Mechanical Ventilation in the Newborn

University Hospitals of Leicester NHS Trust

Trust ref: C34/2013

1. Introduction and who this guideline applies to

This guideline is aimed at all Health care professionals involved in the care of infants within the Neonatal Service.

Key Points

- Targeted tidal volume ventilation is a useful modality to control and stabilise the delivered tidal volume, potentially reducing the risk of volutrauma.
- This is the standard mode for initiating ventilation as per NICE guidance. Other modes may be used in particular scenarios under consultant guidance. (Appendix 1)
- It is particularly useful for ventilated newborns less than 34 weeks who have respiratory distress syndrome but its use is not exclusive to this group.
- Volumes of 3.5-6ml/kg are used with a starting volume of 4.5ml/kg
- A large leak (>20%) renders this mode ineffective.
- As compliance improves the delivered peak inspiratory pressure will decrease guiding the clinician to a window for extubation.

Background

Damage caused by over-distension of the lungs (volutrauma) has been implicated in the development of bronchopulmonary dysplasia (BPD). It is possible to target a set tidal volume as an alternative to traditional pressure-limited ventilation such as SIMV. This aims to produce a more stable tidal volume. It is recommended as the default mode of mechanical ventilation by NICE for managing preterm babies with respiratory distress syndrome. A recent Cochrane review demonstrated a reduction in the combined outcome of death and chronic lung disease when volume-targeted ventilation was compared to pressure limiting modes. There was also a reduction in hypocarbia and cranial ultrasound abnormalities (grade A). There is however no evidence on the impact of neurodevelopmental disability at follow-up. The optimal tidal volume to target is between 3.5ml/kg and 6ml/kg with evidence of lung injury evident at extremely low and high tidal volumes (grade C).

Aim

This document produces guidance on commencing targeted tidal volume (TTV) ventilation in preterm infants with RDS as well as an algorithm for weaning. It also provides some important troubleshooting information and practical bedside advice for using this ventilation mode.

2. Algorithm for use with the SLE 5000 (grade C)

TTV ventilation has particular advantages for the infant with rapidly changing compliance such as the preterm infant (<34 weeks) who has just received surfactant for respiratory distress syndrome. This mode of ventilation is an option for this group of infants at consultant discretion.

Initiation

- TTV should be implemented as soon as possible after initiation of mechanical ventilation (see the associated powerpoint learning package for a pictorial description of how to do this).
- Set the leak compensation to 20% - if the leak is > than 20% then TTV will not be reliable and so SIMV alone should be used instead. Reintubation with a larger endotracheal tube (ETT) for the sole purpose of using TTV is **NOT** recommended.
- Set the initial TTV at 4.5ml/kg (smaller babies >750g may need a larger volume up to 6ml/kg due to increased dead space in the tubing if the CO_2 is high or oxygenation poor).
- Set PEEP, Ti and RR as usual (suggest PEEP 4-5cm water, Ti 0.35 – 0.4s, rate 50 breaths per minute)
- Set the Pmax at 20cm of water in the first instance. This is the maximum pressure that the ventilator will deliver to give the selected tidal volume. It is important to watch the baby for chest excursion as well as the ventilator flow loops at this time.
- If the TTV is not reached then ensure that the ETT is in the correct position, there is no pneumothorax and the leak is not >20%. Pmax can then be increased.
- It is essential to chart both Pmax (set PiP) and Pinsp (the PiP the baby is actually receiving) to ensure that the amount of respiratory support the baby is receiving is clear. This should be charted on the ITU nursing observation chart.

Subsequent adjustments

- If the CO_2 is high then the minute volume can be increased.
- Increasing the tidal volume or the rate will increase the infant's minute volume.
- We suggest you alternate increasing firstly the tidal volume by 0.5ml/kg with increasing the rate. If the baby still has a high CO_2 on 6ml/kg of tidal volume then they will need a different mode of ventilation.
- Likewise if the baby is over-ventilated support can be reduced. It is important to note that if the tidal volume is insufficient the baby may become tachypnoeic.
- In some babies there can be relatively low pressures delivered but poor oxygenation. In these babies recruitment of the lung may not be achieved appropriately on TTV and there should be consideration of changing to a pressure limited mode. This is more commonly seen if the baby is very active.

Weaning and readiness for extubation

- When the target tidal volume is set at the low end of the normal range (4ml/kg) and $PaCO_2$ is allowed to rise provided the pH is >7.25. Pinsp occurs automatically ("self weaning") according to changing lung compliance.
- If an infant appears not to be weaning as expected despite apparently improving lung disease then try to reduce the tidal volume to 3.5ml/kg as long as the blood gases are adequate and work of breathing does not appear excessive.
- Most infants can be extubated when they consistently maintain a tidal volume at or above the target value with delivered PIP <10-12cm water (<12-15cm water in babies >1Kg).
- Remember that TTV only is active for the set breaths in SIMV mode rates <25 may lead to atelectasis.

