### Subject:
VOLUME TARGETED VENTILATION in NICU

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### Disclaimer:
It should be noted that this document reflects what is currently regarded as a safe and appropriate approach to care. However, as in any clinical situation there may be factors that cannot be covered by a single set of guidelines, this document should be used as a guide, rather than as a complete authoritative statement of procedures to be followed in respect of each individual presentation. It does not replace the need for the application of clinical judgment to each individual presentation.

### Rationale:
To promote individualised patient care and optimise long term respiratory health outcomes according to best evidence based practice.
INTRODUCTION - VOLUME TARGETED VENTILATION

Over the years multiple advances in respiratory management of the neonate have occurred, including the development of newer ventilatory technologies which has allowed a greater understanding of respiratory function.

Newborn infants with respiratory distress syndrome who develop signs of acute lung injury and subsequently develop chronic lung disease are at increased risk for developmental delays, future problems with reactive airways disease and infectious respiratory illnesses. Despite improvements in respiratory care, ventilator induced lung injury remains an important cause of morbidity and mortality in neonatal patients who require assisted ventilation. For many years ventilator induced lung injury has been extensively studied to determine the most likely cause of chronic lung disease. Initially barotrauma was understood to be the key influence of ventilator induced lung injury, however there is now increasing evidence that suggests that excessive volume, leading to overexpansion (volutrauma), and also inadequate volume, leading to under expansion and atelectasis (atelectrauma) are more important aetiologically. Animal models of respiratory distress syndrome clearly show that ventilator strategies that produce excessive tidal volumes can worsen clinical and pathological evolution of respiratory distress syndrome.

Time cycled, pressure limited ventilation has been the standard mode of ventilation for premature infants with RDS, however, a major shortcoming has been the inability to deliver consistent tidal volumes. The major benefit of volume targeted ventilation is minimising barotrauma, by setting a peak inspiratory limit, and additionally minimising volutrauma through targeting set volumes.

Volume target ventilation is used in combination with synchronized intermittent mandatory ventilation (SIMV), assist control (A/C) or pressure support ventilation (PSV). It allows the clinician to determine the target tidal volume. The addition of volume targeting requires the ventilator to deliver a set tidal volume with each breath in response to changes in patient compliance and resistance.

To achieve the set tidal volume the ventilator delivers PIP which is ≤ a pre-set PIP and is based on the volume delivered over the previous three breaths.

The advantages of volume target ventilation include:
- Maintenance of relatively constant tidal volume
- Prevention of over distention and volutrauma following surfactant treatment
- Response to sudden changes in compliance and resistance, and
- Stabilization of minute ventilation.

TERMINOLOGY
- VOLUME TARGETING – The ventilation strategy
- VOLUME LIMITING – VLim – terminology used by the Stephanie Ventilator
- VOLUME GUARANTEE – VG – terminology used by Drager Babylog Ventilator
INDICATIONS FOR VOLUME TARGETED VENTILATION

When making the decision on whether volume targeted ventilation is appropriate for your patient, there are key factors that require consideration.

Is there an ETT leak? As the VT is measured on expiration by the pneumotacograph any ETT leak will provide inaccurate volumes and feedback resulting in frequent ventilator alarms. Any patient with an ETT air leak of greater than 30% should not ideally be ventilated with the volume limited option.

Gestation of the infant. Whilst volume targeting can be utilised for both preterm and term infants, the strategy is focused on supporting preterm and extremely preterm infants requiring ventilation to minimise all levels of lung trauma and thereby reducing the risk of chronic lung disease.

Respiratory disease process. Consideration must also be given to the progression of the infants’ disease process. For example, if the lungs are stiff and non-compliant secondary to RDS then volume target ventilation is advantageous following surfactant administration as compliance is expected to improve, PIP essentially weans itself as similar volumes can be achieved with smaller pressures.

CHOOSE YOUR PATIENT CAREFULLY!

