A look at today's top-end intensive care ventilators: Trigger and pressurization performance

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Introduction

The trigger and pressurization performance of top-end ICU ventilators can significantly impact the patient's work of breathing (WOB). As part of its product development process, HAMILTON MEDICAL tests its ventilators against other manufacturers' devices to ensure that its ventilators perform to standard.

Objective

The objective of this bench testing was to compare the triggering and pressurization performance of five top-end ICU ventilators: the GALILEO Gold (HAMILTON MEDICAL), the RAPHAEL Silver (HAMILTON MEDICAL), the Evita 4 (Dräger), the 840 (Tyco), and the Servo 300 (Siemens).

Materials and methods

In order to follow a well recognized and validated method for comparing the ventilators, we used a study design and lung model similar to that recently reported by Richard and associates.[1] In short, the model is based on two connected compartments of a Michigan Instruments test lung attached to a driver ventilator (a HAMILTON MEDICAL VEOLAR^{FT}) at one side and to a test ventilator on the other side. The test lung resistance and compliance and the driving pressure of the driving ventilator were varied to mimic several clinical conditions.[1] The parameters investigated (Figure 1) were trigger time delay, maximal airway pressure drop, and pressure time product, all of which give an approximation of the patient's WOB required to trigger a breath. The lower these values, the better for the patient.

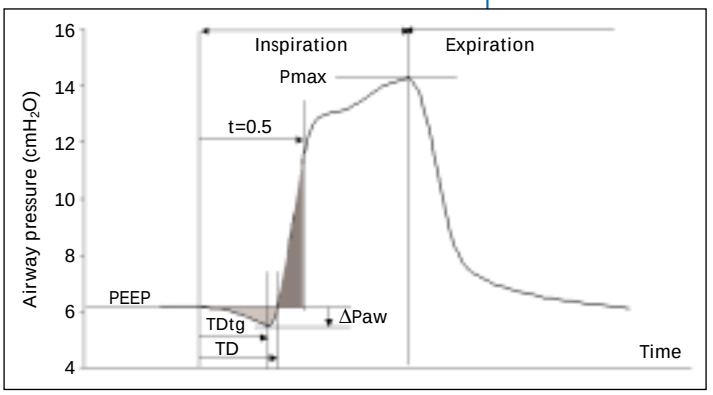

Figure 1: Parameters investigated. The pressure-time product is the gray area and is an approximation of the patient's work of breathing required to trigger the breath. The pressurization process was assessed by the net pressure-over-time after the onset of inspiration and was the sum of the gray and black areas. Abbreviations: TDtg: trigger time delay, TD: time delay; ΔPaw: maximal airway pressure drop; PEEP: positive end expiratory pressure.

The pressurization performance was assessed using the net pressure-over-time area 0.3 and 0.5 s after the onset of inspiration (i.e., the sums of negative and positive pressures over the first 0.3 or 0.5 s of the inspiration). The greater this area, the higher the ventilator-delivered pressure at a given time. To mimic clinical situations, the data were obtained at two levels of driving force, corresponding to P0.1 values of 2 and 4 cmH_2O, and at different levels of pressure support (5, 10, and 15 cmH_2O).

Results

Complete numerical values are given in the appendix.

1. Trigger test

Regardless of the level of PEEP or respiratory drive, the trigger time delay was always less than 0.06 s, except in the Evita 4. In the GALILEO Gold, the Servo 300, and the 840, the delays differed from one another by less than 0.01 s (Figure 2). The RAPHAEL Silver showed better results than the Evita 4 (Figure 2). At a low respiratory drive, the GALILEO Gold showed the best results for the airway pressure drop (Figure 3). At a high respiratory drive, the GALILEO Gold showed results similar to the other ventilators, while the Evita 4 showed a pressure drop higher than 1.5 cmH_2O.

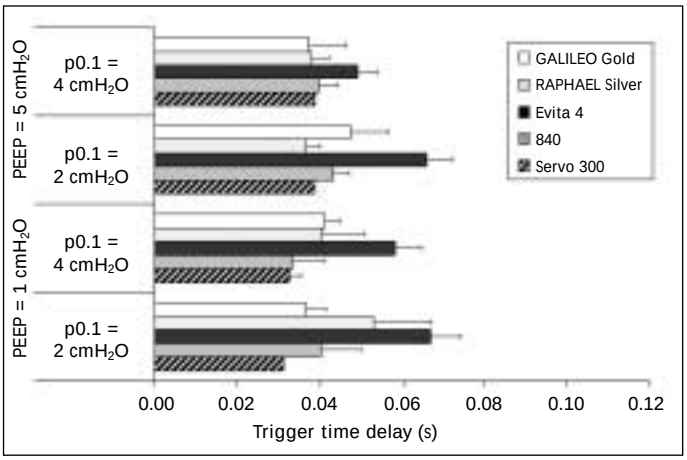

Figure 2: Means ± standard deviation of the trigger time delay was always shorter than 0.06 s, except in the Evita 4. The differences between the GALILEO Gold, the Servo 300, and the 840 were always less than 0.01 s. Abbreviations: p0.1: pressure generated in the airway opening during the first 0.1 s of inspiration; PEEP: positive end expiratory pressure.