Troubleshooting

The main alarm that frequently sounds is tidal volume too low:

- Baby has worsening lung disease leading to reduced compliance – increase Pmax, consider need for further surfactant or chest X-ray
- Mechanical issue (think DOPE)– ***D***islodged or displaced tube, ***O***bstructed airway, ***P***neumothorax or ***E***quipment problem (e.g. flow sensor)
- Check the settings. Is the Pmax too low, is Ti too short
- Check for leak. The SLE 5000 can compensate for up to 20% leak
- Is the baby extremely active and has an erratic breathing pattern

Charts

The ventilator settings should be recorded on both the nursing ITU observation chart and blood gas charts. To include:

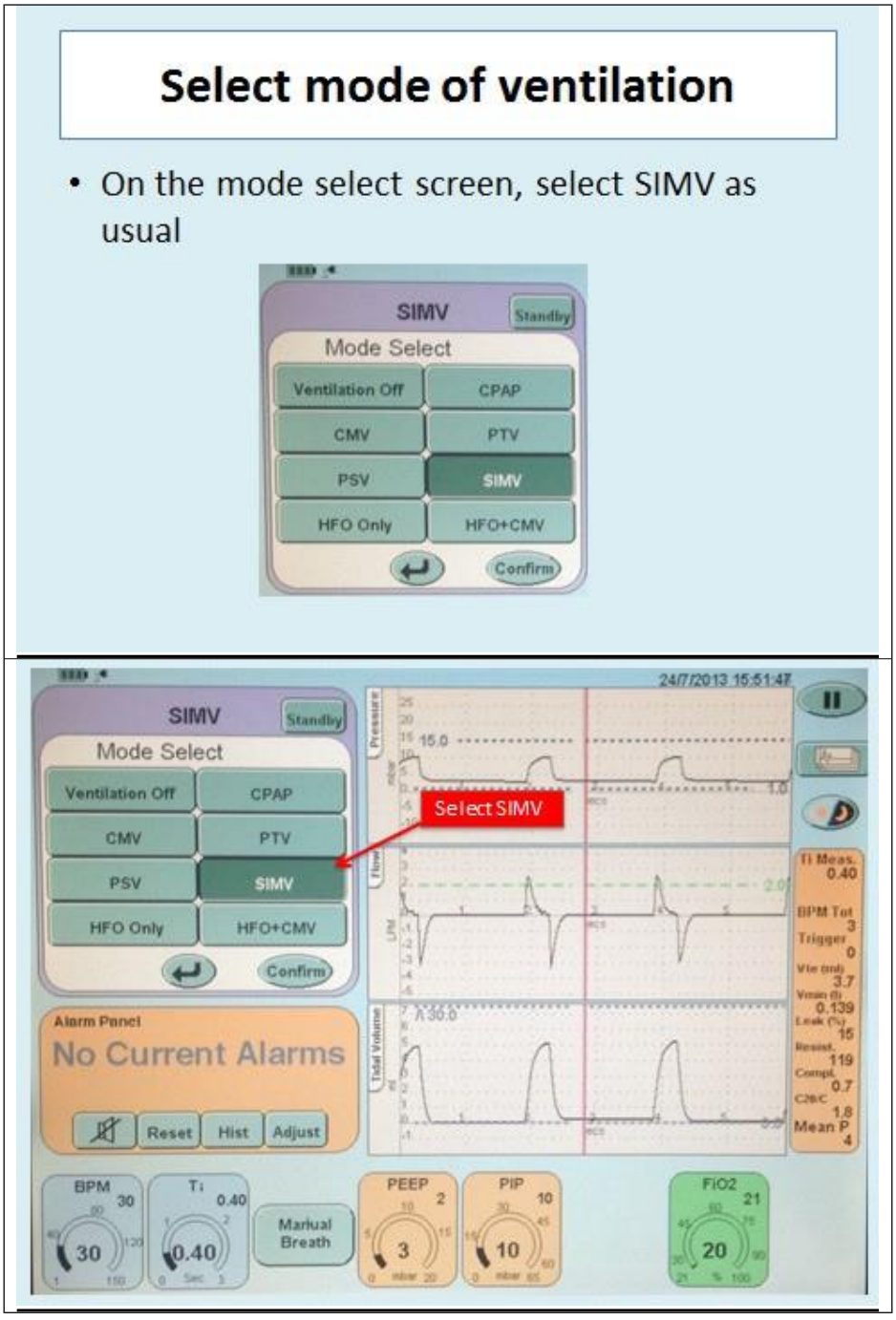
- **Set tidal volume (tidal volume target)**
- **Set PiP (maximum set peak inspiratory pressure)**
- **Delivered PiP**

