Volume Guarantee Ventilation

Introduction

Volume Guarantee Ventilation allows effective control of delivered tidal volumes while offering ventilatory support to low birth weight preterm infants. One of the major disadvantages of pressure-limited ventilation is the variable tidal volumes that are generated as the lung compliance and resistance changes. Ventilation allowing large tidal volumes results in volutrauma which is important in the pathogenesis of bronchopulmonary dysplasia. Volume guarantee ventilation facilitates for the appropriate use of tidal volumes with the aim of reducing lung damage. Our target population is all neonates requiring mechanical ventilation.

History

Volume Guarantee ventilation is possible in small preterm babies due to the development of sensitive and accurate flow sensors which allows for the measurement and tracking of gas flow. Improved software development prevents over/undershoot and rapid obtaining of target tidal volumes. The flow sensors assist in avoiding overexpansion (volutrauma) and underexpansion (atelectotrauma). In animal studies ventilation at low and high lung volumes has also been shown to cause lung injury especially in surfactant deficient lungs. This injury is believed to be related to the repeated opening and closing of lung units with each mechanical breath (atelectotrauma).

Modes of Volume Targeted Ventilation

Volume targeted ventilation includes Volume Guarantee, Volume-Controlled and Volume Limited Ventilation. Volume Guarantee is available on the Drager VN 500, Volume control on the VIP Bird and Siemens Servo 300 and Volume-Limited on the Bear Cub 750 PSV.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Volume Guarantee Ventilation</th>
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<tbody>
<tr>
<td>Ventilator model</td>
<td>Drager VN 500</td>
</tr>
<tr>
<td>Trigger type</td>
<td>Flow sensor</td>
</tr>
<tr>
<td>Sensor Position</td>
<td>At Y Piece</td>
</tr>
<tr>
<td>PIP</td>
<td>Variable, set max</td>
</tr>
<tr>
<td>Volume measured that affect</td>
<td>VTi and VTe (default setting should be VTe)</td>
</tr>
<tr>
<td>ventilation</td>
<td></td>
</tr>
<tr>
<td>Set maximal VT</td>
<td>Inflation stopped if VTi &gt; 130% set VT</td>
</tr>
<tr>
<td>Adjusts for low VT</td>
<td>Yes</td>
</tr>
<tr>
<td>Modes available</td>
<td>PC-SIMV, PC-AC, PC-PSV</td>
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At the RPA we use Volume Guarantee Ventilation on the Drager VN 500.

Principles of Operation

The ventilator adjusts the inspiratory pressure based on the exhaled tidal volume of the previous breath, to deliver the tidal volume that has been set. Exhaled tidal volume is used for regulation of inspiratory
pressure as it more closely approximates true tidal volume in the presence of a significant leak around the endotracheal tube (not uncommon in newborns with uncuffed endotracheal tubes). If there is a large endotracheal tube leak, tidal volume may be underestimated and overcompensation can occur with subsequent breaths. The pressure increment limit is 3 cm H20 which prevents over correction.

1. The set tidal volume is achieved with the working pressure in (a).
2. The set tidal volume is not achieved with the second breath (b); this resulted in an increased pressure required (within the maximum PIP set) to achieve the desired tidal volume in the third breath (c)
3. The increased tidal volume with increased pressure (d) resulting in subsequent reduced pressure and targeted tidal volume achieved with last breath (e).

**Indications**

At the RPA Hospital Volume Guarantee with SIPPV is the initial mode of ventilation for all neonates requiring mechanical ventilation.

Volume Guarantee Ventilation can be used on any neonate requiring mechanical ventilation. Preterm babies who have received endotracheal surfactant have rapidly changing lung compliance which results in changes in tidal volumes and pressure requirements. Volume Guarantee Ventilation is protective against lung injury as a result of the above changes. Preterm infants who are having apnoea or periodic breathing will also benefit from volume ventilation as their tidal volumes will vary from breath to breath.

