.36 L/kg/min
1. If on "back-up"** - decrease rate.
2. Decrease VT by 0.5ml/kg (min 4ml/kg) until MVe is 0.24-0.36 L/kg/min.

Check a blood gas in 30 mins

** "Back up" means that most (i.e. >50%) of breaths are NOT triggered, i.e. baby is not breathing consistently above set rate

Escalating support on VTV

PCO2 > accepted upper limit, increase in FiO2
There is no consensus for accepted upper limit for Pco2, values >8.5kPa are considered to be associated with adverse neurodevelopment (6)

For every scenario go through clinical assessment + DOPE sequence:
D Displacement of ET tube
O Obstruction of ET tube
P Pneumothorax
E Equipment failure

CONSIDER CXR in all cases.

Baby tachypnoeic, with retractions+- indicative of suboptimal minute ventilation*

Baby has poor respiratory effort.

Increase Tidal volume (Vt) in steps of 0.5ml/kg until maximum of 6ml/kg

Consider central cause.
Increase back up rate.
Wean sedation/paralysis where relevant.
Reduce trigger sensitivity.

NB: Consider whether target volume is not being delivered due to pressure requirements exceeding set Pmax limit- consider exceeding Pmax limit, BUT caution advised in preterm <28week GA**

Persistent hypercarbia- Discuss with consultant/tertiary referral centre/transport team, about HFOV.

*** Minute ventilation (MVe) is the defining principle of neonatal respiratory support**
MVe= Volume delivered (Vt)x Respiratory rate (RR)
If baby gets low volumes than required, they will try and compensate with increased RR resulting in clinical assessment of increased Work of breathing.

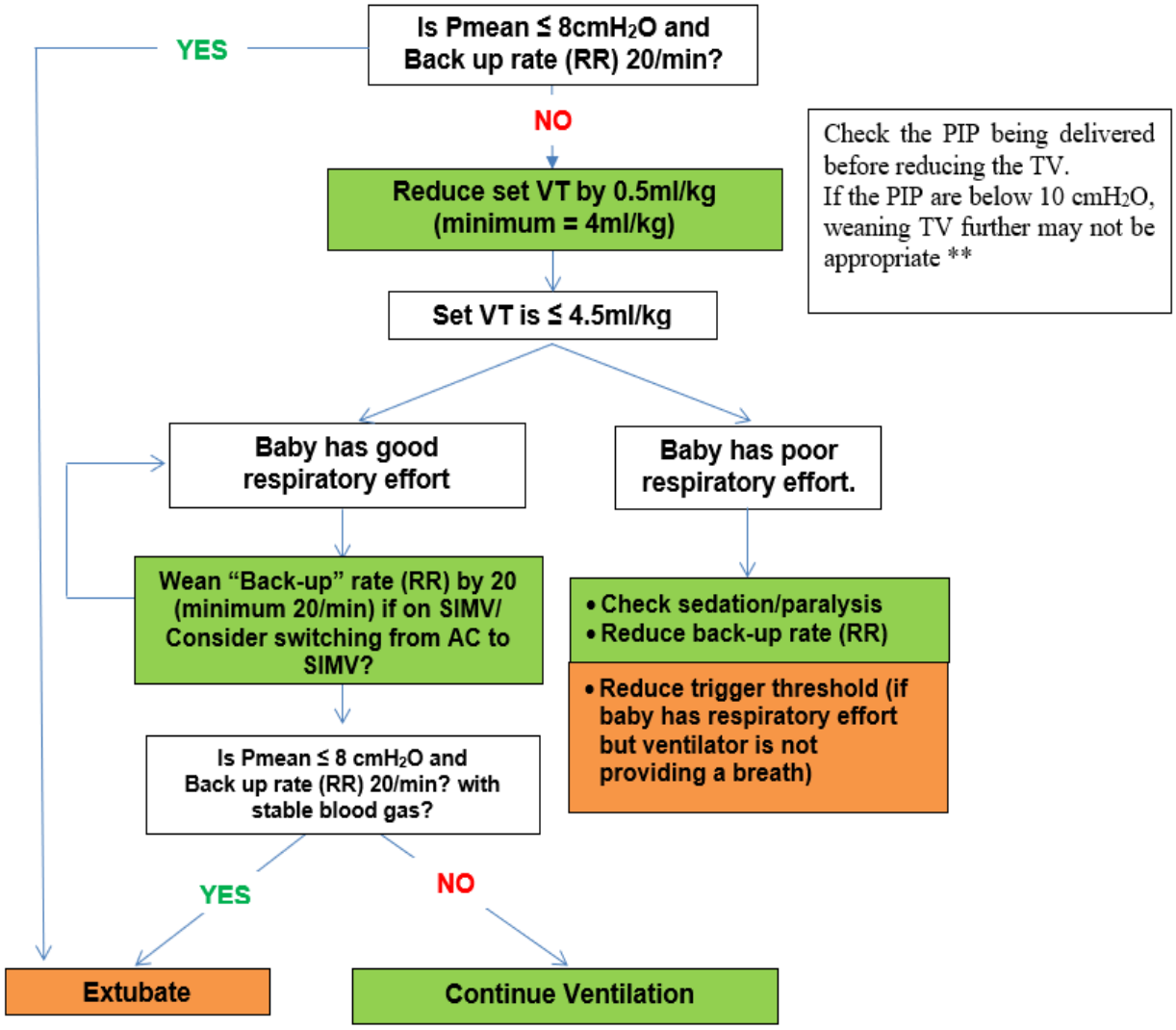
****For allowing ventilator to deliver Vt, Pmax should ideally be 4-5 cm > required PIP (this can be assessed from ventilator screen)**
In extreme preterm babies, it is not desirable to allow high PIPs and HFOV might be a more protective option if PIP required exceeds 26-28cm H20.