Asynchrony

- There is a mismatch between the patient and the ventilator in breath timing delivery.
- Clinical signs may include increase work of breathing, frequent alarming of the ventilator or ineffective ventilation.
- Detection requires close examination of the patients' respiratory pattern and the pressure, flow or volume waveforms.
- Changing from SIMV to more physiological modes such as PTV or PSV can be helpful in assessing and improving the asynchrony.
- Optimisation of ventilator settings, review of the equipment and correct pain management are vital to correct asynchrony.

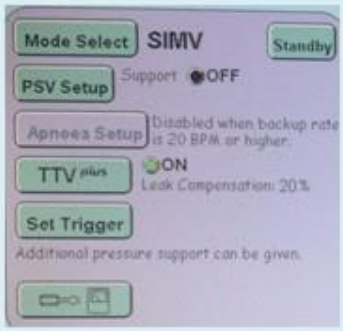
Asynchrony	Action
Inspiratory flow mismatching	Increase gas flow, decrease respiratory drive and assess analgesia and sedation
Prolonged cycling	Decrease Ti
Short cycling	Increase Ti
Double triggering	Increase Ti, try PTV or PSV, consider paralysis if adequate
Ineffective inspiratory effort	Adjust trigger sensitivity, reduce air trapping (reduce RR, optimise PEEP, prolong Te, Reduce Ti)
Auto-triggering	Adjust trigger sensitivity, check for leak and water in circuit
Expiratory muscle contraction during prolonged cycling	Decrease Ti
Expiratory muscle contraction during expiration	Check for excessive assistance, rule out air trapping

