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Proportional Ventilatory Support: A Comparison of Proportional Assist Ventilation, Proportional Pressure Support and Proportional Pressure Ventilation

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Proportional Ventilatory Support: A Comparison of Proportional Assist Ventilation, Proportional Pressure Support, and Proportional Pressure Ventilation

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Introduction: This bench study was conducted to gain more insight into three modes of ventilation that provide inspiratory pressure proportional to the patient's effort, i.e. "Proportional Ventilatory Support" (PVS). The modes included in this study were Proportional Assist Ventilation (PAV+) on the Puritan Bennett 840 (PB 840) and Puritan Bennett 980 (PB 980), Proportional Pressure Ventilation (PPV) on the Philips Respironics V60 (Philips V60), and Proportional Pressure Support (PPS) available on the Drager V500 (Drager V500). Each ventilator was connected to the IngMar Medical ASL 5000 Electronic Lung Simulator set to simulate a COPD model at three different levels of inspiratory efforts. The goal of the study was to determine if the three different modes of PVS provide support proportional to the patient's inspiratory effort.

Methods: The IngMar Medical ASL 5000 Electronic Lung Simulator (ASL 5000) was configured to simulate a COPD lung model using settings recently published by Arnal et al[1]. ASL 5000 settings: compliance 59 ml/cm H_2O; resistance in (inspiratory resistance) 22 cm H_2O/L/sec; resistance out (expiratory resistance) 18 cm H_2O/L/sec; respiratory rate 14 bpm. A 7.5 mm I.D. endotracheal tube was connected to the ASL 5000 inlet and to each ventilator. The simulated inspiratory muscle effort (Pmus) was set on the ASL 5000 at 12 cm H_2O, 18 cm H_2O and 24 cm H_2O. PEEP was set at 7 cm H_2O for all three ventilators, in all modes, and for each level of Pmus. See Table 1 for the ASL 5000 settings and the ventilator settings.

In order to determine the appropriate settings for PPV on the Philips V60 and PPS on the Drager V500, 25%, 45% and 65% of elastance and resistance were used. Resistance was calculated as the average of resistance in and resistance out. Elastance was calculated as the inverse of the compliance set on the ASL 5000.

The ventilator was connected via the ETT to the ASL 5000. ASL 5000 Pmus was set at 12 cm H_2O and the ventilator was set at 25% support (See Table 1). The ventilator was allowed to ventilate the ASL 5000 for 2 minutes; data were gathered automatically by the ASL 5000 software. Data were averaged for 1 minute after allowing stabilization of values. Percent Support was increased to 45% and the ventilator was allowed to ventilate the ASL 5000 as noted above. Then, Percent Support was increased to 65% and the ventilator was allowed to ventilate the ASL 5000 as noted above. Next, the Pmus was increased to 18 cm H_2O, and data were gathered, following the process described above, beginning with a Percent Support of 25%, then 45% and then 65%. Finally, the Pmus was increased to 24 cm H_2O, and the same process was followed. The above-stated process was followed for each of the four ventilators. The variables evaluated include tidal volume, peak inspiratory pressure, inspiratory time, and time-to-trigger.

Table 1: Ventilator Settings

Ventilator	Mode	Percent Support	Additional Settings	ASL 5000 Pmus Settings
PB 840	PAV+	25% 45% 65%	Esens 3 LPM	12, 18, 24 cm H_2O
PB 980	PAV+	25% 45% 65%	Esens 3 LPM	12, 18, 24 cm H_2O
Drager V500	PPS	25% 45% 65%	Flow Assist 5 cm H_2O/L/s; Volume Assist 4.3 cm H_2O/L Flow Assist 9 cm H_2O/L/s; Volume Assist 7.7 cm H_2O/L Flow Assist 13 cm H_2O/L/s; Volume Assist 11 cm H_2O/L	12, 18, 24 cm H_2O
Philips V60	PPV	25% 45% 65%	Max E 17 cm H_2O/L; Max R 20 cm H_2O/L/s	12, 18, 24 cm H_2O

Results: As percent support and/or Pmus increased, tidal volume and peak inspiratory pressure increased on all ventilators, as expected. As percent support increased, time-to-trigger decreased on all ventilators; however, as Pmus increased, time-to-trigger increased. On the PB 840, PB 980 and Drager V500, as percent support increased, inspiratory time increased; conversely, on the Philips V60, as percent support increased, inspiratory time decreased. The PB 980 had the highest average inspiratory time, peak inspiratory pressure and time-to-trigger. Inspiratory time on the PB 980 increased due to multiple inspiratory pauses, used to measure airway resistance and static compliance. The inspiratory pauses were longer on the PB 980 than on the PB 840. See Tables 2, and Figures 1 and 2.

