

Trust Guideline for Neonatal Volume Guarantee Ventilation (VGV)

A Clinical Guideline

For use in:	Neonatal Intensive Care Unit
By:	Doctors, Nurses, and Advanced Neonatal Nurse Practitioners (ANNPs)
For:	Neonates and infants
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Quick reference guideline

Initial Settings < 1kg

- Select AC-PC + add VG
- TV 5 ml/kg
- P_{max} 25cm H₂O (PIP limit)
- PEEP 5 cm H₂O
- Inspiratory time 0.3 seconds
- Back up respiratory rate (BURR) 40/minutes

Initial Settings > 1kg

- Select AC-PC + add VG
- TV 4.0 mL/kg
- P_{max} 30cm H₂O (PIP limit)
- PEEP 5 cm H₂O
- Inspiratory time 0.35 seconds
- Back up respiratory rate (BURR) 40/minutes

Ongoing Management on VGV

- Adjust set TV in increments of 0.5m//kg or BURR 5-10/min based on P_{CO2} and work of breathing
- Consider checking blood gas within 30min - 1 hour if settings are changed
- P_{max} limit must be adjusted periodically to keep the limit close to the working delivered PIP pressure
- Delivered PIP > 26 cmH₂O – consider HFOV

Adjustments when PC_{o2} high

- Is the set TV and BURR rate adequate?
- Is the TV_{low} alarm going off?
 - Exclude airway obstruction/leak
 - Is P_{max} limit set adequate?
 - Enough Ti to reach PIP?

Does the baby need a chest X-ray?

Adjustments when PC_{o2} low

- High RR
 - ? agitated/pain -sedation
 - ?autotriggering - ↓Trigger sensitivity & circuit free of water
- Normal/low RR
 - Reduce set TV

Weaning and Extubation

- Allow delivered PIP to self-wean
- Avoid over sedation during the weaning phase
- Once the set TV is at the low end of the normal range (usually 4ml/kg), P_{CO2} is allowed to rise to help in self-weaning by improving respiratory drive
- If the TV is set too high, resulting in a high pH > 7.40, the baby will not have a good respiratory drive and will not self-wean
- Over distension with normal PCO2 may be best addressed by reducing PEEP
- If significant oxygen requirement persists FiO₂ > 40%, PEEP may need to be increased to keep MAP from falling as delivered PIP is auto weaned, to prevent atelectasis, worsening lung compliance and failure of extubation
- Reduce BURR to 20 – 30/min to ensure good respiratory drive
- Consider Extubation if mean airway pressure is consistently <8 to 10 cm H₂O or delivered PIP < 12 cm H₂O in babies < 1kg or delivered PIP < 15 cm H₂O in babies > 1kg, with set TV 4.0 to 4.5 ml/kg, FiO₂ less than 35%, blood gases are satisfactory with good sustained respiratory effort.

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Glossary	
AC	Assist-Control
BPD	Bronchopulmonary Dysplasia
BURR	Back-Up Respiratory Rate
CLD	Chronic Lung Disease
ETT	Endotracheal Tube
PIP	Peak Inspiratory Pressure
PLV	Pressure-limited ventilation
RDS	Respiratory Distress Syndrome
SIMV	Synchronised Intermittent Mandatory Ventilation
SIPPV	Synchronised Intermittent Positive Pressure Ventilation
TV	Tidal Volume
VG	Volume Guarantee
VGV	Volume Guarantee Ventilation

Objective

To guide the Neonatal team in using Volume Guarantee Ventilation (VGV) in preterm and term infants

Rationale

Mechanical ventilation is required to manage neonates with severe respiratory failure. Pressure-limited ventilation (PVL), delivers a fixed Peak Inspiratory Pressure (PIP). This has one major disadvantages of delivering variable tidal volumes as the lung compliance and resistance changes. VGV allows effective control of delivered tidal volumes while offering ventilator support to low birth weight preterm infants.

Ventilation allowing large tidal volumes results in volutrauma which is important in the pathogenesis of Bronchopulmonary Dysplasia (BPD). VGV facilitates for the appropriate use of tidal volumes with the aim of reducing lung damage. VGV 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 under expansion (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). VGV is protective against lung injury as a result of the above changes. Recent systematic review and meta-analysis shows that VGV compared to PLV reduce death and BPD

Process to be followed

Initiation

VGV is initiated using the **Drager VN 500**. VG can be used in conjunction with Synchronised Intermittent Mandatory Ventilation (SIMV), Synchronised

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Intermittent Positive Pressure Ventilation (SIPPV)/Assist-Control (AC) or Pressure Support Ventilation.