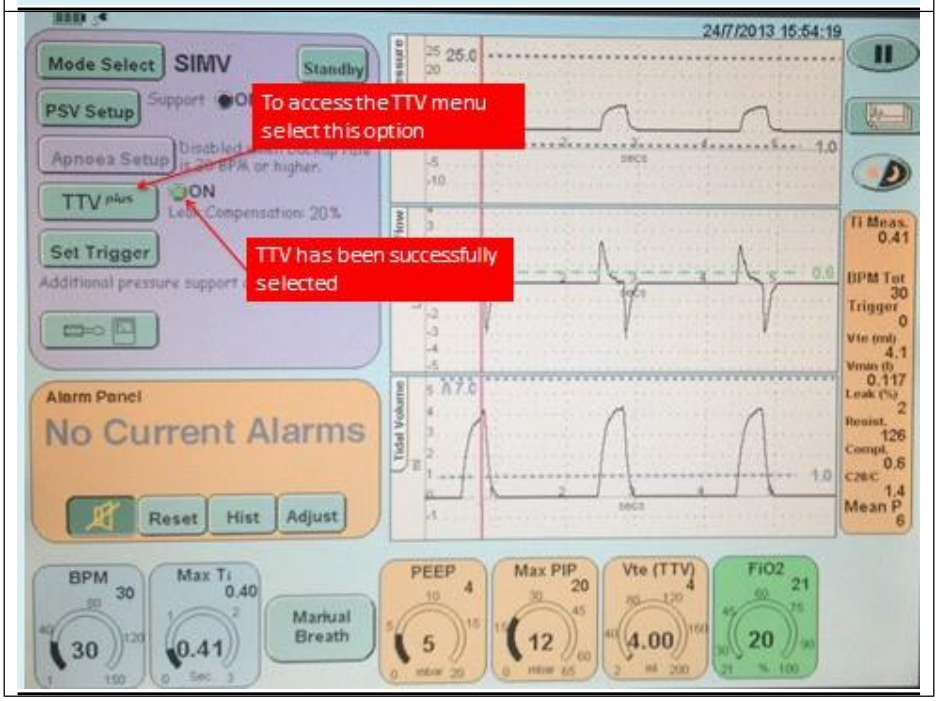
2.1 Diagramatic Algorithm



Access the TTV menu

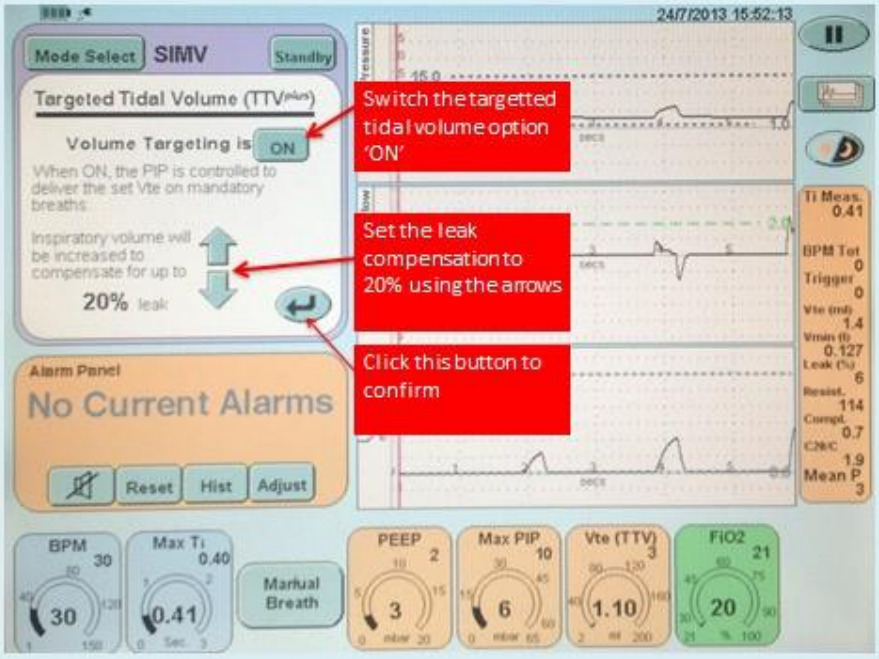
- There are a number of ventilation options that come up in the SIMV menu box
- In order to access the TTV menu select the "TTV^{plus}" button
- Once selected the green disc will be illuminated and "ON" will appear





The TTV^{plus} menu options

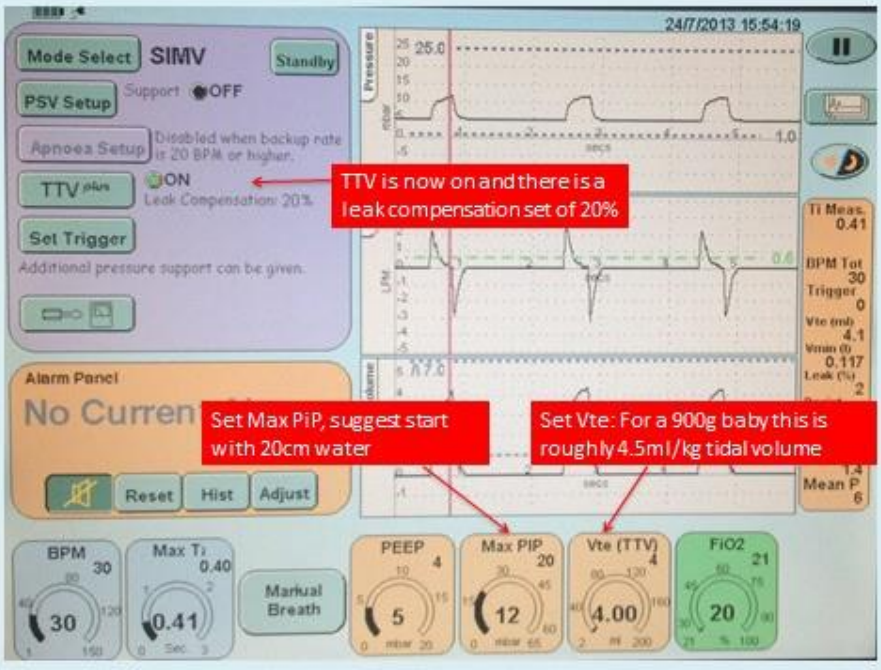
- You can turn TTV on or off by selecting the button on this screen
- The SLE 5000 can accommodate for a degree of leak and still perform TTV ventilation effectively. Set the leak compensation to 20% by using the cursors
- Confirm any changes and exit the screen by pressing enter



Setting the targeted tidal volume

In TTV mode you will notice some differences in the dials at the bottom of the ventilator display:

1. The inspiratory time is displayed as a maximum
2. The PiP is displayed as a maximum (20), delivered PiP is the large number (12)
3. There is a dial labeled Vte (TTV)

