Noninvasive ventilation in critically ill patients: Ventilator trigger and pressurization performance

Barbara Camen, ICU Nurse and Product Manager, HAMILTON MEDICAL AG
Marc Wysocki, MD, Head of Medical Research, HAMILTON MEDICAL AG

Noninvasive ventilation (NIV) is widely used to support ventilation in critically ill patients with acute respiratory failure. Previous investigations have compared the characteristics of homecare-design NIV ventilators, but few have compared NIV ventilators specifically designed for patients presenting with severe acute respiratory failure. The aim of this paper is to compare the triggering and pressurization performance of two ICU-design NIV ventilators: the BIPAP® Vision® (Respironics®) and the RAPHAEL Color (HAMILTON MEDICAL). The present study found that both NIV ventilators provide better triggering and pressurization performance than homecare-design NIV ventilators, and that the RAPHAEL Color showed better performance than the Vision ventilator, with the added benefit that it can also be used if the patient ultimately requires endotracheal intubation.

Introduction

Noninvasive ventilation (NIV) is widely used to support ventilation in critically ill patients with acute respiratory failure[1,2]. It has been proven to eliminate the need for endotracheal intubation and to improve survival in chronic hypercapnic patients with acute exacerbation[3] as well as in specific hypoxemic patients[4]. NIV is also used to shorten the weaning period in endotracheally intubated patients[5] or to prevent reintubation in patients with respiratory failure, after extubation[6].

In these cases, NIV aims to eliminate the need for, or shorten the duration of, endotracheal intubation. The ease and success with which NIV achieves these goals is partly related to the triggering and pressurization performance of the ventilator used[4,7].

Previous investigations have compared the characteristics of homecare-design NIV ventilators[8,9], but few have compared NIV ventilators specifically designed for patients presenting with acute respiratory failure. The aim of this paper is to compare the triggering and pressurization performance of two NIV ventilators designed for patients with acute respiratory failure: the BIPAP® Vision® (Respironics®) and the RAPHAEL Color (HAMILTON MEDICAL). As a starting point for the comparison, two homecare-design NIV ventilators have been included in the study: the LEGENDAIR® (AIROX) and the BiPAP Synchrony® (Respironics).

Materials and methods

A well recognized and validated method to assess ventilator performance was used. This method was recently reported by Richard and associates[10]. In short two connected compartments of a Michigan Instruments test lung were attached to a driver ventilator (VEOLAR^{FT}, HAMILTON MEDICAL) on one side and to the ventilator under test on the other side. The test lung resistance and compliance and the driving pressure of the driver ventilator were varied to mimic several clinical conditions.

The parameters investigated (Figure 1) were trigger time delay (TD_{tg}), maximal airway pressure drop (dPaw), and pressure time product (PTP), all of which give an approximation of the patient's WOB required to trigger the breath. The lower these values, the better for the patient.

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 larger this area, the faster and greater the patient support.

To mimic clinical situations, data were obtained at two levels of driving force, corresponding to P0.1 values of 2 and 4 cmH_2O, at different levels of pressure support (5, 10, and 15 cmH_2O) and PEEP (1 and 5 cmH_2O).

Results

Complete numerical values are given in the appendix.

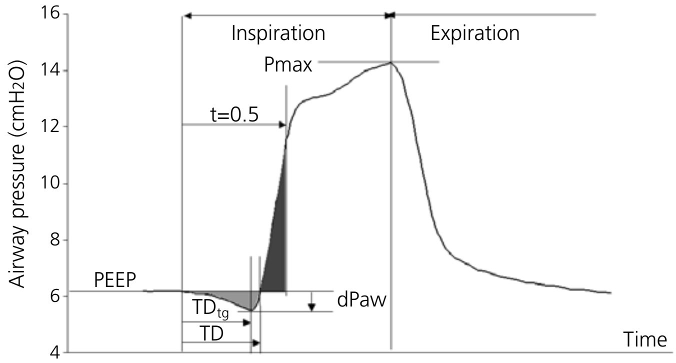

Figure 1. Parameters investigated. The pressure-time product is the gray area and is an approximation of the patient's work of breathing required to trigger the breath. The pressurization process was assessed by the net pressure-over-time after the onset of inspiration and was the sum of the gray and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

Trigger performance

The shortest trigger time delay (TD_{tg}) was observed with the RAPHAEL (Figure 2) with values close to 50 ms as compared to 80 to 100 ms with the other ventilators. Similar results were observed for the time delay (TD); see appendix.

The pressure drop below PEEP of 5 cmH_2O (dPaw) was similar for all the ventilators tested (Figure 3).

