Journal of Critical Care 29 (2014) 380–385

Contents lists available at ScienceDirect

Journal of Critical Care

journal homepage: www.jccjournal.org

Cycling-off modes during pressure support ventilation: Effects on breathing pattern, patient effort, and comfort

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ARTICLE INFO

Keywords:
Pressure support ventilation
Cycling-off criteria
Patient ventilator interaction
Patient comfort

ABSTRACT

Purpose: Expiratory asynchrony during pressure support ventilation (PSV) has been recognized as a cause of patient discomfort, increased workload, and impaired weaning process. We evaluated breathing pattern, patient comfort, and patient effort during PSV comparing 2 flow termination criteria: fixed at 5% of peak inspiratory flow vs automatic, real-time, breath-by-breath adjustment within the range of 5% to 55%.
Materials and methods: Randomized crossover clinical trial. Sixteen awake patients, in the process of weaning, under PSV for more than 24 hours were subjected to 3 phases of PSV, each lasting 1 hour and using 1 of the 2 aforementioned termination criteria.
Results: Effective pressure support during automatic adjustment (AA) was 12.5 ± 3.2 cm H_2O vs 12.5 ± 3.9 cm H_2O ($P = .9$) with the fixed termination criterion, and external positive end-expiratory pressure was 6.2 ± 1.8 vs 6.8 ± 2 ($P < .05$). The effective termination criterion was higher during AA (31% [23-39] vs 12% [6-23]; $P < .01$), but without producing premature breath terminations. Pressure overshoots and alternative cycling-off were also decreased. Throughout the AA period, we observed a higher respiratory rate (24 ± 8 breaths/min vs 19 ± 6 breaths/min; $P < .001$), lower tidal volume (484 ± 88 mL vs 518 ± 102 mL; $P < .001$), and shorter inspiratory times (1.0 ± 0.3 seconds vs 1.3 ± 0.3 seconds; $P < .001$). Automatic adjustment was associated with lower airway occlusion pressure after 0.1 second (P0.1) (1.8 ± 0.9 cm H_2O vs 2.4 ± 1 cm H_2O; $P < .01$), lower pressure-time product to trigger the ventilator, and lower subjective discomfort (visual analog scale, 3.7 ± 1.3 vs 4.5 ± 1.2; $P < .001$).
Conclusions: When compared with a fixed termination criterion, the use of a variable, real-time–adjusted termination criterion improved some indices of patient-ventilator synchrony, producing better breathing pattern, less discomfort, and slightly lower patient effort during PSV.

1. Introduction

Expiratory asynchrony during pressure support ventilation (PSV) has been progressively recognized as a cause of patient discomfort, increased workload [1–3], and impaired weaning process. New solutions to improve synchrony, terminating ventilator inspiratory flow in conjunction with the precise end of the patient's neural inspiration, have been recently proposed [2,4–6].

In some ventilators, inspiration ends when flow decays to a preselected absolute flow; in others, inspiration ends when the ventilator flow decays to a preselected proportion of peak inspiratory flow (usually 5% or 25%) [2,4,6]. In an attempt to improve expiratory synchrony, some modern ventilators allow the termination criterion to be manually set, within the range of 5% to 80% of peak inspiratory flow [2,4,6]. In recent studies [1,2], manual adjustment of the termination criterion by investigators was able to reduce asynchrony in a patient population with high prevalence of obstructive disease. Manual adjustment increased the termination criterion to values at least 40% of peak flow, and a decrease in patient workload was observed in most cases. Nevertheless, when a similar adjustment was performed in a population of patients with restrictive lung disease, the consequence was increased patient workload [4], with frequent premature termination of breaths.

Thus, although desirable, adjustment of the flow termination criterion in a heterogeneous population of patients with acute respiratory failure seems complex, especially when considering that lung mechanics may vary significantly during the first few days of

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http://dx.doi.org/10.1016/j.jcrc.2014.01.015

mechanical ventilation. Furthermore, it is not yet clear whether an optimal termination criterion (ie, one resulting in simultaneous termination of machine and neural inspiratory time), even when decreasing the asynchrony rate, results in an improved subjective sensation of comfort. In fact, in most studies where an optimal termination criterion was achieved through manual adjustment, investigators observed a shorter inspiratory time and an increased respiratory rate [1–3], both of which are traditionally interpreted as indicative of higher patient distress [7,8].

Recently, an algorithm to minimize expiratory asynchrony was described, proposing an automatic termination criterion that changes breath-to-breath according to respiratory time constant and the profile of supraplateau pressures measured on previous breaths [9,10]. The authors tested this closed-loop system in a pulmonary model [10], and Tassaux et al [5] later validated its rationale in a clinical setting. Theoretically, the closed-loop system was expected to minimize expiratory asynchrony for a broad population of patients, regardless of underlying lung disease.

Based on such promising findings, we decided to test whether the practical implementation of this algorithm in a mechanical ventilator would result in comprehensive improvement both of parameters reflecting "objective" synchrony (ie, patient effort, breathing pattern, and asynchrony) and in a subjective parameter (patient comfort). A mixed sample of patients with obstructive and restrictive disease was studied so as to test the efficacy of this algorithm in the general case of a patient receiving PSV.