**Contraindications**

**Relative:**

Large air leak if the leak is greater than 65% do not use volume guarantee as the volume targeted cant be achieved.
Evidence

Volume guarantee ventilation has been shown in clinical trials to be as safe as pressure limited ventilation with potential benefits including reduction in duration of ventilation, intraventricular haemorrhage and air leak.

The Cochrane Review found eight randomised trials which compared time-cycled, pressure limited ventilation with a volume targeted mode. Three were excluded as they did not report specific outcomes. A fourth trial was excluded because it compared different modes of triggered ventilation as well as the use of either volume or time cycled modes. The four randomised control trials which were included in the Review (Keszler 2004; Lista 2004; Piotrowski 1997; Sinha 1997) recruited 178 preterm infants. Antenatal steroids and surfactant were available in all participating units; their use was not significantly different in the Individual studies. A randomised control trial by Singh et al was published after the Cochrane review. This study was designed to assess the safety and efficacy of volume targeted ventilation.

The Cochrane review suggests the following when comparing volume-targeted ventilation with pressure limited ventilation:

- No effect on mortality
- No effect on incidence of bronchopulmonary dysplasia
- No data available comparing the different neurodevelopmental outcomes
- Significant reduction in duration of intermittent positive pressure ventilation
- Reduction in severe intraventricular haemorrhage
- Reduction in rates of pneumothorax

The modes of volume targeted ventilation used were not compared. None of the studies looked at long term neurodevelopmental outcome and the number of patients included in the trials were relatively small.

Singh et al confirmed the safety and efficacy of Volume control ventilation. His study included 109 patients between 24 and 31 weeks gestation. There were trends toward faster weaning and reduction in duration of respiratory support in the group on volume control ventilation; these were statistically significant in the subgroup of babies weighing less than 1000g.

Practical Guidelines

Volume Guarantee Ventilation is initiated using the Drager VN 500. Although VG can be used in conjunction with synchronised intermittent mandatory ventilation (SIMV), synchronised intermittent positive pressure ventilation (SIPPV) or Pressure Support Ventilation (PSV) on the VN 500 the preferred ventilatory mode in our unit is SIPPV. It is a time-cycled pressure limited mode which automatically adjusts the delivered peak inspiratory pressure (PIP) to achieve a target volume set by the operator. An upper limit of PIP needs to be set the machine will adjust the pressure delivered to target the volume selected. If the ventilator can not deliver the volume selected using the maximum PIP set the machine will alarm.

Setting the ventilator

1. Select AC-PC on the Drager VN 500.
2. Add Volume Guarantee. On the VN 500 you need to go into Alarm Settings to set the Peak Inspiratory Pressure prior to switching on Volume Guarantee.
3. Set the desired tidal volume start at 4ml/kg (Larger tidal volumes may be needed in infants with chronic lung disease). Targeting a volume of 4mls/kg has been associated with acceptable PaCO2 levels at the first blood gas measurement. The target range for PaCO2 is 40-50mmHg. Using tidal volumes > 6ml/kg are not recommended.
4. The initial settings for babies with lung disease (reference Conventional Ventilation Protocol) are:
a. Vt 4ml/kg  
b. PIP 25cm H2O (limiting pressure)  
c. PEEP 5 cm H2O  
d. Inspiratory time 0.3 seconds  
e. Back up respiratory rate of 60 breaths/min

5. **Check target Vt is being delivered.** If not - check the set upper limit of pressure look at what pressure is required to achieve the tidal volume. When using Volume Guarantee the PIP should be set 5 cm H2O above the usual settings i.e. 25 cm H2O. In babies with variable lung compliance higher PIP limits may need to be set.

6. Document the PIP limit, the range of PIP and the leak. If the leak is greater than 65% consider alternative ventilatory mode or an ETT size change. The ventilator will alarm (low tidal volume) if the tidal volume cannot be delivered using the maximum PIP set. If the ventilator repeatedly alarms due to an inadequate tidal volume delivery with the PIP set 5cm H2O above the usual limit re-evaluate the infant (clinical deterioration) and consider an X-ray to exclude an air leak.