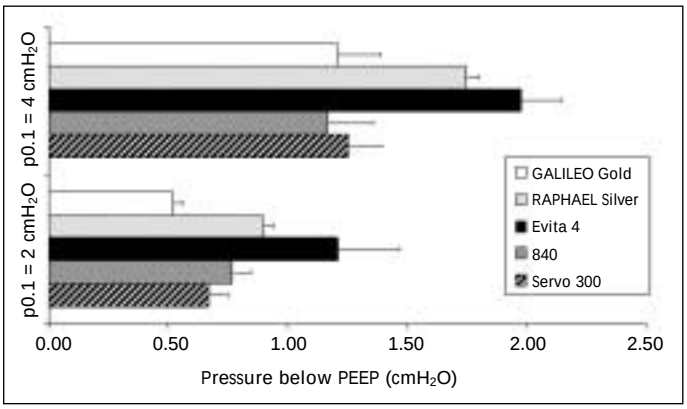

Figure 3: Means ± standard deviation of the pressure drop below PEEP (5 cmH_2O). At p0.1 of 2 cmH_2O, the best result for the airway pressure drop was observed with the GALILEO Gold. At a high level of drive, the GALILEO Gold gave results similar to other ventilators. The Evita 4 always gave a pressure drop greater than 1 cmH_2O. Abbreviations: p0.1: pressure generated in the airway opening during the first 0.1 s of inspiration; PEEP: positive end expiratory pressure.

2. Pressurization test

The ventilators showed very similar net areas under the pressure-time curve at 0.5 s. These values depended on the level of pressure support and drive (see the appendix). With the exception of the RAPHAEL Silver, at 15 cmH_2O of pressure support the differences between the ventilators never exceeded 1 cmH_2O per second, even at a high level of drive.

Discussion

Our results are in line with those of Richard and associates.[1] The triggering and pressurization performance of the current GALILEO ventilator was very similar to that of the 840 and Servo 300. The Evita 4 showed lower performance. Significant improvements in triggering and pressurization performance were noted between the first GALILEO version and the latest,[2] which was tested for this study. Finally, except for the Evita 4, the differences between the GALILEO Gold and the other ventilators were very marginal and might be of no clinical relevance.

For this study, 8 GALILEO units were tested under the same conditions. Only marginal deviations were noted in the measured parameters, indicating a stable production quality.

Interestingly, the lower-end RAPHAEL Silver ventilator exhibited triggering performance very similar to the top-end ventilators (Figures 2 and 3). It exhibited acceptable pressurization performance at low or normal drive (see the appendix).

Conclusions

In keeping with previous studies,[1] the present results confirm the high performance of the GALILEO Gold ventilator in terms of triggering and pressurization. They also confirm the high performance of the mid-range RAPHAEL Silver ventilator.

References

1. Richard J-C. et al: Bench testing of pressure support ventilation with three different generations of ventilators. Intensive Care Med 2002, 28:1049-1105.
2. Tassaux D. et al: Comparative bench study of triggering, pressurization, and cycling between the home ventilator VPAP II and three ICU ventilators. Intensive Care Med 2002, 28:1254-1261.

Appendix: Mean values under all investigated conditions

	PEEP (cmH_2O)	P0.1 (cmH_2O)	GALILEO Gold	RAPHAEL Silver	840	Evita 4	Servo 300
TDtg (s)	1	2	0.037	0.0531	0.041	0.067	0.031
	1	4	0.041	0.0408	0.034	0.059	0.033
	5	2	0.048	0.0367	0.043	0.066	0.039
	5	4	0.038	0.0383	0.04	0.049	0.039
TD (s)	1	2	0.057	0.0711	0.048	0.07	0.031
	1	4	0.078	0.0634	0.05	0.063	0.035
	5	2	0.059	0.0633	0.054	0.073	0.041
	5	4	0.076	0.0633	0.056	0.056	0.046
ΔP (cmH_2O)	1	2	0.743	0.9611	0.525	1.264	0.489
	1	4	1.656	1.4220	1.151	2.367	0.716
	5	2	0.519	0.8955	0.765	1.206	0.665
	5	4	1.205	1.7450	1.167	1.973	1.252
PTP ($cmH_2O.s$)	1	2	-0.023	-0.0411	-0.015	-0.039	-0.008
	1	4	-0.067	-0.0522	-0.033	-0.082	-0.011
	5	2	-0.016	-0.0345	-0.021	-0.047	-0.013
	5	4	-0.055	-0.0614	-0.033	-0.06	-0.022

	Effort	PS level (cmH_2O)	GALILEO Gold	RAPHAEL Silver	840	Evita 4	Servo 300
A0.3 ($cmH_2O.s$)	Low	5	0.18	0.1497	0.371	0.16	0.481
	Moderate	5	-1.056	-0.8502	-0.275	-0.666	-0.311
	High	5	-2.667	-2.3485	-1.572	-2.186	-1.813
	Low	10	0.587	0.5161	0.872	0.699	1.023
	Moderate	10	-0.2	-0.1508	0.509	0.177	0.642
	High	10	-1.795	-1.6621	0.809	-1.349	-0.968
	Low	15	1.071	0.8519	1.348	1.156	1.512
	Moderate	15	0.613	0.4608	1.184	1.038	1.314
	High	15	-0.954	-1.0682	-0.008	-0.56	-0.171
A0.5 ($cmH_2O.s$)	Low	5	0.64	0.6291	0.985	0.685	1.22
	Moderate	5	-1.004	-0.8782	0.142	-0.433	0.135
	High	5	-3.797	-3.7832	-2.297	-3.242	-2.668
	Low	10	1.555	1.4097	1.993	1.737	2.278
	Moderate	10	0.9	0.7346	1.687	1.351	1.934
	High	10	-1.842	-2.2559	-0.667	-1.477	-0.897
	Low	15	2.613	2.1759	2.994	2.72	3.33
	Moderate	15	2.318	1.8701	2.881	2.743	3.182
	High	15	0.05	-0.8591	1.003	0.192	0.85

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