Evaluation of Three Small Volume Nebulizers for Use with Infant Ventilator Circuits

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BACKGROUND

Aerosolized medication delivery is common in mechanically ventilated neonates. Medications commonly administered include beta agonists, parasympathetic antagonists, corticosteroids, and antibiotics. We, as well as others, have previously demonstrated that the flow needed to power a conventional small volume nebulizer (SVN) can cause several adverse patient conditions such as altered volume delivery and patient-ventilator dyssynchrony[1] in the spontaneously triggering infant. Metered dose inhalers may obviate the need for SVN devices in some, but not all, situations. Not all of the aforementioned categories of medications are available in MDI form. In addition, depending on the FIO_2 and propellant gas volume, a hypoxic gas mixture may be given in children with V_T of 100ml or less. Dead-space and compressible volume also must be considered.[2] Another option, dry powder inhalers, is not appropriate for mechanical ventilation. New nebulizer technology is currently available that is intended for use with infants receiving mechanical ventilation. This device utilizes a unique vibrational element and aperture plate to create respirable particles without using additional flow.[3] One of the purported benefits of this medication delivery device is that it contributes less external flow into the ventilator circuitry, thereby relieving the known hazards.

PURPOSE

To compare three SVN devices and their impact on ventilation parameters and patient-ventilator synchrony during continuous flow nebulization with infant mechanical ventilation.

MATERIALS AND METHODS

Ventilator model: a Servo 300 ventilator (S300) (Siemens, Danvers, MA)

Settings: pressure control/SIMV mode: frequency (f): 30 B/min, inspiratory time (T_I): 0.4 seconds, PEEP: 4 cm H_2O, peak inspiratory pressure (PIP): 15 cm H_2O above PEEP, pressure support level (PSV): 10 cm H_2O above PEEP, and sensitivity set to the most sensitive flow trigger setting without auto-triggering.

Patient model: a double bellows test lung (Michigan Instruments, Grand Rapids, MI) driven by an LTV-1000 (Pulmonetics, Minneapolis, MN) to simulate an infant spontaneously breathing 40 B/min.

Ventilator settings were the same for all test conditions: The LTV was adjusted to ensure that each spontaneous effort was sensed by the S300 during control conditions (C) resulting in a PSV-supported inspiration.

Airway resistance: 2.5 mm ID endotracheal tube

Lung compliance: 1 ml/cmH_2O

Control (C): an unaltered infant circuit

Nebulizers: All nebulizers were placed in the inspiratory limb of the C circuit at the temperature probe adapter.

#1-The Aeroneb Pro (Aerogen, Sunnyvale, CA) was operated electronically according to the manufacturer's recommendations.

#2- A Mistyneb conventional SVN (Allegiance, McGaw Park, IL) powered by 6 L/min of flow.

#3-A miniHEART SVN (Westmed Inc, Tucson, AZ) powered by 2 L/min of flow.

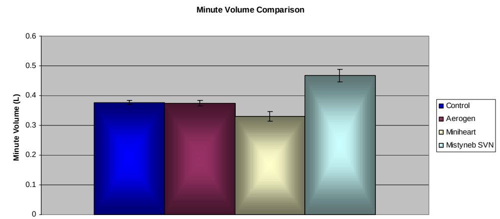
Measurements: V_T, f, minute volume (MV), PIP, PEEP, and T_I

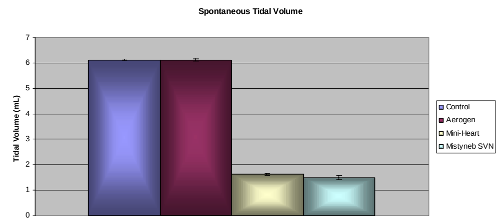
CO_2SMO differential pressure transducer (Novametrix, Wallingford, CT) placed between the ventilator circuit and the ETT (independently displayed values-IDV) for the C and all test conditions.