Volume limit setting may not benefit infants who:

- Are less than 500 grams (inability to set/deliver accurate tidal volumes below 2 mL)
- Are breathing vigorously
- Have a large ETT leak (>30%)

WHAT IS AN OPTIMAL TIDAL VOLUME TO TARGET?

Large tidal volumes have been shown to be detrimental with dose dependent lung injury. However, tidal volumes which are too low may also be quite harmful.

Studies showing measurement of lung cytokines have demonstrated higher levels of inflammation in the preterm neonate when using tidal volumes of 3ml/kg as opposed to 6ml/kg during the acute phase of RDS. Also, studies measuring the work of breathing have shown higher work of breathing when tidal volumes of 4ml/kg were used in comparison to targeting 5ml/kg of tidal volumes in preterm neonates during weaning.

Optimal tidal volumes may therefore be 5-6ml/kg for infants < 32 weeks gestation.
VENTILATOR SETTINGS FOR VOLUME TARGETING

1. Assess the infants’ ventilation to determine what tidal volume (VT) the baby is achieving on current ventilation settings.

2. Normal VT ranges from 3-8mls/kg per breath (depending on infants gestation and lung condition). When initiating volume targeted ventilation, a safe starting point should be 5mls/kg per breath. This minimises the risk of over ventilation whilst providing scope for increasing VT if required for the individual infant.

3. As volume targeting is an “add on” ventilatory setting, selection of an appropriate ventilation mode must be determined, either A/C or SIMV. Note: Assist Control is the ideal mode of ventilation as this mode promotes better respiratory synchronisation (see CPG 5.1.4a Assisted Ventilation of the newborn).

4. After selecting the desired mode of ventilation set appropriate settings, including PIP limit, PEEP, rate (SIMV) and Back-up rate (A/C), inspiratory time (0.3 to 0.45), trigger level and flow wave formation (e.g. sine wave).

5. Selection of PIP limit is important as this acts as the maximum pressure available during inspiration. It is therefore necessary to monitor the infants’ response to the set pressure limit to ensure the pressure is adequate enough to achieve the set volume target.

6. Next go to options icon on scroll bar at the bottom of the screen and click to select.

7. Scroll along to VT parameter option and select modify the scale to the 1:10 ratio and click to select.

8. After selecting the scale a message will appear on the screen stating “CHECK VT SETTINGS” at this point turn the VT knob (located to the right of the inspiratory button) to the required setting, remembering each increment of 10mls will now account for 1ml, that is if VT required is 4mls turn the knob to 40.

9. A second message will then appear stating “Change VT SCALE to 1:10” and select YES and click to confirm.

10. Next scroll to MODIFY and select VOLlim ON to turn mode on.

11. V Lim should now appear in the upper right corner of the screen under the mode of ventilation.

12. It is now necessary to adjust alarm limits by scrolling to Alarm Limits and selecting Automatic to confirm.


14. Continue to monitor infant to ensure VT is being achieved whilst ensuring adequate levels of pressure are available. After an adequate time frame, tidal volume trends can be accessed via the trend screen (see troubleshooting section- how to access).

15. Attend blood gas assessment as per Consultant or Medical officer.
DOCUMENTATION

- At each handover document all ACTUAL settings in RED pen on the level 3 flowchart, including the set pressure limit and targeted volume. (Actual settings are recorded from the ventilator knobs on the bottom panel of the Stephanie ventilator).

- Record regular ventilation observations at hourly intervals including,
  - Mode of ventilation i.e. VT A/C,
  - Oxygen level (FiO2)
  - Delivered PIP
  - Delivered PEEP
  - Inspiratory time
  - Set ventilator rate/back-up rate
  - Delivered tidal volume
  - Minute volume
  - Trigger sensitivity setting
  - Flow wave formation
  - Vital signs

Note: Observed/Delivered ventilation is recorded from the displayed values on left most column on the Stephanie ventilator screen.

- Calculate and document the average tidal volume achieved over the previous 6 hour period. Clearly document in RED pen at bottom of level 3 flowchart.