7. The rate set is a back up rate (initially 40 breaths per minute) if the baby is not breathing on their own.

8. Flow should be set at 10l/min. Note: infants on high respiratory rates may require an increase in flow rate.

9. **On the Drager VN 500, Leak compensation should be OFF.**

**Weaning from the ventilator**

The pressure required to deliver the tidal volume will automatically decrease as the baby's lung compliance improves auto weaning. The back-up rate (on SIPPV) should be weaned to 20 breaths/min for a few hours prior to extubation to ensure the baby has sufficient respiratory drive to sustain respiration. Significantly reducing the tidal volume has been associated with poor outcomes as a result of injury caused by repeated opening and closing of alveoli with each mechanical breath (atelectotrauma).

**Avoiding Over-ventilation**

**Signs of over-ventilation:** The infant does not breathe above the ventilator (no triggering). If the tidal volume (Vt) is set too high and the PaCO2 is low the baby will not have a respiratory drive and will not self wean. Auto-triggering due to water in the circuit or excessive air leak also cause over-ventilation.

**Correction of over-ventilation:** Check for auto-triggering. If the baby's lung disease is improving and they are hyperventilating, you may need to intervene to maintain normocarbia. Two possibilities for weaning in this instance are reducing the supported respiratory rate (by changing to SIMV) and/or reducing the VT. Abubakar and Keszler made the observation that infants on volume guarantee with SIMV were more tachypnoiec and had consistently lower saturations with an increased work of breathing.

**Avoiding Under-ventilation**

**Signs of under-ventilation:** The infant has an increased work of breathing, or moderate to severe respiratory distress.

Correction of under-ventilation: If the ventilator continually alarms (low tidal volume) due to inadequate tidal volume delivery consider:

- Clinical deterioration with increased work of breathing surfactant deficiency.
  - Give surfactant
- Possible air leak - medical review transillumination and / or CXR
  - Intercostal drain
- Inadequate Vt either due to inadequate maximum PIP (i.e. Vt is pressure limited) or infant requires higher Vt. Either:
  - Increase maximum PIP, or
  - Increase Vt (Note you will need to adjust maximum set PIP)
- Short Inspiratory time
  - Check flow / time graphs no post-inspiratory pause
• Inadequate flow especially at high rates
  - Check pressure / time graphs prolonged time to obtain target PIP

Exubation criteria are discussed in our Conventional Ventilation Policy. Babies born before 30 weeks gestation should be loaded with a methylxanthine (caffeine) prior to extubation.

**Advantages**

Potential advantages of Volume Guarantee Ventilation are:

1. Less risk for barotrauma because the tidal volume delivered is limited
2. Reduced peak pressure especially when the baby makes a significant contribution from spontaneous effort
3. Auto-weaning on inspiratory pressure as the lung compliance improves which reduces barotrauma
4. Reduction in biotrauma Lista and Colleagues \(^\text{7}\) reported decreased levels of pro-inflammatory cytokines in the tracheal aspirates of infants on volume guarantee ventilation.
5. **Volume Guarantee ventilation is as safe as pressure limited ventilation with potential benefits including reduction in duration of ventilation, IVH and air leak** \(^\text{4}\).

**Keypoints**

<table>
<thead>
<tr>
<th>Volume Guarantee Ventilation is as safe as pressure limited ventilation with potential benefits including reduction in duration of ventilation, IVH and air leak.</th>
<th>Level of evidence 1 b Grade of Recommendation A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume Guarantee Ventilation has no benefit in reducing mortality or the incidence of bronchopulmonary dysplasia</td>
<td>Level of evidence 1b Grade of Recommendation A</td>
</tr>
</tbody>
</table>

**References**


6. Auckland Newborn Services Clinical Guideline.

7. Keszler M. Clinical Guidelines and Observations on Babylog 8000+ with Pressure Support Ventilation (PSV) and Volume Guarantee (VG)


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