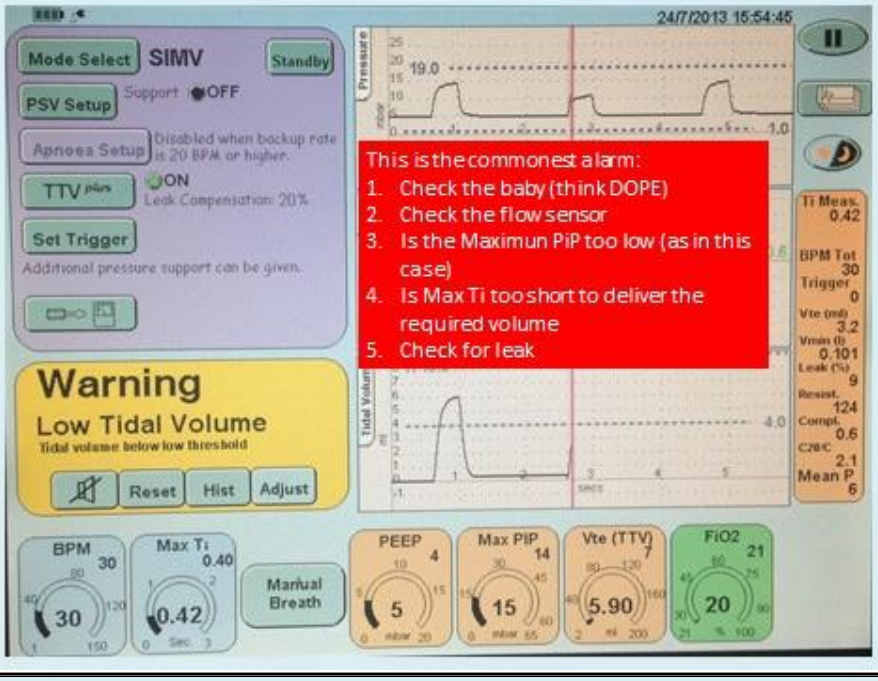


Troubleshooting

- When there is an alarm the alarm panel will change from orange to yellow.
- Two common alarm messages when using TTV are:
  - Low tidal volume
  - High patient leak

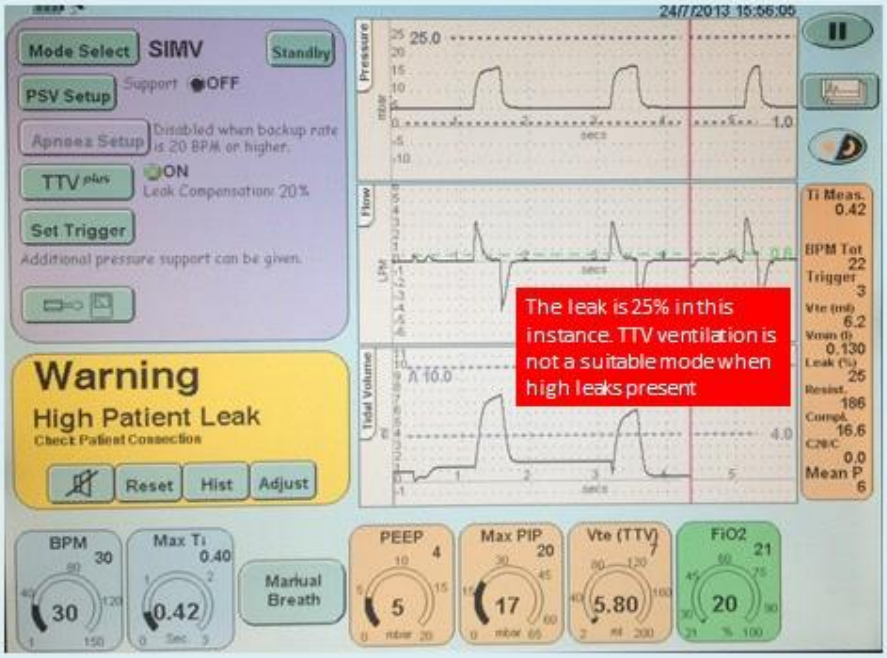
Low tidal volume alarm

What reasons can you think for the delivered tidal volume being too low?



High patient leak

This means that the leak is greater than the leak compensation that has been set i.e. 20%



How to set up SIMV-TTV Summary

Click on the arrows to revisit an area again. Press the escape key to exit the programme or click the home button to start the package from the beginning

Mode select - SIMV
Enter the TTV plus menu
Switch TTV to on
Set the leak compensation to 20%
Click the enter button to confirm
Set the maximum PiP initially to 20cm water
Set the desired tidal volume at 4.5ml/kg
Set the rate and Ti
Review the delivered tidal volume
Remember to assess the infant carefully playing particular attention to oxygenation and work of breathing

3. Education and Training

None

4. Monitoring Compliance

What will be measured to monitor compliance	How will compliance be monitored	Monitoring Lead	Frequency	Reporting arrangements
The audit standards for this guideline are focused on ensuring that TTV ventilation is used safely in an appropriate patient group	The ventilator settings are charted on the nursing ITU chart and demonstrate that: - The set tidal volume is between 3.5 and 6ml/kg (100%) - The set PiP is consistently recorded (100%) The delivered PiP is consistently recorded (100%)			

Evidence Criteria

Evidence according to RCPCH

Grade A	At least 1 randomised controlled trial addressing specific recommendation
Grade B	Well conducted clinical trials but no randomised trial on specific topic
Grade C	Expert committee report or opinions

5. Supporting References

Specialist neonatal respiratory care for babies born preterm
NICE guideline [NG124] Published date: April 2019

Kezler M, Gautham K S: Assisted Ventilation of the Neonate 7th Edition

Wheeler K, Kingenberg C, McCallion N, Morley CJ, Davis PG. The Cochrane Library 2011, Issue 6. *Volume-targeted versus pressure-limited ventilation in the neonate*.

