

# Can Volume Controlled Ventilation Re-emerge in Pediatric Anesthesia?

**Authors:** PR Bachiller<sup>\*#</sup>, JM McDonough<sup>§</sup>, and JM Feldman<sup>\*</sup>

**Affiliations:** <sup>\*</sup>Dept of Anesthesiology and Critical Care, <sup>§</sup>Division of Pulmonary Medicine, Children's Hospital of Philadelphia; <sup>#</sup>Dept of Anesthesia and Critical Care, Massachusetts General Hospital

**INTRODUCTION:** Pressure controlled ventilation (PCV) is often preferred for pediatric patients in the operating room. Delivered tidal volume ( $V_t$ ) is not assured during PCV, and neither exhaled volume measurement nor end-tidal carbon dioxide measurement can be relied upon to indicate that volume delivery has changed (1, 2, 3). Modern anesthesia ventilators have been designed to consistently deliver accurate  $V_t$  during volume controlled ventilation (VCV) even to very small patients. The goal of this study was to determine if volume delivery during VCV with a modern anesthesia ventilator is accurate enough to be used for pediatric patients.

**METHODS:** Three anesthesia ventilators were evaluated to determine the accuracy of volume delivery to the patient's airway during VCV at volume settings of 100, 200 and 500 mL under different conditions of breathing circuit and lung compliance. All ventilators were tested with two circuit compliance configurations—a fully extended (108") and fully contracted (42") circuit (Ped Circle, Vital Signs, Totowa, NJ). Actual circuit compliance was measured using 20-mL and 50-mL syringes (B-D, Franklin Lakes, NJ), a calibrated screen pneumotachograph (Hans Rudolph, Kansas City, MO) and custom software (TestPoint, Norton, MA). A test lung (Adult/Infant TTL, Michigan Instruments, Grand Rapids, MI) was used to simulate lung compliance for an easy-to-ventilate (peak pressure approx. 30 cmH<sub>2</sub>O) and a difficult-to-ventilate patient (peak pressure approx. 40-50 cmH<sub>2</sub>O) at each of the set  $V_t$ . We tested the 7900 "Smartvent", "Avance" and "Aisys" anesthesia ventilators (GE Healthcare, Madison, WI) and the Apollo anesthesia ventilator (Draeger Medical, Telford, PA). The 7900 and Avance ventilators use inspiratory flow sensors to control the volume delivered, whereas the Aisys and Apollo ventilators compensate for the compliance of the circuit. For all measurements, fresh gas flow was set at 2 L/min of air and 0.2 L/min of O<sub>2</sub>, respiratory rate of 20/min and I:E ratio of 1:2. An airway resistance of 20 cmH<sub>2</sub>O was placed between the circuit and the test lung. Volume delivered to the airway was measured using the same calibrated screen pneumotachograph as above.  $V_t$  measured by the sensor built into the anesthesia machines was also recorded. Three consecutive volume measurements were recorded under each condition of  $V_t$ , circuit and lung compliance.

**RESULTS:** Circuit compliances were 1.6-1.8 mL/cmH<sub>2</sub>O for the extended circuit and 0.8-1.0 mL/cmH<sub>2</sub>O for the contracted circuit. The ventilators using breathing-circuit compliance compensation (Aisys and Apollo) were able to deliver set  $V_t$  to the airway with an accuracy of about  $\pm 5\%$  under all conditions tested. Changing lung compliance most affected the tidal volume delivered to the airway by the other ventilators. With a lung compliance of 2.5 mL/cmH<sub>2</sub>O the percentage of the set tidal volume actually delivered to the airway ranged from 45.6% to 103.7% depending on the type of ventilator (Table). Without compliance compensation, the configuration of the breathing circuit (extended or contracted) had a major effect on the  $V_t$  when lung compliance and  $V_t$  were low (Table). Changing a circuit from contracted to extended reduced the tidal volume delivered to the airway by an additional 20%. The exhaled volume measurement on the Smartvent and the Avance did not accurately measure the  $V_t$  delivered to the airway (except if the optional Avance airway flow-sensor was in place, not shown here). The exhaled volume measured by ventilators using compliance compensation did agree with the set  $V_t$ .

**“Worst Case” Example of Volume Delivery to the Airway  
Target Vt 100 mL, Lung Compliance 2.5 mL/cmH<sub>2</sub>O**

<b>Ventilator</b>	<b>Circuit</b>	<b>Vt at Airway (mL ± Std Dev)</b>	<b>Vt by Machine Volume Sensor (mL ± Std Dev)</b>
7900	Extended	55.4 ± 0.10	110.7 ± 0.82
7900	Contracted	74.6 ± 0.06	110.2 ± 0.75
Avance	Extended	45.6 ± 0.06	89.5 ± 1.05
Avance	Contracted	66.8 ± 0.06	91.2 ± 0.98
Aisys	Extended	99.6 ± 0.06	106.5 ± 1.64
Aisys	Contracted	98.3 ± 0	103.0 ± 1.10
Apollo	Extended	100.0 ± 0.06	100.3 ± 1.63
Apollo	Contracted	103.7 ± 0	96.8 ± 2.71

**DISCUSSION:** Volume delivery can be sufficiently accurate to use VCV to ventilate a pediatric patient in the OR. However, accurate tidal volume delivery requires an anesthesia ventilator capable of compliance compensation, with the pre-use compliance measurement properly performed.

**REFERENCES:**

1. Pan PH, van der Aa JJ. *Can J Anaesth* 1995; 42: 831-5.
2. Hoogerland et. al. *Anesthesiology* 2005; 103: A1393.
3. Stayer et al. *Anesth Analg* 2000; 91: 1145-50.