- Any change in ventilation is written on the observation chart and highlighted by documenting in RED pen.

- Document all ventilation settings including volume target and average over shift in patient notes.

VENTILATOR ADJUSTMENTS DURING ONGOING CARE

Abnormal pCO2 on arterial or capillary blood gas may necessitate changes in ventilatory settings. Appropriate increase or decrease in minute ventilation is usually required for correction i.e. change in set VT or RR (if infant on SIMV or if on A/C mode but not breathing consistently above the ventilator, backup rate). Remember that it is possible to achieve ‘good’ gases but have inappropriate ventilator settings for the infant’s needs.

Scenario 1: pCO2 high

Set VT is being achieved AND
PIP required to deliver the set VT is less than set PIP

Increase the set VT by 0.5mL/kg increments
Always check that the set PIP is still adequate to achieve the new VT target
Scenario 2: pCO2 high

**Set VT is being achieved**

AND

**PIP required to deliver the set VT is equal to the set PIP**

Increase the set VT by 0.5mL/kg increments
Also increase the set PIP level (if appropriate) to achieve the new VT target

Scenario 3: pCO2 high

**Set VT is not being achieved**

AND

**PIP required to deliver the VT is equal to the set PIP**

Increase the set PIP level (if appropriate) so that the VT targeted is achieved

Scenario 4: pCO2 low

**Set VT is being achieved**

AND

**PIP required to deliver the set VT is less than set PIP**

Reduce the set VT by 0.5mL/kg decrement

(Be careful! Do not lower the targeted VT too much, as this may lead to increased lung injury or work of breathing or both)

NOTE: Blood gas estimation *may* need to be repeated within 1-2 hours of change in settings to ensure pCO2 levels in target zone. Please check with medical staff.

**WEANING FROM VOLUME TARGETED VENTILATION**

Successful weaning and extubation is a balance between adequate pulmonary gas exchange and respiratory muscle performance, and is influenced by:

- Differing stages of lung development
- Changing status of the underlying disease
- Secondary influences such as medications with sedative actions
- The interaction between neonatal heart and lungs
- Relationship between central control of respiratory drive and respiratory muscles

Weaning is also relative to the mode of ventilation utilised in combination with the volume target option;

1. Reduce tidal volume cautiously in small decrements (no greater than 0.5mL/kg) until the lower end of the target is reached i.e. 4-5 ml / kg.

2. Rates may be reduced to no less than 30 breaths/minute (only if on SIMV) to maintain required pCO2

3. If on A/C mode, increase the trigger in 0.1 unit increments up to 0.5 to 1.0
(respiratory ‘muscle conditioning’) depending on gestation and birth weight to wean the number of breaths supported by the ventilator. This also allows assessment of whether the neonate can initiate an inspiratory pressure adequate enough without relying on ventilatory support.

4. Consider extubation when lower tidal volume is reached, the minimum rate is set on ventilator, FiO2 is in the desired range, infant is breathing regularly above the back up rate and other clinical conditions are met.

TROUBLESHOOTING

It is important to note that Volume target ventilation relies upon accurate expired tidal volume (Vte) measurement.

As previously discussed, a large air leak may cause inaccurate volume measurement. Continue to monitor for this in the event an infant airway may initially have no leak, from trauma/oedema, and as this resolves an air leak may appear. Alternatively, change in ETT placement or ETT orientation from change in patient position may result in change in the amount of ETT leak.

The presence of rainout/water in the ventilation tubing and particularly the pneumotach will influence the accuracy of volume measurements. If rainout is visible or delivered VTe is fluctuating significantly, disconnect the pneumotach from circuit, empty rainout and dry lines and replace for improvement in volume measurements.

Lastly, if there is frequent alarming of ventilator, ensure alarm limits are set appropriately and re-attend automatic alarm limit function. If the alarms persist, assess whether infant is achieving the target volume or is receiving adequate pressure to ensure set VT achieved; if not or unsure contact medical staff/NNP or Neonatologist.