Wheeler K, Klingenberg C, Morley CJ, Davis PG. Neonatology 2011;100:219-227. Volume-Targeted versus Pressure-Limited Ventilation for Preterm Infants: A Systematic Review and Meta-Analysis.

Dargaville PA, Tingay DG. Journal of Paediatrics and Child Health. *Lung protective ventilation in extremely preterm infants.*

Keszler M, NeoReviews 2006; 7; e250-e257. *Volume-targeted Ventilation*

6. Key Words

Peak Inspiratory Pressure (PIP), Respiratory Disease Syndrome (RDS), Targeted Tidal Volume (TTV)

The Trust recognises the diversity of the local community it serves. Our aim therefore is to provide a safe environment free from discrimination and treat all individuals fairly with dignity and appropriately according to their needs.
As part of its development, this policy and its impact on equality have been reviewed and no detriment was identified.

CONTACT AND REVIEW DETAILS			
Guideline Lead (Name and Title) Author: Dr Joanna Behrsin, Consultant Neonatologist			**Executive Lead** Chief Medical Officer
Details of Changes made during review:			
Date	**Issue Number**	**Reviewed By**	**Description Of Changes (If Any)**
3/12/2013	**1**	Neonatal Guidelines Meeting	new guideline
16/4/2014	**2**	Neonatal Governance	Minor amendments
May – June 2017	**3**	Neonatal Guidelines Meeting Neonatal Governance	Minor amendment in line with extended use of TTV (Author - JB)
June 2020	**4**	Neonatal Guidelines Meeting Neonatal Governance	
October 2024	**5**	Neonatal Guidelines Meeting Neonatal Governance	Title changed from targeted tidal ventilation to mechanical ventilation Added This is the standard mode for initiating ventilation as per NICE guidance. Other modes may be used in particular scenarios under consultant guidance. To key points Asynchrony section added Added appendix 1: Description of Ventilation Modes available on the SLE 5000

Appendix 1: Description of Ventilation Modes available on the SLE 5000

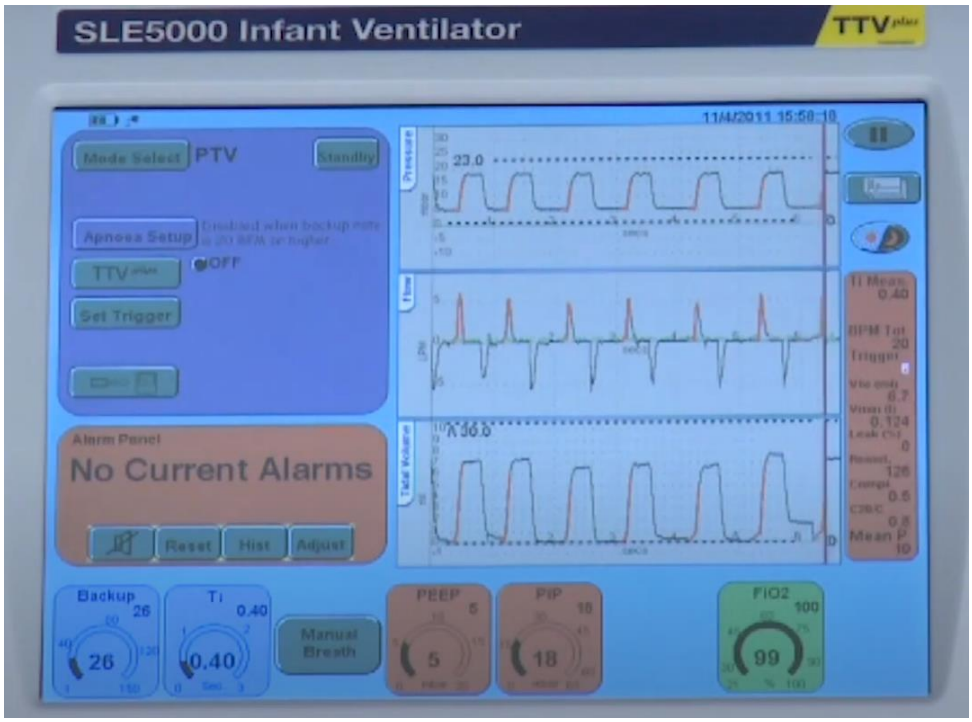
For patient triggered modes (SIMV, PTV, PSV) it is important to set a trigger sensitivity that enables the baby to trigger. The default is 0.6l/min but this will need to be reduced in the smallest most premature babies.

