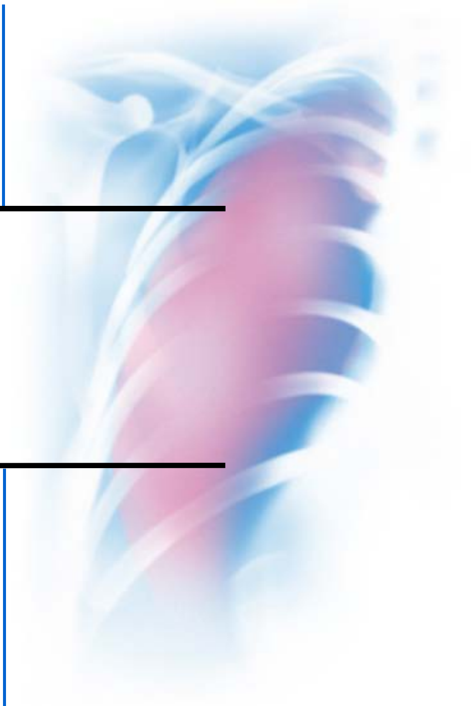

New Modes of Ventilation:

Proportional Assist Ventilation; Adaptive Support Ventilation; SmartCare.

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Introduction

Proportional Assist Ventilation (PAV), Adaptive Support Ventilation (ASV) and SmartCare (SC) are new modes of ventilation that have recently become available on the market. Although these modes have numerous similarities, there are several important differences that clinicians should be aware of to ensure successful and appropriate application of each. The present paper will describe each mode and will propose a synthetic comparison to enhance the clinician's understanding of how to implement each of them into his or her daily practice.

Similarities

Each of these modes aims to provide ventilatory support according to measured patient characteristics:

- PAV according to the patient's effort, based on the respiratory flow signal;
- ASV according to the patient's respiratory mechanics, based on the expiratory time constant and lung compliance;
- SC according to the patient's respiratory comfort, based on the spontaneous respiratory rate, the tidal volume, and the end-tidal CO_2.

In other words, each mode tries to match the ventilator output to the demands of the patient as much as possible.

All these modes work by using at least one closed-loop algorithm:

- PAV by adjusting inspiratory airway pressure in proportion to the patient's effort;
- ASV by adjusting respiratory rate and inspiratory airway pressure according to the patient's respiratory mechanics;
- SC by adjusting inspiratory airway pressure according to the patient's respiratory rate, tidal volume, and end-tidal CO_2.

With each mode, the main output is the inspiratory airway pressure. However, because ASV incorporates two closed-loop algorithms, an additional output for respiratory rate is also available.

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Descriptions

Proportional Assist Ventilation

PAV was first described in 1992 by Magdy Younes[1,2]. PAV is a pressure-regulated mode of ventilation, in which the pressure within each breath is titrated by the ventilator in proportion to the patient's inspiratory airflow, which is used as an estimate of the patient's respiratory muscle effort. The proportionality between flow and airway pressure is determined by a

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"gain" setting, which is adjusted by the clinician to determine the proportions of the total work of breathing to be performed by both ventilator and patient. In contrast with previous modes of ventilation, in PAV, the clinician sets the "gain" (proportion of work of breathing, expressed as a percentage) based on the patient's respiratory mechanics. In other words, resistance (R_{rs}) and compliance (C_{rs}) of the respiratory system are evaluated and the percentage of assistance adjusted accordingly. However, in addition to the difficulties associated with assessment of R_{rs} and C_{rs} in actively breathing patients, PAV may become unstable in certain situations, or if the gain is improperly set. This potential complication of PAV has been termed "runaway", and results when the algorithm-induced changes affect an input variable, thereby creating an undesirable change to the output, in a cyclical fashion (increasing pressure results in increased flow, which may increase measured R_{rs}, resulting in further increases in pressure).