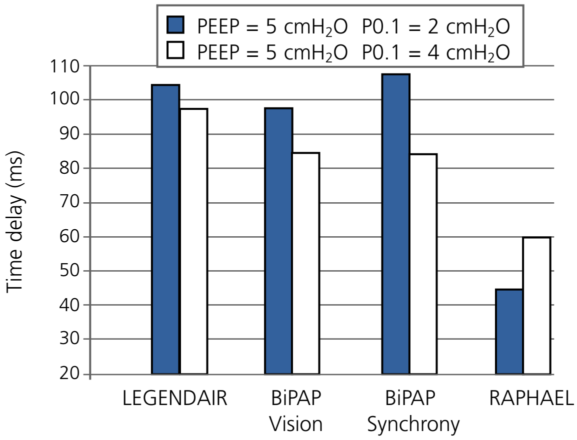

Figure 2. Breath triggering time delay in test ventilators

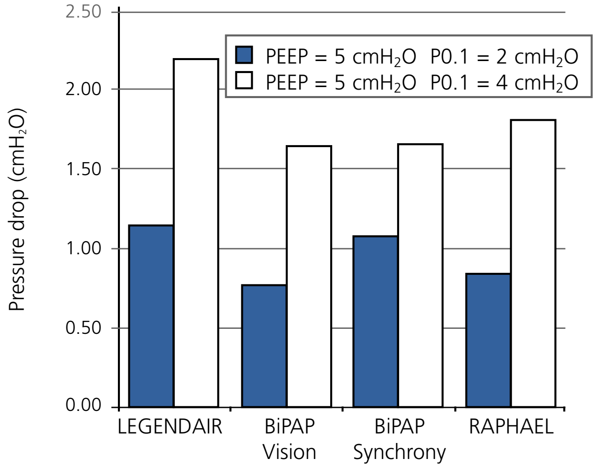

Figure 3. Trigger pressure drop in test ventilators

Pressurization performance

The two NIV ventilators (Vision and RAPHAEL) clearly showed much better pressurization performance than the homecare-design ventilators (see appendix). The differences are obvious in cases with high respiratory drive: the homecare-design NIV ventilators could not generate a positive pressure even 1 s after the beginning of inspiration (Figure 4). In all cases, the RAPHAEL ventilator showed slightly better performance than the Vision ventilator (Figure 4).

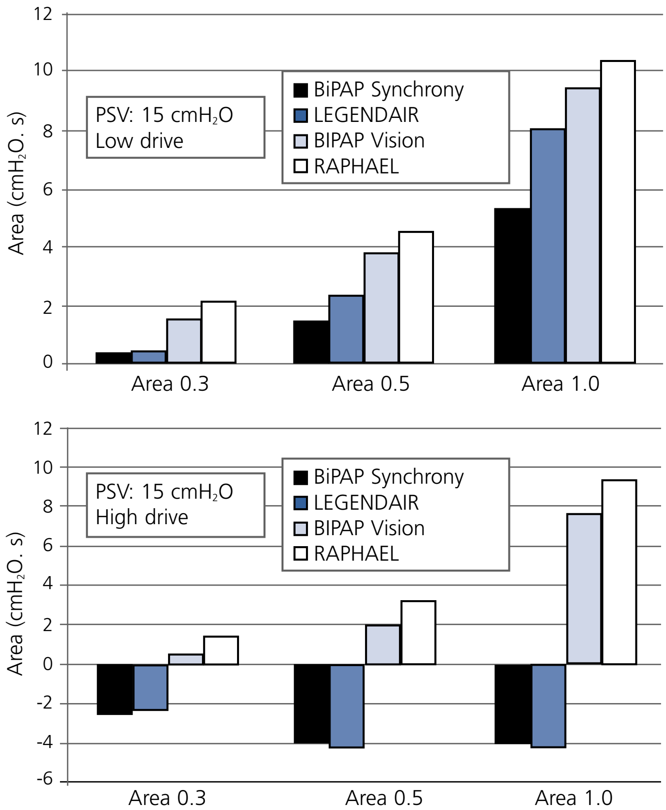

Figure 4. Area under the pressure-time curve at 0.3, 0.5, and 1 second in low and high drive situations

Discussion

This study is unique in comparing two NIV ventilators designed for patients with acute respiratory failure. This comparison is of clinical value since respiratory mechanics and driving conditions of patients with acute respiratory failure are different from those observed in stable homecare ventilated patients. Most importantly, patients with acute respiratory failure are in unstable and life-threatening situations and the ventilator should be able to respond and deliver the pressure as fast as possible. The present study clearly confirms the superiority of triggering and pressurization performance in NIV ventilators for patients with acute respiratory failure. In all cases investigated, the RAPHAEL showed slightly better performance than the Vision ventilator, possibly because of the difference in the pressure generation system (turbine-based in the Vision ventilator). The differences observed might be of marginal clinical impact—usability and other clinical considerations should also be taken into account.

NIV failed in 20 to 50% of the cases. These failures were related to the situation and to the severity of the patient's illness. This means that invasive ventilation should be introduced or reintroduced in half to a quarter of the patients. Ideally, a device such as the RAPHAEL, which can provide both noninvasive and invasive ventilation to the highest ICU standards, should be used.

Conclusions

The present study found that the NIV ventilators designed for patients with acute respiratory failure provide better triggering and pressurization performance than homecare-design NIV ventilators. The RAPHAEL ventilator showed slightly better performance than the Vision ventilator. It also has the added benefit that, if the patient ultimately requires endotracheal intubation, it can be used without need to switch ventilators. The RAPHAEL's complete and advanced monitoring capabilities, including lung mechanics and trends, suit it well for such a contingency.