On the Drager VN 500 the preferred ventilator mode is SIPPV/AC as it is associated with more stable expired Tidal volume (TV), better oxygenation and reduced tachypnea when compared with SIMV+VG.

It is a time-cycled pressure limited mode which automatically adjusts the delivered PIP to achieve a target volume set by the operator. An upper limit of P_{max} needs to be set; the machine will adjust the pressure delivered to achieve the target TV selected. If the ventilator cannot deliver the TV selected using the P_{max} set the machine will alarm. Breaths that are unsupported by inflation during continuous mandatory ventilation +VG or SIMV +VG are not volume targeted.

Setting the ventilator

1. Select AC-PC on the Drager VN 500
2. Add VG + ensure correct weight has been entered into the ventilator at initiation
3. Setting the desired TV

Start at 4mL/kg during the acute phase of Respiratory Distress Syndrome (RDS) in infants larger than 1kg. Babies with birth weight less than 1kg require TV of 5 mL/kg because of the additional 1mL dead space of the flow sensor has a larger impact in the smallest infants. Subsequent adjustment to TV may be needed based on PC_{O_2} . The usual increment is 0.5mL/kg.

Substantially larger tidal volumes may be needed in infants with chronic lung disease because of increased anatomical dead space due to stretching of the trachea and increased physiologic dead space.

TV of 6-8mL/kg is often used to achieve good gas exchange in infants with moderate to severe Chronic Lung Disease. For babies with Congenital Diaphragmatic Hernia after birth start with low TV 4mL/kg and high ventilator rates.

4. Setting the Peak Inspiratory Pressure (PIP) limit (P_{max})

During VGV the set PIP is not the same as the delivered PIP because the VG mode continuously alters the delivered PIP to achieve the set TV. The set P_{max} needs to be high enough to allow fluctuations around the average delivered PIP. Start VG ventilation with a PIP limit (P_{max}) of 25 cm H₂O for babies less than 1 kg and 30cm H₂O for babies more than 1 kg. This enables the ventilator to choose a PIP lower than this to deliver the set TV.

Thereafter, the P_{max} can be adjusted to at least 5 to 10 cm H₂O above the working delivered PIP, allowing the ventilator flexibility to deliver the set TV during variable Endotracheal Tube (ETT) leaks and untriggered inflations. The patient and ventilator should be assessed if the delivered PIP progressively

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increases, is persistently high (for example >30 cm H₂O), or if the ventilator frequently alarms 'low tidal volume'.

The main causes are: increasing ETT leak, baby splinting its abdominal muscles against ventilator inflations, untriggered inflations, worsening lung mechanics, air leaks, the ETT slipping down the right main bronchus or ETT kinking.

5. Setting the Trigger Sensitivity

The flow-sensor trigger threshold should be set at its greatest sensitivity. If sensitivity is decreased, triggering is delayed and reduces synchrony between the baby's inspiration and ventilator inflation, and increases work of breathing. Movement of water within the circuit (rain out) is often misinterpreted by the flow sensor as the onset of a breath.

This inappropriately triggers inflations which are out of synchrony with the respiratory rate of the infant's own ventilation. The circuit must be kept free of condensed water. The flow sensor should be positioned with the plug pointing upwards to reduce condensation in the sensor. It is inappropriate to reduce the humidity in the circuit to prevent rain out. The gas must be delivered to the airways at 37 °C and 100% humidity to maintain cilia and mucus function and prevent epithelial dehydration.

6. Setting the Inflation Time (T_i)

Sufficient T_i is required for the pressure to rise to the PIP selected by the ventilator and form a small plateau. If the T_i is too short, the PIP will not rise to a level sufficient to deliver the set TV and a 'low tidal volume' alarm occurs. In an AC mode set the T_i 0.3 s for babies with RDS and < 1 kg which is similar to their spontaneous T_i . Infants with other lung pathologies may need a longer T_i . The appropriateness of the T_i can be evaluated by observing the ventilator graphics. If T_i is set too long, the pressure plateau is held after the inflation flow has stopped and there is no further increase in TV.

7. Setting the Ventilator Back-Up Respiratory Rate (BURR)

When using AC modes select a ventilator back-up BURR.

BURR delivers untriggered inflations if the infant's breathing rate falls below this rate. If the BURR is high, the baby has less opportunity to trigger inflations before the ventilator delivers untriggered inflations.

In a study comparing BURRs of 30, 40 and 50 per minutes in ventilated spontaneously breathing infants, there were most triggered inflations at a BURR of 30 per minutes. It is important that infants trigger as much inflation as they need because their breathing contributes to the TV, and therefore, the delivered PIP required is lower.