Adaptive Support Ventilation

ASV was introduced in 1994 by Laubscher and coworkers[3,4]. ASV may be thought of as an "electronic ventilator protocol" that incorporates the most recent and sophisticated measurement tools and algorithms in an attempt to make ventilation safer, easier, and more consistent. This mode is designed to accommodate not only ventilated patients who are passive, but also those who are actively breathing. ASV recognizes spontaneous respiratory activity and automatically switches the patient between mandatory pressure-controlled breaths and spontaneous pressure-supported breaths.

With ASV, the clinician determines the desired minute ventilation, and the algorithm determines the optimal respiratory-rate/tidal-volume combination according to the patient's respiratory mechanics. Any change in respiratory mechanics or patient effort results in an updated optimal breathing pattern (respiratory-rate/tidal-volume combination), and ASV continuously and gently moves the patient to the new, updated, target. Intelligent breath-to-breath safety rules maintain ventilation parameters within safety ranges, and if for any reason the patient fails to breathe actively, ASV automatically increases the number of mandatory pressure-controlled breaths needed to maintain the minute volume target. Additional safety limits minimize intrinsic PEEP, and avoid hypoventilation, high deadspace ventilation, and baro- and volu-trauma.

The intrinsic requirement for determination of the optimal breathing pattern is the breath-to-breath measurement of respiratory mechanics, including the expiratory time constant, based on the volume-flow loop method[5]. Figure 1 shows a part of the ASV screen as implemented on GALILEO, with the selected minute ventilation target (green curve), respiratory-rate/tidal-volume target (target circle), the patient's current status (yellow cross), and the safety frame (large red rectangle).

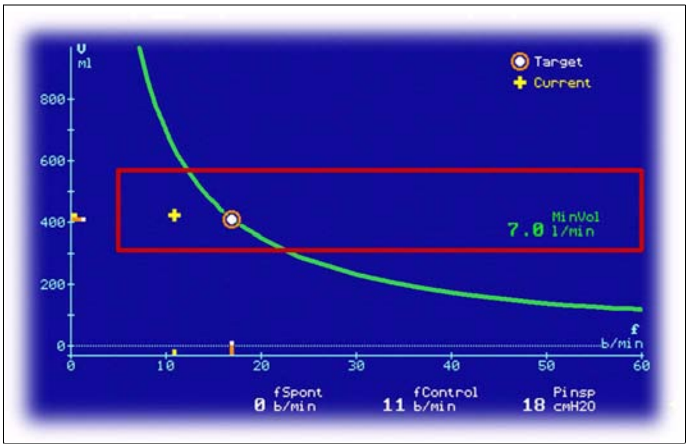

Figure 1: Highlight from the ASV screen implemented on GALILEO.

By monitoring the trended total respiratory rate, spontaneous respiratory rate, and inspiratory pressure, respiratory staff can determine the patient's medium- and long-term response and interaction with ASV.

SmartCare

SC is a mode of ventilation specifically designed to expedite the weaning process. It utilizes only pressure support breaths, with varying levels of inspiratory pressure. The principle was initially developed using a HAMILTON MEDICAL[6,7] ventilator that used the measured respiratory rate to adjust the level of PSV (increasing PSV if RR is high, decreasing PSV if RR is low). The level of pressure support is also adjusted to maintain tidal volume (V_T) above, and $PetCO_2$ below, certain values. The switch from controlled ventilation to SC, and back to controlled ventilation, is not automatic, and requires manual intervention.

Comparisons

Table 1 summarizes the main differences between PAV, ASV and SC.

Based on these comparisons, it appears that PAV might be used in active patients in which the patient-ventilator synchrony is a concern. PAV has been used extensively during noninvasive ventilation, even though approximation in R_{rs} and C_{rs} in this application may limit its effectiveness in reducing the work of breathing[8,9].

Although SC is a mode of ventilation designed to expedite weaning, patient readiness and ability to wean still needs to be assessed by the clinician.