2. Materials and methods

This study was conducted in the adult intensive care units of 2 hospitals. The protocol was accepted by their respective research ethics committees and is registered in ClinicalTrials.gov with identifier NCT00910286. All patients (or their next of kin) provided written informed consent for participation.

Patients who were under PSV, all of them during invasive ventilation, for more than 24 hours and who were able to answer a visual analog scale (VAS) of discomfort symptoms were consecutively enrolled. All patients were hemodynamically stable, receiving no sedation, and undergoing the ventilator weaning process.

2.1. Study design

Two termination criteria were tested: (*a*) a fixed termination criterion (5% of peak inspiratory flow—Servo 300 ventilator [Siemens-Elema, Solna, Sweden]) or (*b*) a variable termination criterion adjusted in real time at every breath (automatically selected from a range of 5%-55% of peak flow—Newport E500 ventilator [Newport Medical Instruments, Costa Mesa, CA).

The patients were randomized to 2 sequences of three 1-hour phases of PSV. In each sequence, 1 of the 2 termination criteria was repeated in the first and in the third phase (Fig. 1). Oxygen fraction, pressure support (PS) and positive end-expiratory pressure (PEEP) levels, inspiratory sensitivity, and rising time (pressurization rate) were previously determined by clinical staff based on the clinical decisions and remained unchanged across the 3 phases of the protocol. Patients were kept in a semirecumbent position (45°) throughout the protocol. Tracheal suctioning was performed beforehand.

The transition between the 2 ventilators was accomplished through a 3-way directional valve, with the patient not knowing which ventilator was effectively delivering support (both ventilators were located at the back of the bed). By analyzing airway pressure and flow tracings in a preliminary bench study, we calibrated the precise adjustments of sensitivity and rising time that would provide equivalent ventilator assistance at breath onset with both machines (see "Bench calibration" in E-method). We used these comparable settings during the entire protocol.

2.2. Study variables

Airway pressure (P_{aw}) and flow signals were obtained with a differential pressure pneumotachometer located at the distal end of the ventilator circuit [11]. Each phase of the protocol included 3 recording periods of 5 minutes each: at 5, 30, and 55 minutes. Data were digitized at 100 Hz.

A total of 9 recording periods (3 recordings per phase) from each patient were analyzed (Fig. 1). A mean cycle representing a coherent average of approximately 100 ventilatory cycles from each 5-minute recording period was generated, from which we extracted the following variables (see details in E-method):

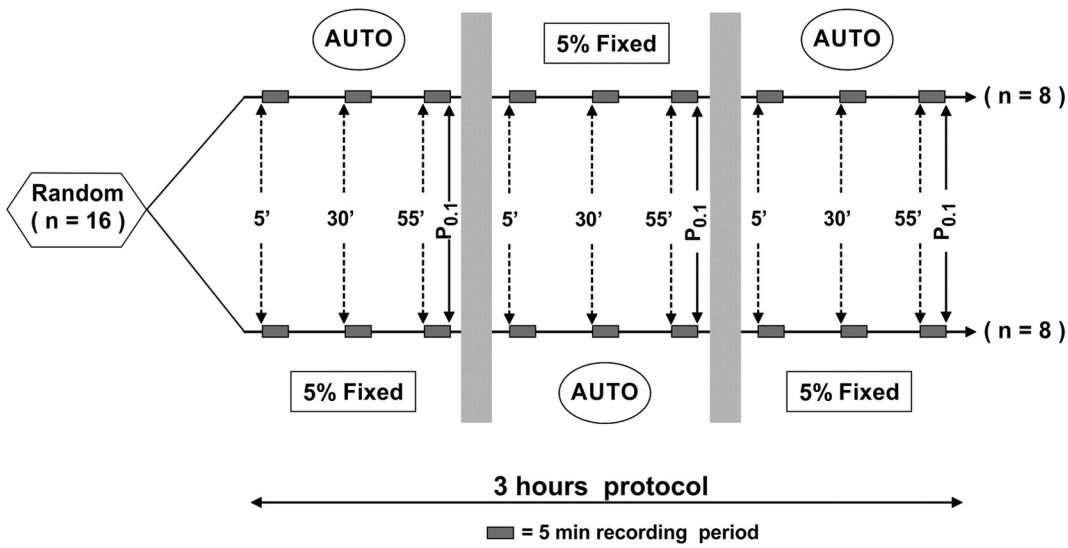

Fig. 1. Distribution of patients according to the randomized sequence. Two groups of 8 patients were randomly assigned to 1 of the 2 experimental sequences. In total, each patient was submitted to 3 hours of protocol, with 3 sequential phases of 1 hour. Each phase represented a different termination criterion, with the first and the third phases using similar termination criterion, in order to exclude carryover effects. Three sets of measurements (dashed arrows) were performed during each phase. Each set consisted of a 5-minute recording (P_{aw} and flow signals) followed by comfort evaluation. P0.1 measures were only performed in the last minute of the last recorded period of each phase (solid arrows). AUTO indicates automatic flow termination criterion (adjustable between 5 and 55% of peak inspiratory flow); 5% Fixed, fixed flow termination criterion at 5% of peak inspiratory flow.