

TECHNICAL REPORT

PRESSURE CONTROL VENTILATION–VOLUME GUARANTEED (PCV-VG)

Modern anesthesia ventilators offer a wide variety of ventilation modes, some of them originating from the ICU, enabling complex ventilatory care for the critically ill patient. VCV and PCV represent the basic controlled mechanical ventilation modes used in anesthesia today and are summarized below:

Volume Control Ventilation (VCV)

Volume Control Ventilation (VCV), has been the traditional controlled ventilation mode in anesthesia. In VCV, the ventilator delivers the preset tidal volume (TV) with a constant flow during the preset inspiratory time (T_i) at the preset respiratory rate.

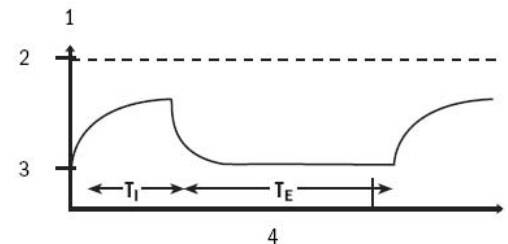
The benefits of VCV are the well-known technique and the controllable Minute Volume.

The concern of VCV is the constant flow that may cause high peak pressures and thus expose the patient to the risk of barotraumas.¹

Gas distribution in the lungs may not be optimal during VCV, as difficult to fill alveoli may not fill until late in the inspiratory time, leaving less time for gas exchange. VCV may not be the ideal ventilation mode for patients with lung disease or for pediatrics. Pediatric patients have very small airways and the small bore ET tubes and LMAs necessary for use in pediatrics may cause high airway resistance. The combination of constant flow and high resistance can produce very high inspiratory pressures. In addition, uncuffed ET tubes may cause airway leaks around the ET tube.

Main Parameters for VCV:

- Tidal Volume (TV) -set in ml
- Respiratory Rate (BPM)
- I:E Ratio -setting for the ratio of Inspiratory time (T_i) to expiratory time (T_E)
- PEEP-Positive end expiratory pressure
- $T_p\%$ = Inspiratory Pause (0-50% of T_i)
- Pressure Limit, P_{max} (cmH₂O)



1. P_{aw}
2. P_{max}
3. PEEP
4. Time

Pressure Control Ventilation (PCV)

Pressure Control Ventilation (PCV), the ventilator generates the preset pressure during a preset inspiratory time at the preset respiratory rate. The pressure is constant during the inspiratory time and the flow is decelerating. PCV provides advantages over volume-controlled breaths 1, 2:

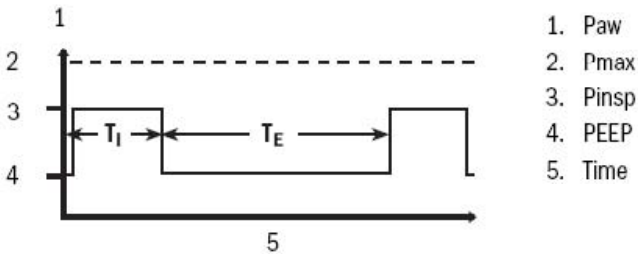
- Lower peak airway pressures to deliver the same volume
- Better volume distribution within the lungs
- Better oxygenation
- Less risk of barotrauma
- Leak compensation without affecting volume delivery to the patient
- Ability to ventilate every patient type.



The one significant disadvantage of pressure control ventilation is that tidal volume delivery will increase and decrease with changes with patient compliance, and is not guaranteed. Extra clinical vigilance is required when using pressure control ventilation to avoid under or over ventilating patients whose compliance changes. These compliance changes may occur due to underlying disease, surgical positioning, presence of surgical packs or retractors, and changes in the degree of relaxation or insufflation.

Parameters for PCV:

- P_{insp} in cmH₂O
- Inspiratory time (T_i) in sec. or I: E Ratio determines the cycling time from insp.to exp.
- Respiratory Rate in breaths/min determines the start of inspiratory time
- PEEP in cmH₂O
- P_{max}-Maximum airway pressure, at which time the ventilator will alarm and end inspiration
- Rise Rate-How quickly the ventilator will reach the targeted airway pressure



1. Paw
2. P_{max}
3. P_{insp}
4. PEEP
5. Time

By combining these two modes VCV and PCV into PCV-VG we are able to realize the advantages of both modes by delivering the preset tidal volume (TV) with a decelerating flow at the lowest possible peak inspiratory pressure during a preset inspiratory time, at the preset respiratory rate thereby enhancing and facilitating patient ventilation.

Aisys Carestation*, Avance Carestation* and AespireView* with PCV-VG

A controlled ventilation mode combining the advantages of Volume control and the clinical benefits of Pressure control ventilation.