Conclusions: This study demonstrates that as patient effort and/or ventilatory support increased in PAV+, PPV, and PPS the peak inspiratory pressure and tidal volume increased. PPV on the Philips V60 requires the clinician to input the estimated patient's elastance and airway resistance; however, it is not possible to provide an inspiratory pause and actually measure the airway resistance and elastance while ventilating the patient with the Philips V60. Additionally, the airway resistance and static compliance have the potential to change during ventilation as the patient's condition changes. On the Drager V500, Volume Assist and Flow Assist are settings in PPS as a percentage of elastance and percentage of airway resistance, requiring clinicians to alter values based on the changes in elastance and airway resistance. On the PB 840 and PB 980 during PAV+ an inspiratory hold is automatically delivered every 4-10 breaths to calculate resistance and compliance. During the bench study, the PB 980 provided consecutive inspiratory pauses, causing an increase in inspiratory time. Further research is required to evaluate the clinical use of the various modes that provide proportional ventilatory support in patients.

Figure 1: PIP at 45% Support

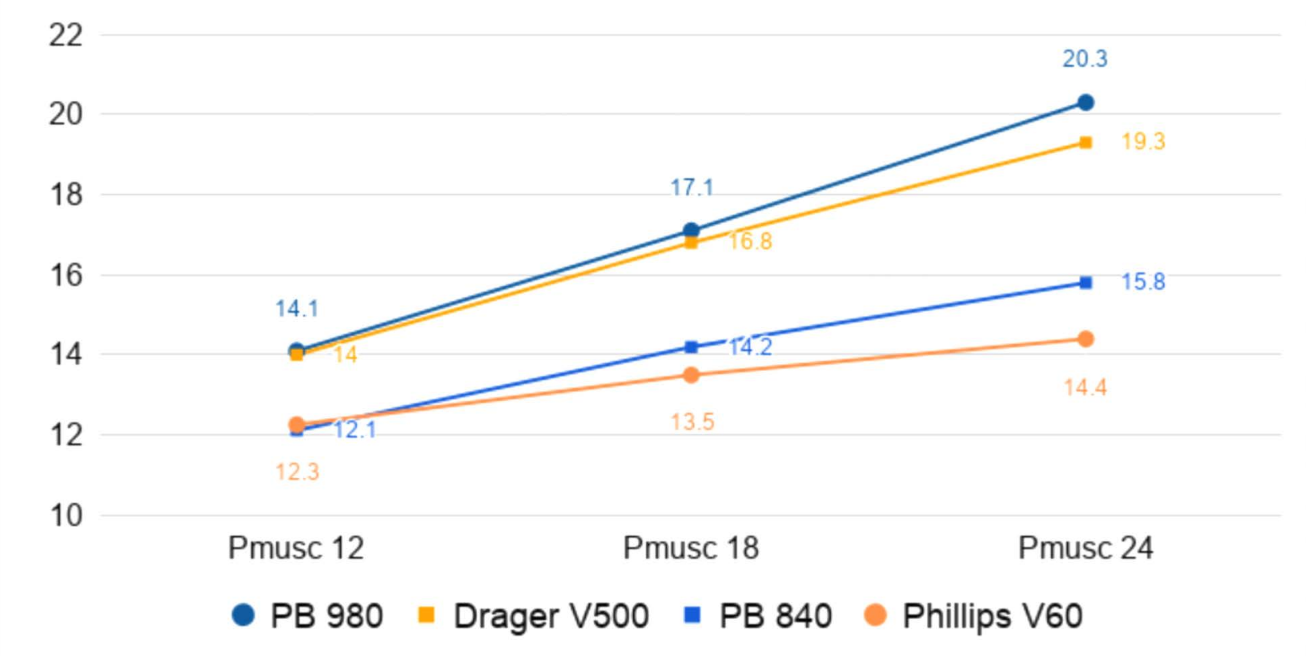

Figure 2: Tidal Volume at 45% Support

