Fresh Gas Flow Affects Tidal Volume during Pressure Control Ventilation

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Introduction

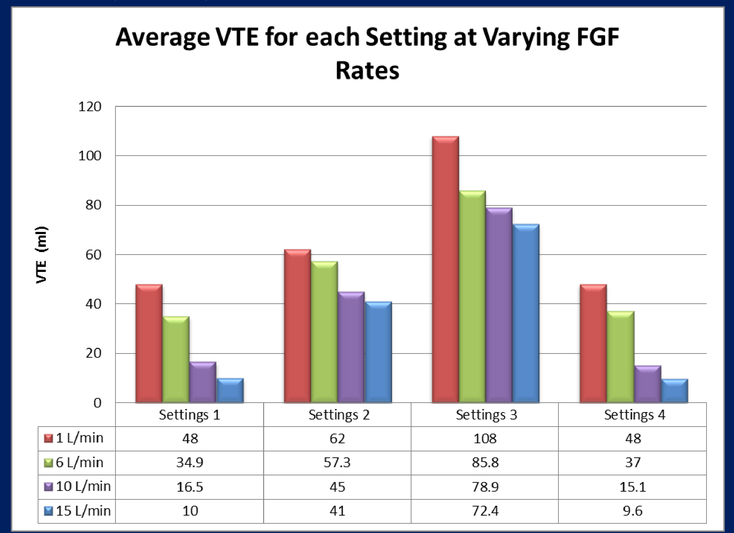
We observed that higher fresh gas flow (FGF) appears to decrease exhaled tidal volume (VT) during pressure control ventilation (PCV). A literature search produced no description of this effect whereby unintended VT changes can cause hypoventilation or barotrauma in infants.[1] We designed and performed bench experiments to investigate our observation.

Methods

To model an infant's lungs, one lung of a mechanical lung model (Dual Adult TTL 1600, Michigan Instruments, Inc., Grand rapids, MI) was set at a compliance of 0.0068 L/cm H2O. An Rp50 resistor (27.2 cm H2O/L/s @ 15 L/min) simulated bronchial resistance.[2,3] The simulated lung was connected to a pediatric breathing circuit via a 3.5-mm cuffed endotracheal tube. A ventilator (Model 7900) with PCV capability (Aestiva, GE Healthcare, Madison, WI) and a flow monitor (NICO, Respironics, Murraysville, PA) measured exhaled VT, peak inspiratory flow, positive end-expiratory pressure (PEEP), and peak inspiratory pressure. In PCV mode, exhaled VT at FGF rates of 1, 6, 10, and 15 L/min reported on the 7900 ventilator display was manually recorded. The initial values for set inspired pressure (10 cm H_2O), I:E ratio (1:2), PEEP (0 cm H_2O), and respiratory rate (20 breaths/min) were later changed for further data collection. Data were analyzed by a non-parametric ANOVA with separate pairwise Wilcoxon signed rank tests used for post hoc analysis. To correct for multiple comparisons, p=0.001 was considered significant.

Results

Higher FGF rates in PCV mode significantly decreased exhaled VT ($p< 0.001$). From post hoc tests for each setting, exhaled VT overall decreased as FGF rate increased ($p=0.0001$ across all settings). Across the multiple ventilatory settings, when comparing FGF rates of 1 to 6, 10 and 15 L/min, exhaled VT decreased by up to 27%, 68%, and 80%, respectively.



	Settings 1	Settings 2	Settings 3	Settings 4
1 L/min	48	62	108	48
6 L/min	34.9	57.3	85.8	37
10 L/min	16.5	45	78.9	15.1
15 L/min	10	41	72.4	9.6

Figure 1: At all settings combinations, there is a consistent decline of exhaled tidal volume as the FGF rate increases. Settings 1 is the standard parameters. Settings 2 added PEEP, settings 3 increased set inspired pressure, and settings 4 decreased respiratory rate.

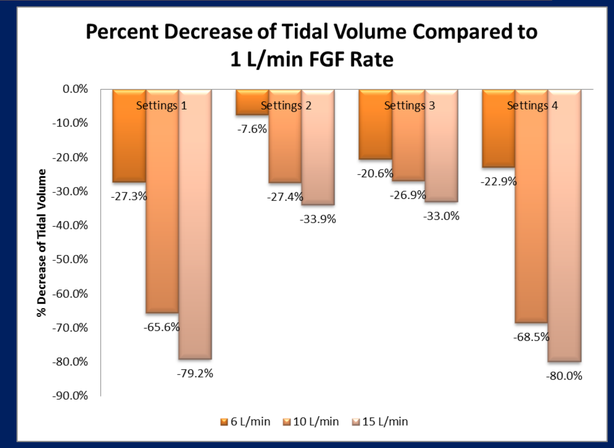


Figure 2: Percent decrease of tidal volume when comparing FGF of 1 L/min to 6, 10, and 15 L/min. The higher the FGF rate, the more drop of tidal volume is noted when compared to 1 L/min FGF.

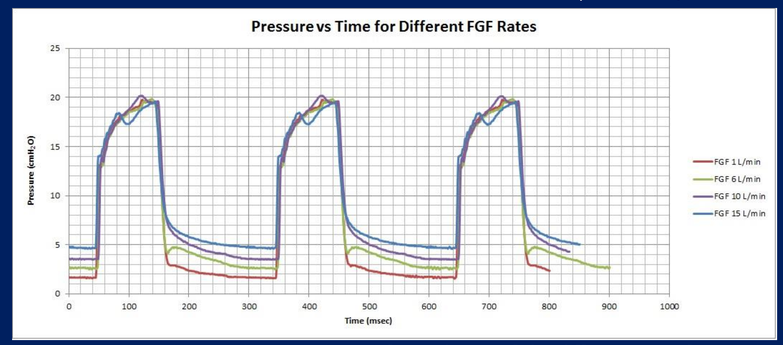


Figure 3: Pressure (cm H_2O) vs time (msec) for each one of the different FGF of 1, 6, 10, and 15 L/min. The data was recorded using a NICO flow monitor which continuously measured pressure at the Y-piece as the ventilator delivered breaths.

Conclusions

We found that FGF has a significant effect on VT during PCV with a bellows ventilator, suggesting caution when changing FGF during PCV in infants. Our hypothesis for this heretofore undescribed interaction is that at higher FGF rates, an inadvertent "PEEP" is developed by the flow resistance of the ventilator relief valve that is not recognized nor compensated for by the ventilator. At a higher unintended baseline "PEEP," less change in pressure is needed to reach the set inspired pressure, resulting in lower VT delivery at higher FGF rates. An option is to use PCV with volume guarantee (PCV-VG), if available. This underappreciated interaction seems to apply to actual patients; data collection with IRB approval in patients is needed to further evaluate the FGF-VT interaction during PCV with a bellows ventilator.

References

1. *Anesth Analg* 2008;106:1392-1400
2. *Pediatrics* 1964;34.4:525-532
3. Nunn's Applied Respiratory Physiology, 7th ed. Churchill Livingstone: Elsevier, 2010

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