However, for infants with apnoea, or a poor respiratory drive, a BURR about 50 to 60 per minutes may be needed to maintain minute volume.

8. Setting the Positive End-Expiratory Pressure (PEEP)

Adequate PEEP is vital to maintain functional residual capacity, prevent atelectasis and improve oxygenation. Most intubated infants will require a PEEP ≥ 5 cm H₂O due to underlying lung disease and the ETT bypassing the larynx.

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Insufficient PEEP may contribute to heterogeneous ventilation, increasing the risk of regional lung injury from local volutrauma and shear stress.

9. The Initial Settings for Babies with RDS and < 1 kg are:

- a. TV 4.5 mL/kg
- b. P_{\max} 25cm H₂O (PIP limit)
- c. PEEP 5 cm H₂O
- d. Inspiratory time 0.3 seconds
- e. Back up respiratory rate of 40 breaths/min

10. Weaning and Extubation from Volume Guarantee Ventilation (VGV)

VG ventilation automatically weans the PIP as an infant's lung function improves. In AC the infant controls the ventilator rate. The only parameters that should be altered during weaning are the FiO₂ and the set TV.

Reducing the ventilator rate during AC has no effect on delivered rate unless respiratory effort is poor or the BURR is greater than the infant's breathing rate. Over-sedation must be avoided during the weaning phase.

When the set TV is below the infant's spontaneously generated TV, the PIP will be reduced, Therefore the infant will be breathing on an ETT with continuous positive airway pressure, potentially increasing work of breathing and the risk of subsequent extubation failure due to fatigue. If the above scenario is observed for more than short periods, extubation should be considered. Weaning is not recommended TV below 3.5 mL/kg.

Consider extubation:

- If the mean airway pressure is consistently <8 to 10 cm H₂O or delivered PIP < 12 cm H₂O in babies < 1kg or delivered PIP < 15 cm H₂O in babies > 1kg, with set TV 3.5 to 4.5 mL/kg.
- FiO₂ less than 35%, blood gases are satisfactory with a good sustained respiratory effort.

11. Alarm, Endotracheal Tube (ETT) Leak and Troubleshooting VGV

The VG option will generate additional alarms due to low tidal volume (TV_{low}).

A 'low tidal volume' or 'ETT obstructed' alarm occurs if there is

- Significant fall in lung compliance,
- Decreased spontaneous respiratory effort,
- ETT slipping into the right bronchus,
- Air leaks
- Forced expiration with tightening of abdominal muscles such that gas entry to the lungs during inflation is prevented, often termed as 'splinting'.

It is critical to evaluate the cause of repeated alarms and correct any correctable problems. Large leak results in underestimation of delivered TV and triggers the

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low tidal volume alarm when the ventilator is unable to reach the target TV at the set P_{max} . In general, VGV can be used with ETT leaks up to 50% because the ventilator adjusts the delivered PIP to deliver the set TV.

An increasing ETT leak with a concomitant rise in delivered PIP may be misinterpreted as worsening lung disease. The number of these TV_{low} alarms may be reduced by increasing the P_{max} if the alarms sounds repeatedly in the absence of excessive leak, obstruction and adequate Ti and then investigate the cause.

In a ventilated infant who is breathing well and has adequate blood gases despite having a large ETT leak, extubation may be appropriate. Otherwise, if an infant has a large ETT leak it is prudent to place a larger ETT rather than turning off VG and leaving TV delivery uncontrolled.

Surfactant administration often causes brief increases in airway resistance and ETT obstruction. To maintain the set TV, the P_{max} should be set 10cm H_2O or more above the pre-surfactant delivered PIP to enable the set TV to be delivered. Within 1 hour, the working delivered PIP falls as lung compliance improves.

Clinical Audit Standards

To ensure that this document is compliant with the above standards, the following monitoring process will be undertaken:

1. All neonates in need of mechanical ventilation should be started on volume guarantee with assist control mode of ventilation

The audit results will be sent to the Women and Children's Clinical Governance Meeting for discussion and to review the results and make recommendations for further action.

Summary of development and consultation process undertaken before registration and dissemination

This guideline was drafted by Dr Rahul Roy, on behalf of the Neonatal Intensive Care Unit. During its development it has been circulated to consultant neonatologist colleagues for comments. It has been presented and discussed at the neonatal unit clinical guidelines meeting (attended by medical, nursing and ANNP staff of the neonatal unit). This version has been endorsed by the Clinical Guideline Assessment Panel.

Distribution List

Hospital Intranet

References

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