Open lung concept

Always try and achieve recruitment through use of optimal PEEP.
PEEP can be increased in steps and titrated with reduction of FiO2 requirement to assess optimal level.
Optimal PEEP is when Vt is achieved with lowest PIP

Weaning Ventilation on VTV mode

- **Tidal Volume DOES NOT ROUTINELY need weaning as pressures required auto wean with improvement of lung compliance***
- **Wean set volume if PCO2 <4.5Kpa And /OR PH >7.35**



*If physiological volumes (5ml/kg) are being delivered and pressure requirement (PIP generated) is between 12-16cm H2O and Pmean is between 6-8 cmH2O, baby can be safely extubated (7)

**As lung disease improves, the PIP required to meet the set VT decreases. If this is close to the value of the PEEP, then the baby is receiving CPAP through the ET tube. This is uncomfortable & potentially harmful. In this case, do not wean the VT further. Consider extubation, or, if not possible, increase the VT to generate a PIP 3-4cmH_2O higher than the PEEP

Appendix 1: Initial Ventilator settings of common Neonatal respiratory conditions (8)							
Condition	**PEEP (cm H2O)**	**Tidal Volume (VT) (mL/kg) (PC-AC with VG)**		**PIP (cm H2O) [PC AC – without VG]**	**Ti (sec)**	**Back up Rate /min**	**FiO_2**	**Comments**
Preterm RDS	**6-8**	**<0.7 kg** **0.7-1.25 kg** **>1.25 kg**	**6** **5** **4.5**	**20-25 (may need higher)**	**0.3-0.4 PIE: can use 0.25**	**40**	**30%**	**Recruitment with higher PEEP till FiO2<30 % or CXR 8-9 ribs (open lung strategy); Decrease PEEP once lung recruited. Do not reduce PEEP <5. Can repeat surfactant dose at 8-12 hrs if needing MAP>10, FiO2>30%.**
RDS pre-extubation	**<6**	**4-5**		**<16**	**0.35-0.4**	**10-20**	**<40%**	**Optimise Caffeine dose. Extubation to CPAP preferred <28 weeks.**
Apnoea of prematurity (with 'normal' lungs)	**5**	**4-5**		**12-16**	**0.35-0.4**	**<20**	**21%**	**Should need minimal respiratory support as lungs have normal compliance (no SDLD)**
Air leak (PIE, Pneumothorax)	**4-6**	**4-5**		**12-20**	**0.3-0.35**	**50-60**	**As needed**	**Accept ↑FiO2 & ↑PCO2; avoid large VT, maintain lung volume with moderate PEEP.**
Preterm evolving BPD, > 2 weeks old	**5-6**	**5.5-8**		**25-30**	**0.4-0.5**	**40**	**As needed**	**Ventilation for >2 weeks have tracheal dilatation and need ↑ VT to clear CO2**
Preterm, with established severe BPD	**6-8**	**7-12 (↑↑alveolar + anatomical dead space needs ↑↑Vt)**		**Often >30**	**0.5-0.8**	**<20**	**As needed**	**Predominantly *atelectatic lung*: use Ti 0.5-0.8, low rate, VT ~ 5-7 ml/kg. PEEP up to 10 may be needed to recruit. Predominantly *cystic lung*: use PEEP of 5-8, with Ti ~ 0.5, with VT 10-12 ml/kg, and low rate.**