ACCESSING THE TREND SCREEN

To access the trend screen select the 2nd curve option, and select the volume/time V(t) option.

The volume time graph screen should now appear, following this select the trend screen button which is located second from the top on the right side of the ventilator.

The trend button should now be highlighted with a four graph screen visible. This screen should display a timed history graph of both pressure and volume received over the selected time frame (see attached graphics).

To extend the time viewed go to the scale button and scroll down to -1 option. Highlight the -1 and further time options (up to 24 hours) will be available. Confirm desired timeframe.

To return to the previous screen unselect the trend screen button, and select the 2nd curve option and select the Flow/time V’ (t) graph to return to normal settings.
SET-UP CARD FOR VENTILATOR

Calculate desired volume target - begin at 4mls/kg
(* note: keep target between normal range 4-8mls/kg)

Select appropriate ventilation mode and modify settings as appropriate for individual infant

Re-confirm PIP setting as this acts the maximum pressure limit

Turn VT knob (located right of the inspiratory button) to zero

Go to options

Select VT parameter option

Scroll scale option to ratio 1:10 (thereby making each increment of 10 equivalent to 1ml of volume)

Following this a message will appear on the screen “check VT settings” turn VT knob to the targeted volume required

Next the screen will display “change VT scale to 1:10” select “Yes”

The main display on the ventilator should now read “VT ratio 1:10” in red font above the top graph

Go to modify option at bottom of screen and select “Vol-Lim” and confirm to turn it on

“V-Lim” should now appear in the upper right corner of screen under the mode of ventilation (*if v-lim does not appear it has not been turned on)

Now scroll to alarm limits and select automatic option for correction of alarm limits to new settings

Monitor baby for an adequate period to ensure volumes and being delivered and ensure pressure limitations are adequate enough for targeted volume
REFERENCES


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APPROVED BY: NICU Exec MAC   2/11/2011
### APPENDIXES:

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<tr>
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<th>Skin</th>
<th>Crib Temperature</th>
<th>Blood Gases</th>
<th>Respiratory Support</th>
<th>Nitric</th>
<th>Suction</th>
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#### Blood Gases:
- **pH**: 7.34
- **PaCO₂**: 66.9
- **PaO₂**: 34
- **SBC**: 35.8
- **SBE**: 8.5
- **BSL**: 5.6
- **UAC / IAL Calibration**: CAP

#### Ventilation Type:
- **NC, CPAP, Nasal**: Aquapack
- **FiO₂**: 0.3 0.28 0.33 0.33 0.28 0.28 0.28 0.28
- **Signature**: PIP / PEEP
  - 20 / 6 20 / 6 20/18 / 6 16 / 6 14 / 6 17 / 6 14 / 6 20 / 13 / 6
- **Amplitude / Frequency (Hz)**
  - for HFOV
- **Flow**
  - Trigger Threshold: 0.4 0.4 0.4 0.4 0.4 0.4 0.4 0.4
  - Backup Rate (Red): 45 45 45 45 45 45 45 45
  - Mean Airway Pressure: 8.3 8.3 8.2 8.1 8.3 8.3 8.4 8.3
  - Inspiration Time (Tᵢ): 0.35 0.35 0.35 0.35 0.35 0.35 0.35 0.35
  - Waveform (Sq/Sin/Tri): SIN SIN SIN SIN SIN SIN SIN SIN
  - Minute Volume (Mᵥ): 0.5 0.56 0.23 0.28 0.3 0.26 0.32 0.39 0.25
  - Tidal Volume (Vₜ): 10 11 5.1 5.1 5 5.1 4.9 4.1 4.9
  - Airway Temperature: 37.1 37.1 37.1 37 37.2 37.1 37.2 37 37
  - Temperature Offset: 0 0 0 0 0 0 0 0 0
  - OG Tube Position: 14cm

**Notes / Signature**
- Et 2.5 secure 7cm @ lips
- Volume target = 5mls
- Volume target O2 15
  - Target 5mls = 5.6mls/kg
  - VT average = 4.8mls