Referred to in this paper as a "mode" of ventilation, Table 1 makes clear that ASV encompasses a number of ventilation modes, namely: PSV, PCV and PCIMV. ASV is the most complete automatic system of ventilation, able to provide full ventilatory support, partial ventilatory support, and seamlessly facilitate

	PAV	ASV	SC
Suitable for passive patients	No	Yes	No
Suitable for active patients	Yes	Yes	Yes
Automatic detection of spontaneous activity	No	Yes	No
Can deliver breaths in PSV mode	No	Yes	Yes
Can deliver breaths in PCV mode	No	Yes	No
Can deliver breaths in P-SIMV mode	No	Yes	No
Automatic adjustment to respiratory mechanics	No	Yes	No
Automatic weaning	No	Yes	Yes
Major setting	% of assistance	Minute ventilation	General clinical information

Table 1: Feature comparison of PAV, ASV and SC.

the weaning process. In recent randomized controlled studies, ASV was able to significantly reduce the weaning time in a population of post-cardiac surgery patients[10] and also reduce the number of nuisance alarms and ventilator manipulations by clinicians, leading to better utilization of resources[11].

Conclusions

Each mode discussed in this paper is designed to better match ventilator and patient, while at the same time making application of the ventilator safer and easier. The nuances of each of these modes must be understood by clinicians in order to appropriately implement and benefit from their use in clinical practice. ASV is the most sophisticated and accomplished mode, incorporating several closed-loops, and constantly monitoring patient safety and adapting to changing patient status on a breath-by-breath basis.

References

1. Younes M, Puddy A, Roberts D, Light RB, Quesada A, Taylor K et al. Proportional assist ventilation. Results of an initial clinical trial [see comments]. Am Rev Respir Dis. 1992;145:121-29.
2. Younes M. Proportional assist ventilation, a new approach to ventilatory support. Theory [see comments]. Am Rev Respir Dis. 1992;145:114-20.
3. Laubscher TP, Frutiger A, Fanconi S, Jutzi H, Brunner JX. Automatic selection of tidal volume, respiratory frequency and minute ventilation in intubated ICU patients as start up procedure for closed-loop controlled ventilation. Int J Clin Monit Comput. 1994;11:19-30.
4. Laubscher TP, Heinrichs W, Weiler N, Hartmann G, Brunner JX. An adaptive lung ventilation controller. IEEE Trans Biomed Eng. 1994;41:51-59.
5. Brunner JX, Laubscher TP, Banner MJ, Iotti G, Braschi A. Simple method to measure total expiratory time constant based on the passive expiratory flow-volume curve. Crit Care Med. 1995;23:1117-22.
6. Dojat M, Harf A, Touchard D, Laforest M, Lemaire F, Brochard L. Evaluation of a knowledge-based system providing ventilatory management and decision for extubation. Am J Respir Crit Care Med. 1996;153:997-1004.
7. Dojat M, Brochard L, Lemaire F, Harf A. A knowledge-based system for assisted ventilation of patients in intensive care units. Int J Clin Monit Comput. 1992;9:239-50.
8. Wysocki M, Richard JC, Meshaka P. Noninvasive proportional assist ventilation compared with noninvasive pressure support ventilation in hypercapnic acute respiratory failure. Crit care Med. 2001;30:323-29.
9. Wysocki M, Meshaka P, Richard JC, Similowski T. Proportional-assist ventilation compared with pressure-support ventilation during exercise in volunteers with external thoracic restriction. Crit Care Med. 2004;32:409-14.
10. Sulzer CF, Chiolero R, Chassot PG, Mueller XM, Revelly JP. Adaptive support ventilation for fast tracheal extubation after cardiac surgery: a randomized controlled study. Anesthesiology. 2001;95:1339-45.
11. Petter AH, Chiolero RL, Cassina T, Chassot PG, Muller XM, Revelly JP. Automatic "respirator/weaning" with adaptive support ventilation: the effect on duration of endotracheal intubation and patient management. Anesth Analg. 2003;97:1743-50.

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