TITLE: AIRWAY RESISTANCE CAUSED BY A PEDIATRIC HEAT AND MOISTURE EXCHANGER

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INTRODUCTION: Disposable heat and moisture exchangers are placed just proximal to an endotracheal tube to warm and humidify inspired gases. Recently, a very small disposable heat and moisture exchanger (Mini Humid-Vent, Gibeck Respiration) has been introduced into clinical practice. The Mini Humid-Vent has a total deadspace of 4.2 ml [when the standard proximal 15 mm (to the Y joint) and distal 22 mm (to the endotracheal tube) connectors are in-line, effective deadspace is 2.7 ml (our measurement)]; as such, the manufacturer recommends the device for pediatric patients who, while breathing spontaneously, have tidal volumes less than 50 ml. Since the humidifier is so small, it may potentially significantly increase airway resistance. The purpose of this study was to measure the airway resistance of the Mini Humid-Vent alone, the airway resistance of standard (National Catheter Corp.) 3.0, 4.0 and 5.0 mm ID endotracheal tubes (with appropriate connectors) alone, and the airway resistance of the Mini Humid-Vent plus an endotracheal tube in series with each other with both dry and humidified gas.

METHODS: The measurement system consisted of, in series, a low-flow rotometer (Lab Crest Series 100, Fischer & Porter Co., calibrated ± 1% from 0-12 L/min), a humidifier with a temperature sensor (Fisher-Paykel Co.), a proximal pressure sensing mechanism, and the test airway device (Mini Humid-Vent, endotracheal tube, or both in series). Two to ten L/min room temperature dry air or 38° C 100% humidified air was used. The pressure proximal to the test device was measured with a calibrated incline water manometer. Since the pressure distal to the test airway device was always atmospheric, the pressure gradient across the test device was always equal to the proximal pressure. At each flow rate, gas flowed through the measurement system until the pressure recorded by the incline water manometer had completely stabilized (approximately 1 min); at each flow rate three determinations were made with variation being less than 1%. The order of flow rates, type of gas, and the test airway device was randomized. Results were analyzed by paired t analysis with $p < 0.05$ considered significant and the results are expressed as mean values.

RESULTS: The Table shows the pressure across the test airway device for the endotracheal tubes alone, the Mini Humid-Vent (MHV in Table) alone, and the Mini Humid-Vent in series with the various endotracheal tubes for both dry and humidified gas. For any given test device at flow rates 6-10 L/min, the resistance was significantly increased with humidified air compared to dry air (the increase ranged approximately 10-30%). The resistance of the 3.0 and 4.0 mm endotracheal tubes greatly exceeded the resistance of the Mini Humid-Vent at all flow rates.

PRESSURE ACROSS TEST AIRWAY DEVICE IN MM H_2O

TYPE OF AIR	TEST AIRWAY DEVICE	FLOW RATE, L/MIN 2	4	6	8	10
DRY AIR	3.0	8.0	24.0	44.0	70.0	96.0
	4.0	2.7	7.2	13.6	23.5	32.0
	5.0	1.7	3.7	5.3	8.6	12.6
	MHV	1.5	3.0	3.9	5.5	6.7
	3.0+MHV	9.3	27.0	47.0	77.0	104.0
	4.0+MHV	3.4	9.3	17.9	30.0	40.0
	5.0+MHV	2.2	4.7	9.4	14.9	19.9
HUMIDIFIED AIR	3.0	10.3	20.0	50.0	79.0	113.0
	4.0	2.5	7.9	20.7	33.0	4.0
	5.0	1.3	3.4	6.4	11.4	18.3
	MHV	1.3	2.8	4.6	6.1	7.6
	3.0+MHV	11.7	31.0	57.0	86.0	120.0
	4.0+MHV	4.2	13.8	24.9	46.0	68.0
	5.0+MHV	2.8	7.2	13.3	21.2	30.0

The Mini Humid-Vent had a resistance approximately equal to a 5.0 mm endotracheal tube at the lower flow rates (2-4 L/min), and had a resistance approximately half the resistance of a 5.0 mm endotracheal tube at the higher flow rates (8-10 L/min). The total resistance of the the Mini Humid-Vent plus the 5.0 mm endotracheal tube was approximately equal to the sum of the individual resistances.

DISCUSSION: The resistances of the 3.0 and 4.0 mm endotracheal tubes are very large and dwarf the resistance of the Mini Humid-Vent. Thus, the addition of the Mini Humid-Vent to either the 3.0 or 4.0 mm endotracheal tube has a negligible effect on the total resistance. However, the Mini Humid-Vent has a resistance approximately equal to that of a 5.0 mm endotracheal tube and, at flow rates of 4 L/min (which is the approximate peak flow rate expected in a pediatric patient spontaneously breathing through a 5.0 mm endotracheal tube[1]), the resistance is doubled by adding the Mini Humid-Vent to a 5.0 mm endotracheal tube. The clinical implication of this latter finding is that the wisdom of allowing an anesthetized patient with a 5.0 mm endotracheal tube and Mini Humid-Vent in-line to breathe spontaneously needs to be carefully considered, and the effectiveness of ventilation under these circumstances (spontaneous ventilation, intubation, anesthetized) needs to be carefully monitored (i.e., end-tidal CO_2 concentration).

REFERENCE

1. Glauser EM, et al: Anesthesiology 33:339, 1961