Title: WORK OF BREATHING AND RESPONSE TIMES DURING SIMV AND PRESSURE SUPPORT VENTILATION BY A MODIFIED PEDIATRIC VOLUME VENTILATOR

Authors: L. D. Martin, M.D., J. F. Rafferty, RRT, R. C. Wetzel, M.B., B.S., F. R. Gioia, M.D.

Affiliation: Department of Anesthesiology and Critical Care Medicine, The Johns Hopkins Medical Institutions, Baltimore, Maryland 21205

Introduction. Volume ventilation in synchronized intermittent mandatory ventilation (SIMV) mode with demand flow ventilators has been shown to impose significant work of breathing during inspiration.[1] A new mode of ventilation, pressure support ventilation (PSV) has been reported to improve ventilator-patient synchrony and decrease imposed work of breathing (W_{imp}). Simple modifications of volume ventilators have been shown to enhance sensitivity and diminish the asynchrony.[2] The purpose of this study was to quantify the performance of a pediatric volume ventilator after several modifications designed to decrease W_{imp} and shorten response time (t_r).

Methods. A test lung was used to quantify volume, pressure, and t_r for assisted ventilation.[3] Minimum withdrawal volume (V_{min}) was defined as that volume of air which, when removed from the circuit, triggered the ventilator in 9 of 10 trials. V_{min} was determined by storing succes-sively increasing volumes (0.5 ml increments) as a vacuum in a syringe and rapidly introducing the vacuum to the ventilator circuit. The ventilator circuit pressure was measured and recorded. Maximum negative pressure (P_{mneg}) was defined as the peak negative pressure deflection. t_r was the time from the initiation of negative pressure to the attainment of 1 cm H_2O positive pressure. W_{imp} required to trigger the ventilator was defined as the product of the V_{min} and P_{mneg}.

Seven Siemens Servo 900C ventilators were tested. Table 1 lists the 16 trial conditions tested on each ventilator by the manipulation of: 1) mode of ventilation (SIMV vs PSV), 2) caliber of ventilator circuit tubing (large vs small), 3) location of ventilator airway pressure transducer (distal vs proximal), and 4) ventilator trigger sensitivity (0 vs -2 cm H_2O). Analysis of variance was used to compare W_{imp} and t_r under all 16 trial conditions. A Duncan multiple range test was used to determine if two means were significantly different ($P < .05$).

Results. There was no difference in W_{imp} between SIMV and PSV (Table 2). W_{imp} was significantly increased by decreasing ventilator trigger sensitivity from 0 to -2 cm H_2O except when small tubing and proximal airway pressure modifications were used. Small bore tubing and proximal pressure monitoring decreased W_{imp} only when trigger sensitivity was at -2 cm H_2O.

Response times were shorter with PSV compared to SIMV. Proximal airway pressure monitoring significantly decreased t_r in all trials. Small bore tubing decreased t_r significantly only when trigger sensitivity was at -2 cm H_2O. Ventilator trigger sensitivity made no difference in t_r.

Discussion. The efficiency of assisted ventilation depends on the ability of the ventilator to sense an inspiratory effort and respond with an adequate gas flow. Until a ventilator responds to a patient's inspiratory efforts, it acts as an inspiratory obstruction and increases work of breathing. This becomes especially important in infants and small children who have higher respiratory rates with correspondingly limited inspiratory time which may result in patient-ventilator asynchrony. Increasing trigger sensitivity will decrease W_{imp} but frequently leads to automatic cycling when used clinically. Both smaller circuit tubing which is less compliant and has smaller volumes; and proximal airway pressure monitoring allow more rapid transmission of pressure waves with decreased W_{imp} and shorter t_r. Shorter t_r were found with PSV compared to SIMV, suggesting that this mode of ventilation may reduce asynchrony in children.

References.

1. Christopher KL, et al: Chest 87:625-630, 1985.
2. Bray JD, et al: Pediatr Res 16:346A, 1982.
3. Epstein RA: Anesth 34:321-326, 1971.

TABLE 1: TEST CONDITIONS

Trial #	Mode of Vent.	Caliber of Tubing	Airway Press. Monitor	Tig. Sens.
1	SIMV	large	distal	0
2	PSV	large	distal	0
3	SIMV	small	distal	0
4	PSV	small	distal	0
5	SIMV	large	proximal	0
6	PSV	large	proximal	0
7	SIMV	small	proximal	0
8	PSV	small	proximal	0
9	SIMV	large	distal	-2
10	PSV	large	distal	-2
11	SIMV	small	distal	-2
12	PSV	small	distal	-2
13	SIMV	large	proximal	-2
14	PSV	large	proximal	-2
15	SIMV	small	proximal	-2
16	PSV	small	proximal	-2

TABLE 2: Mean work of breathing and response time

Trial #	Imposed work of breathing (millijoules/liter)	Response Time (msec)
1	0.20 ± 0.06	127 ± 5
2	0.19 ± 0.06	109 ± 4
3	0.42 ± 0.16	120 ± 9
4	0.43 ± 0.15	109 ± 9
5	0.08 ± 0.04	113 ± 11
6	0.07 ± 0.04	93 ± 8
7	0.04 ± 0.05	102 ± 7
8	0.04 ± 0.01	89 ± 7
9	4.86 ± 1.13	169 ± 23
10	4.52 ± 1.11	131 ± 20
11	1.86 ± 0.55	111 ± 7
12	2.46 ± 0.59	101 ± 5
13	2.58 ± 1.18	132 ± 21
14	2.54 ± 1.25	100 ± 11
15	0.39 ± 0.20	86 ± 6
16	0.21 ± 0.08	79 ± 5

Mean ± SEM