References

1. Carlucci A, Richard JC, Wysocki M, Lepage E, Brochard L. Noninvasive versus conventional mechanical ventilation. An epidemiologic survey. Am J Respir Crit Care Med 2001; 163(4):874-80.
2. Esteban A, Anzueto A, Frutos F, Alia I, Brochard L, Stewart TE et al. Characteristics and outcomes in adult patients receiving mechanical ventilation: a 28-day international study. JAMA 2002; 287(3):345-55.
3. Brochard L, Mancebo J, Wysocki M, Lofaso F, Conti G, Rauss A et al. Noninvasive ventilation for acute exacerbations of chronic obstructive pulmonary disease [see comments]. N Engl J Med 1995; 333(13):817-22.
4. Wysocki M, Antonelli M. Noninvasive mechanical ventilation in acute hypoxaemic respiratory failure. Eur Respir J 2001; 18(1):209-20.
5. Nava S, Ambrosino N, Clini E, Prato M, Orlando G, Vitacca M et al. Noninvasive mechanical ventilation in the weaning of patients with respiratory failure due to chronic obstructive pulmonary disease. A randomized, controlled trial. Ann Intern Med 1998; 128(9):721-8.
6. Esteban A, Frutos-Vivar F, Ferguson ND, Arabi Y, Apezteguia C, Gonzalez M et al. Noninvasive positive-pressure ventilation for respiratory failure after extubation. N Engl J Med 2004; 350(24):2452-2460.
7. Wysocki M. Non-invasive ventilation in acute respiratory failure: Technological issues. In: Vincent JL, editor. Yearbook of Intensive Care and Emergency Medecine. Berlin: Springer, 1998: 519-527.
8. Bunburaphong T, Imanaka H, Nishimura M, Hess D, Kacmarek RM. Performance characteristics of bilevel pressure ventilators: a lung model study. Chest 1997; 111(4):1050-1060.
9. Stell IM, Paul G, Lee KC, Ponte J, Moxham J. Noninvasive ventilator triggering in chronic obstructive pulmonary disease. A test lung comparison. Am J Respir Crit Care Med 2001; 164(11):2092-2097.
10. Richard JC, Carlucci A, Breton L, Langlais N, JABER S, Maggiore S et al. Bench testing of pressure support ventilation with three different generations of ventilators. Intensive Care Med 2002; 28(8):1049-1057.

Appendix: Mean values under all investigated conditions

Parameter	PEEP (cmH_2O)	P0.1 (cmH_2O)	Ventilator			
			LEGENDAIR	Synchrony	Vision	RAPHAEL
TD_{tg} (ms)	1	2	0.11	—	—	0.05
	1	4	0.08	—	—	0.04
	5	2	0.1	0.1	0.1	0.04
	5	4	0.09	0.08	0.08	0.06
TD (ms)	1	2	0.82	—	—	0.08
	1	4	1.86	—	—	0.07
	5	2	1.14	0.14	0.15	0.07
	5	4	2.2	0.12	0.13	0.08
dPaw (cmH_2O)	1	2	0.82	—	—	0.62
	1	4	1.86	—	—	1.62
	5	2	1.14	1.09	0.78	0.85
	5	4	2.2	1.66	1.65	1.82
PTP (cmH_2O.s)	1	2	0.12	—	—	0.03
	1	4	0.28	—	—	0.06
	5	2	0.12	0.09	0.07	0.04
	5	4	0.24	0.12	0.14	0.08
Area 0.3 (cmH_2O.s)	5	2	-0.03	—	0.31	0.59
	5	4	-2.42	—	-0.72	-0.36
	10	2	0.08	—	0.64	1.41
	10	4	-2.23	—	0.05	0.54
	15	2	0.43	0.37	1.47	2.17
	15	4	-2.38	-2.48	0.55	1.59
Area 0.5 (cmH_2O.s)	5	2	0.71	—	1.15	1.43
	5	4	-4.47	—	-0.98	-0.38
	10	2	1.40	—	2.17	2.92
	10	4	-4.13	—	0.70	1.29
	15	2	2.38	1.48	3.81	4.48
	15	4	-4.27	-3.96	1.99	3.39
Area 1 (cmH_2O.s)	5	2	2.76	—	3.30	3.48
	5	4	-4.15	—	0.07	1.03
	10	2	5.22	—	6.26	6.98
	10	4	-1.68	—	4.14	5.21
	15	2	8.10	5.32	9.52	10.39
	15	4	-0.98	-2.20	7.63	9.58

689231/00 © HAMILTON MEDICAL AG 2005. All rights reserved. Printed in Switzerland.

HAMILTON MEDICAL AG
Via Crusch 8
CH-7402 Bonaduz
Switzerland
Phone: (+41) 81 660 60 10
Fax: (+41) 81 660 60 20

Visit our website
www.hamilton-medical.com
www.IntelligentVentilation.org

Swiss Quality

HAMILTON MEDICAL