Patient Triggered Ventilation (PTV)

In this mode all the patient breath attempts are pressure supported. Mechanical breaths are delivered at the set parameters. (Ti, PEEP and PiP). The user sets the following:

- PEEP
- PIP
- Ti
- Backup breath rate
- FiO2

It is possible to also use TTV in this mode. It is important to consider whether the baby is breathing above the ventilator rate when weaning as all breaths are supported. Weaning by reducing the set volume if using TTV or PiP. To facilitate the opportunity for the baby to trigger and synchronise with the ventilator the backup rate should be set around 20bpm l lower than the babies spontaneous breathing rate.



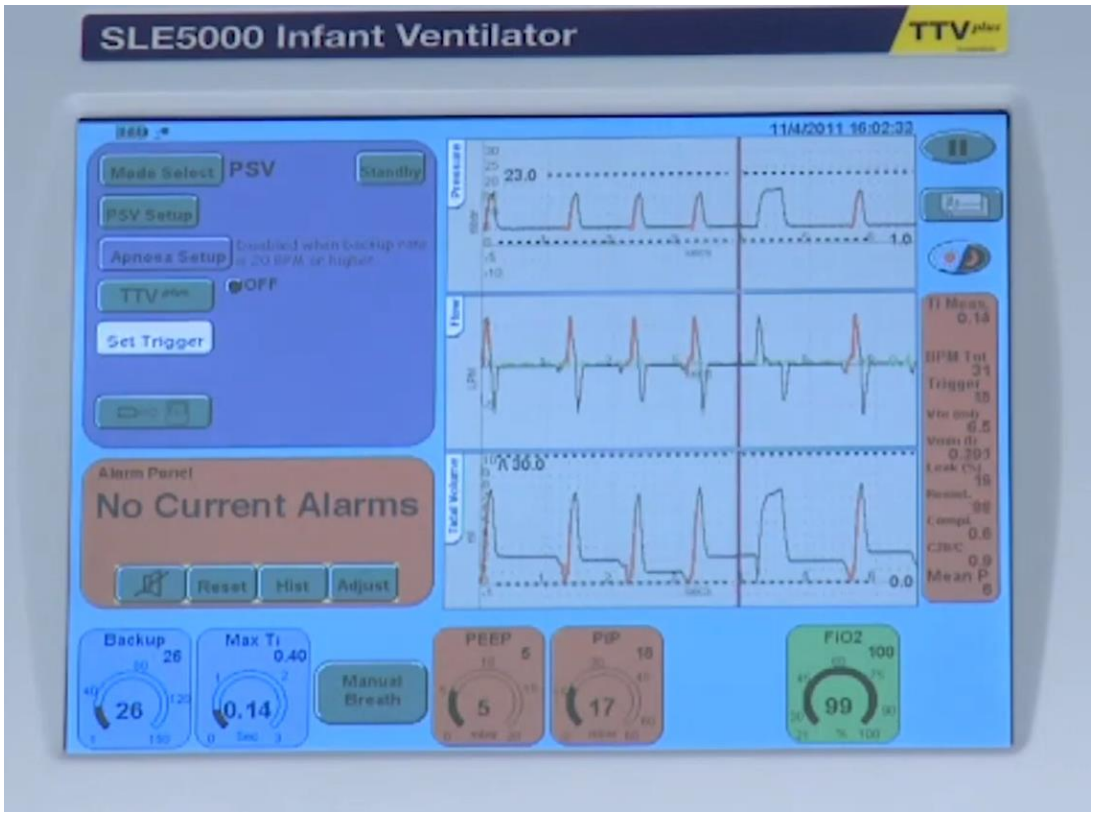
Pressure Support Ventilation (PSV)