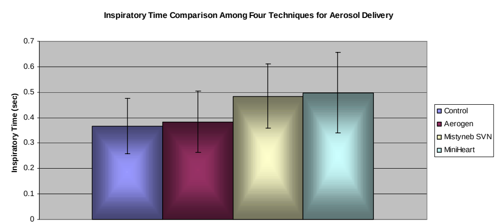
RESULTS

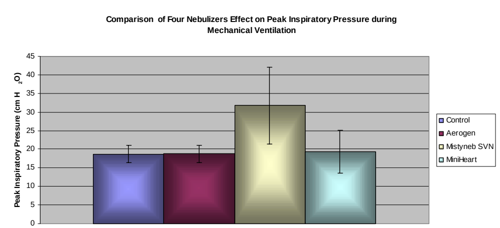
The MV, V_T spontaneous (V_TS), T_I, PIP, and PEEP were significantly different in conditions #2 and #3 compared to the C ($p<0.05$). These parameters were unaltered in condition #1 relative to the C ($p>0.05$).

	MV total (L)	V_T S (ml)	T_I (sec.)	PIP (cm H_2O)	PEEP (cm H_2O)
Control (SD)	0.38 (0.01)	6.10 (0.00)	0.37 (0.11)	18.67 (2.32)	4.51 (0.04)
#1 Aerogen (SD)	0.37 (0.01)	6.11 (0.03)	0.38 (0.12)	18.70 (2.32)	4.47 (0.05)
#2 Mistyneb (SD)	0.47 (0.02)	1.49 (0.08)	0.48 (0.13)	31.77 (10.34)	5.90 (0.07)
#3 MiniHEART (SD)	0.33 (0.02)	1.62 (0.04)	0.50 (0.16)	19.31 (5.81)	4.86 (0.05)









CONCLUSION

Volume change:
- Condition #2 resulted in an increased total MV and a decrease in volume delivered for spontaneous efforts.
- Condition #3 caused a decrease in total MV, possibly because of dyssynchrony, and a decrease in support of spontaneous efforts.
- Condition #1 shows no evidence of change compared to the control.

Pressure change:
- #2 caused an increase in PIP of 13.07 cm H_2O from control and an increase in set PEEP.
- #3 also caused an increase in PIP and PEEP to a lesser extent than condition #2.
- #1 shows no evidence of change compared to the control.

Patient-ventilator dyssynchrony:
- #2 caused a decrease in acknowledged spontaneous effort (V_TS) and an increase in T_I due to added flow.
- #3 resulted in a decrease in total MV, due to unrecognized spontaneous efforts during added flow.
- #1 again caused no change in settings compared to the control.

Compared to the control, condition #1 resulted in the least alteration in set ventilation parameters and patient-ventilator synchrony. Decreased V_TS and increased T_I during conditions #2 and #3 reflect patient-ventilator dyssynchrony not evident during condition #1.
- Condition #1 causes the least change in delivered volumes, inspiratory time, and pressures relative to the control.
- Condition #2 results in the most overall change in chosen parameters.

CLINICAL IMPLICATIONS

Condition #2- Conventional SVN causes:
- over-distention, as evidenced by a 41% increase in PIP and a 24% increase in set PEEP leading to barotrauma.
- relative hyperventilation - An increase in MV from 0.38 L to 0.47 L causes a calculated drop in arterial pCO2 from 40 mmHg to 32 mmHg.
- patient-ventilator dyssynchrony which can be seen as a drastic (76%) decrease in V_TS and a 35% increase in T_I.

Condition #3- Continuous nebulizer causes:
- dyssynchrony- most evident in the decrease in MV and V_TS and the increase in T_I.
- relative hypoventilation - A decrease in MV from 0.38 to 0.33 calculates an increase in arterial pCO_2 from 40 mmHg to 46.1 mmHg.

Condition #1- There is no evidence of these problems in condition #1.

Lung over-distention and patient-ventilator dyssynchrony are a problem in any patient population; however, the consequences may be more obvious and detrimental in neonates and infants. Weight gain is a major focus of medical care for these patients. It is important to control work of breathing (WOB) to decrease energy expenditure in order to facilitate growth. An increased WOB can also delay weaning from the ventilator due to respiratory muscle fatigue.

The Aerogen nebulizer, condition #1, alleviates the problems associated with flow added by either a conventional or miniHEART SVN in this test model. Clinical correlation with this bench model is indicated.

REFERENCES

1. "Continuous In-line Nebulizers Complicate Pressure Support Ventilation" Beaty, Ritz, and Benson: Chest 1989; 96:1360-63.
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