Theory of Operation

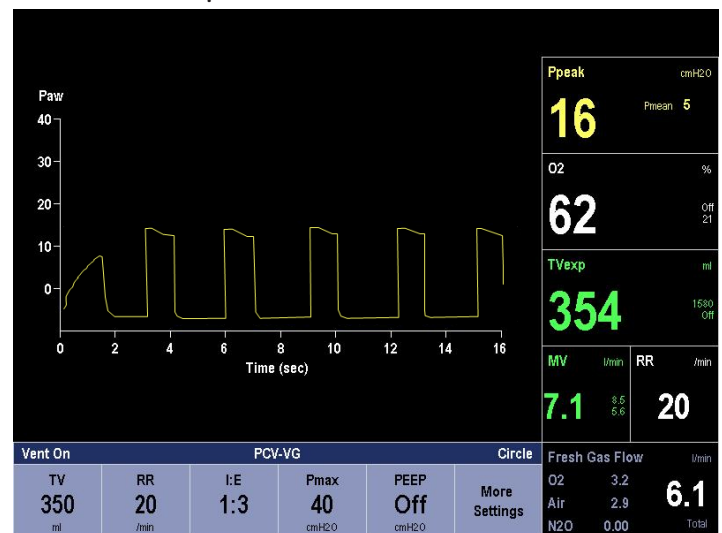
In PCV-VG, the Smartvent 7900 delivers the preset tidal volume with the lowest possible pressure using a decelerating flow. The first breath delivered to the patient is a volume-controlled breath; this is visible on screen with a 'square' flow waveform and 'shark-fin' pressure waveform for the very first breath.

The patient's compliance is determined from this volume breath and the inspiratory pressure level is then established for the subsequent PCV-VG breaths. PCV-VG breaths are characterized by a decelerating flow waveform and square pressure waveform. The screenshot below shows the different flow and pressure waveforms. The yellow highlight shows the volume breath, the red highlight shows the pressure breath.

Screenshot: Aisys & Avance



Screenshot: Aespire View



The Smartvent 7900 will adjust the inspiratory pressure needed to deliver the set tidal volume breath-by-breath so that the lowest pressure is used. The pressure range that the Smartvent 7900 will use is between the PEEP + 2 cmH₂O level on the low end and 5 cmH₂O below P_{max} on the high end. The inspiratory pressure change between breaths is a maximum of ± 3 cmH₂O.

PCV-VG mode will deliver breaths with the efficiency and clinical benefits of pressure controlled ventilation, yet still compensate for changes in the patient's compliance, with consistent tidal volumes.

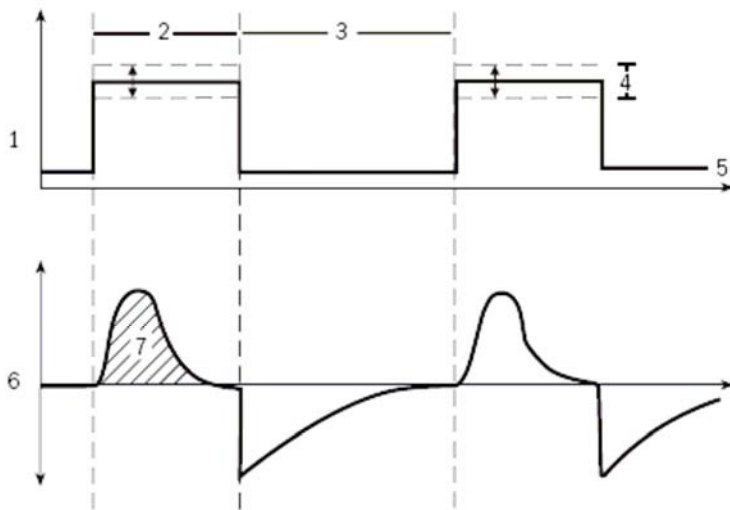
Both pressure control ventilation and volume control ventilation with a decelerating flow waveform (PCV-VG) provide better oxygenation at lower peak inspiratory pressures and higher mean airway pressure compared to volume control ventilation.³

PCV-VG mode settings:

- Tidal Volume (TV) set in ml
- Respiratory Rate (BPM)
- I:E ratio (Ratio of inspiratory time (TI) to expiratory time (TE))
- PEEP-Positive End Expiratory Pressure
- P_{max}
- Rise Rate

SUMMARY OF PCV-VG

1. Delivers the desired tidal volume to the patient, in a decelerating flow pattern, without the constant manual corrections for changes in compliance that would be necessary to achieve a consistent tidal volume when using a pressure control ventilation mode.
2. Offers the benefits of PCV with lowest inspiratory pressure for all breaths, better oxygenation, along with the security of consistent tidal volume.
3. Anesthesia ventilation tailored to the patient's compliance – PCV-VG is useful for underlying disease or any surgical procedure where the patient's compliance is expected to change peri-operatively, such as laparoscopy.
4. Safety features are incorporated to prevent dramatic pressure changes from breath to breath, and a "tidal volume not delivered" warning if the tidal volume is not achievable at the P_{max} less 5 cm H₂O pressure.



References

- 1) Grundlagen der maschinellen Beatmung, Handbuch für Ärzte und Pflegepersonal, Jörg Rathgeber, Aktiv Druck&Verlag
- 2) Pressure-controlled ventilation improves oxygenation during laparoscopic obesity surgery compared with volume-controlled ventilation by P.Cadi, T. Guenoun, D. Journois, J.-M. Chevallier, J.-L. Diehl and D. Safran: British Journal of Anaesthesia 100 (5): 709-16 (2008)
- 3) Journal of Trauma: Injury and Critical Care, November 1996, Volume 41, Issue 5 pp 808-814 "Comparison of Volume Control and Pressure Control Ventilation: Is Flow Waveform the Difference?" Davis, Kenneth Jr. MD, FACS, Branson, Richard D. RRT: Porembka, David T. D.O.

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