Term MAS with classic CXR	**4-6**	**5.5-6 (↑alveolar dead space)**		**Minimum PIP to move the chest (~ 25)**	**0.35-0.50**	**<30**	**As needed**	**Potential for over distension – so use lower rates to avoid air trapping. ↑ alveolar dead space = ↑ VT is needed. When surfactant dysfunction predominates, treat like RDS. iNO may be needed.**
Term MAS with 'white out' CXR	**5-7**	**4.5-5**			**0.35-0.50**	**<30**	**As needed**	
PPHN (without parenchymal disease)	**5-6**	**5-6**		**15-25**	**0.4-0.5**		**30-80%**	**Target pre-ductal saturation 94-98%, PaO2>8**

Appendix 2: Alternative strategies

FiO2:

- FiO2 as required to achieve set target saturation levels. Suggested oxygen saturations are given below:

	Saturation targets	Alarm Limits
Preterm baby on oxygen (<36w), Chronic lung disease	**91-95%**	**90%, 96%**
Preterm baby on air (<36w)	**91-100%**	**90%, 100%**
Term baby in air (>36w)	**94-100%**	**93%, 100%**
Term baby in oxygen (>36w), PPHN	**94-98%**	**93%, 99%**

Appendix 3: Extubation Checklist:

1. Baby has spontaneous respiratory effort, ideally needing PIP below 16cm of H2O
2. On back up rate of 10-15/min or less, baby has consistent acceptable spontaneous RR (between 40-60/min)
3. Factors like sepsis under control and hemodynamically stable
4. Baby off Morphine (ideally off for >12 hours); 'spontaneous breathing test' might be considered if practised in unit.
5. Baby received loading dose of caffeine (<32 wks gestation) and maintenance dose is prescribed
7. Mean airway pressure is <8 cm of H2O
8. FiO2 is ideally less than 40%
9. Haemoglobin is optimised (>120 g/dL)
10. PCO2 ideally < 8 -9 KPa
11. Adequate medical and nursing staffing level in ITU with the co-ordinator and senior neonatal physician aware of extubation so that help is readily available if required.
13. Stomach is aspirated prior to extubation.
14. Appropriate respiratory support equipment (post extubation) is set up and ready to use if required (In babies <28 weeks gestation, extubation to CPAP is preferable as opposed to HFNC). Consider putting non-invasive interface on (CPAP mask/HFNC cannula) before extubating to minimize time without any PEEP and avoid de-recruitment.
15. Oral and ET suction is done prior to extubation to ensure secretions do not block airways and need for post extubation suction is minimised
16. Consider need for IV access prior to extubation
17. Ensure nurse caring for the baby is present and happy with the decision to extubate.

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