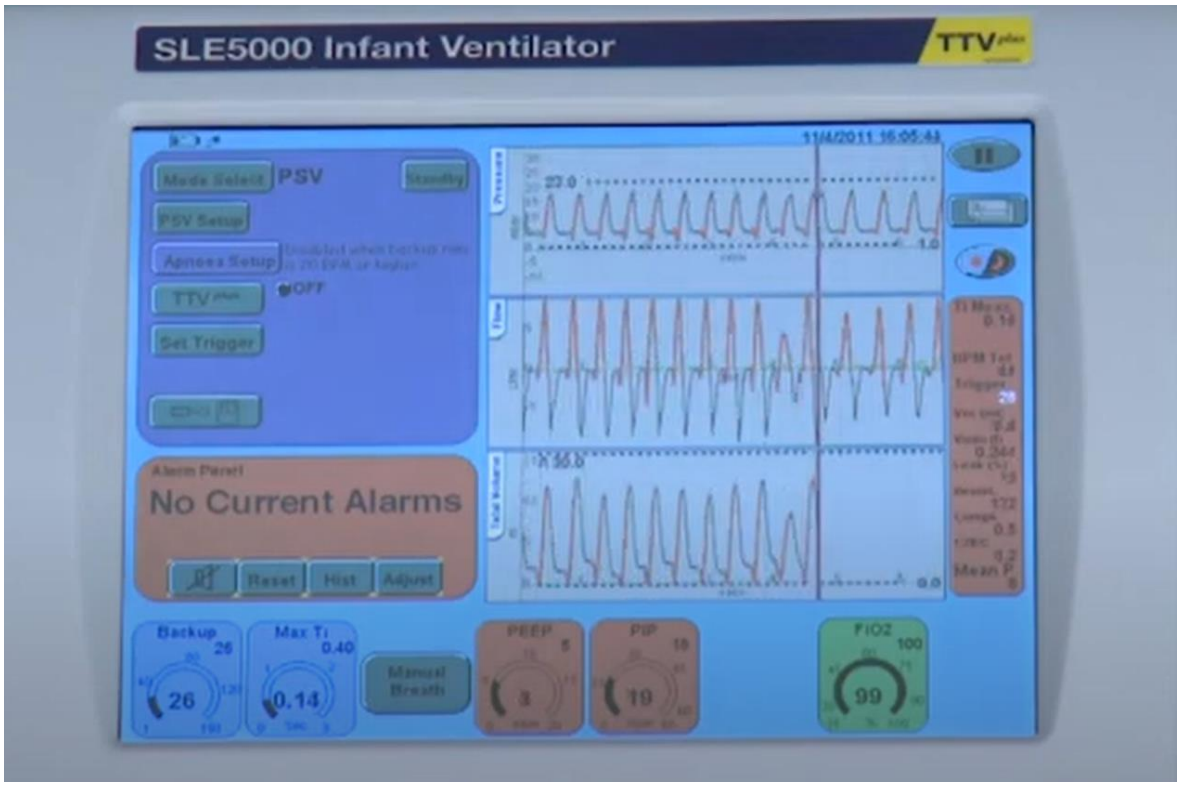
This mode is like PTV in that all breaths are pressure supported. However, in this mode the whole respiratory cycle is controlled by the baby. It may be useful in cases where there is difficult synchronization. TTV can also be used in this mode. Expiration is initiated once the termination sensitivity is met. This is set at 5% of the peak flow and can be increased during weaning. Compared to PTV there is no inspiratory hold, and the Ti is variable.

The user sets the following:

- PEEP
- PiP
- Maximum Ti
- Backup breath rate
- The flow termination sensitivity

This mode is theoretically more physiological so may be beneficial if there are synchronization challenges. Like PTV the backup rate should be set 20 below the babies spontaneous breathing rate. The termination sensitivity can be adjusted during weaning but when doing this the flow scalar waveform should appear as in the figure below.





In patient triggered modes (PTV, PTV) if there is water in the circuit or the trigger sensitivity is too high there may be autotriggering as in the figure above which will cause ventilator compromise.

Continuous Mandatory Ventilation (CMV)

This is a non-synchronised mode and should only be used if the baby is muscle-relaxed. The ventilator will deliver breaths at the set respiratory rate. TTV can be used in this mode.

Synchronised Intermittent Mandatory Ventilation (SIMV)

Here the ventilator will deliver mandatory breaths at the set rate. The ventilator will synchronise the delivery of that breath within a time-window with the baby's respiratory effort. If the baby makes no effort then a breath will be delivered regardless. No breaths above the set rate will be supported.

High Frequency Oscillatory Ventilation (HFOV)

High frequency oscillatory ventilation (HFOV) is a type of mechanical ventilation that uses a constant distending pressure (or mean airway pressure (MAP)) with pressure variations oscillating around the MAP at very high rates (up to 900 cycles per minute). This creates small tidal volumes (often less than the dead space) reducing volutrauma at when higher mean airway pressures are required for lung recruitment. The user sets:

HFO rate (usually 10 Hz)

MAP (2-3 above MAP on conventional ventilation)
Delta P – increase until visible chest wobble

The ventilator calculates a proxy value for CO2 clearance DCO2 the higher this value the greater CO2 clearance. This is useful to record to monitor with blood gases when assessing ventilation efficacy.