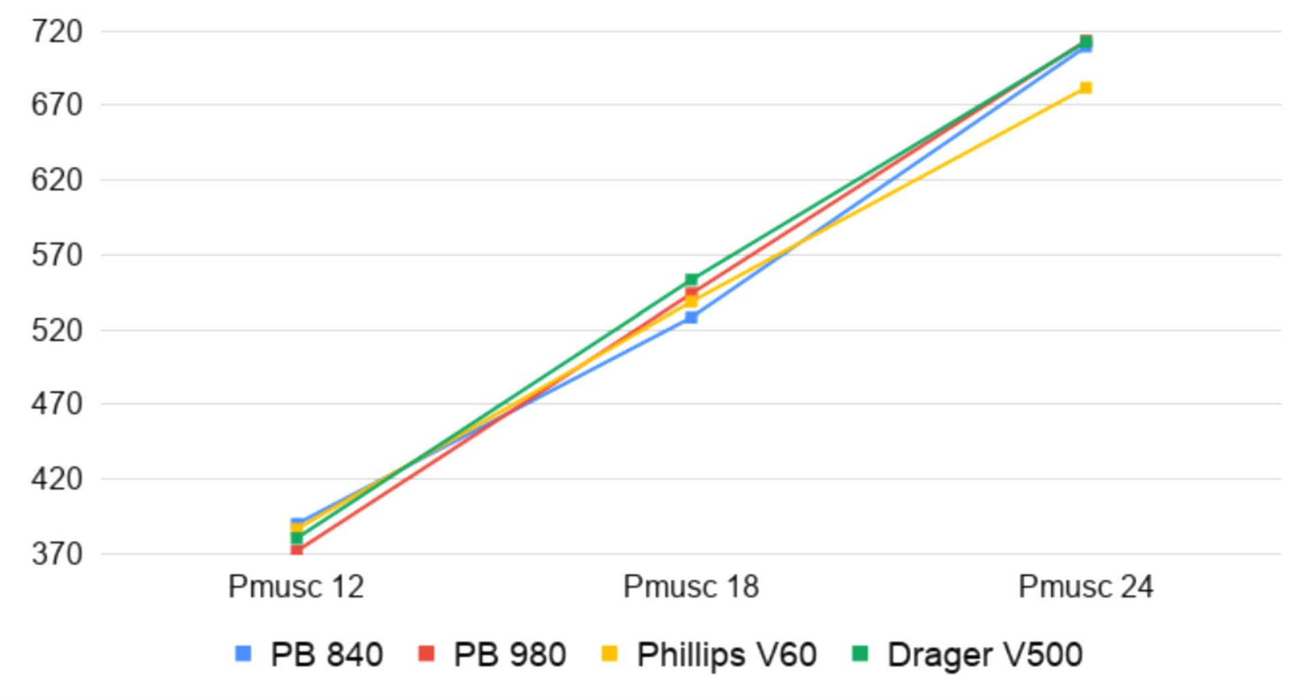

Table 2: Inspiratory Time, Tidal Volume, Time to Trigger and Ppeak Measured Values

	% Support	Pmusc 12 cmH_2O				Pmusc 18 cmH_2O				Pmusc 24 cmH_2O			
		PB 840	PB 980	Philips V60	Drager V500	PB 840	PB 980	Philips V60	Drager V500	PB 840	PB 980	Philips V60	Drager V500
I Time (sec)	25%	1.11	1.17	1.10	1.06	1.12	1.19	1.09	1.07	1.13	1.2	1.09	1.08
	45%	1.14	1.2	1.09	1.11	1.13	1.22	1.07	1.13	1.16	1.22	1.07	1.14
	65%	1.25	1.29	1.06	1.17	1.18	1.3	1.05	1.19	1.16	1.38	1.06	1.19
Insp VT (ml)	25%	293	306	316	298	425	447	450	432	564	585	576	562
	45%	390	372	387	380	528	544	539	553	710	713	682	713
	65%	498	469	501	499	676	707	681	703	889	945	856	885
Time to Trigger (sec)	25%	0.64	0.68	0.40	0.60	0.75	0.71	0.64	0.68	0.79	0.75	0.75	0.78
	45%	0.25	0.53	0.22	0.42	0.37	0.55	0.18	0.46	0.31	0.57	0.16	0.50
	65%	0.26	0.46	0.20	0.37	0.30	0.46	0.17	0.37	0.25	0.48	0.14	0.41
Ppeak (cm H_2O)	25%	9.2	11.3	9.3	10.4	10.35	13.34	9.45	11.83	11.25	15.36	9.09	13.2
	45%	12.1	14.1	12.3	14.0	14.19	17.1	13.52	16.79	15.78	20.27	14.38	19.3
	65%	16.9	18.5	17.7	19.5	20.59	24.46	20.41	23.72	23.17	30.99	22.6	27.47

References: [1]Arnal JM, Garnero A, Saoli M, Chatburn RL. Parameters for Simulation of Adult Subjects During Mechanical Ventilation. Respir Care 2018;63(2):158-168.

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