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Ventilator settings and monitoring parameter targets for initiation of continuous mandatory ventilation: A questionnaire study☆,☆☆,★,★★

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ABSTRACT

Purpose: To inform development of educational tools, we sought to identify initial ventilator settings and monitoring targets for 3 scenarios.
Method: A survey was e-mailed to Canadian Society of Respiratory Therapists members with 2 reminders in March/April 2011.
Results: Total evaluable surveys were 363. More participants selected pressure as opposed to volume ventilation for acute respiratory distress syndrome (ARDS; 77%) than for chronic obstructive pulmonary disease (COPD; 50%) and postoperative ventilation (32%; $P < .001$). Mean tidal volume was lower for ARDS than for COPD and postoperative ventilation (5.7, 6.9, and 7.2 mL/kg, respectively; $P < .001$). Maximum acceptable plateau pressures were highest for ARDS (30 cm H_2O vs 29 cm H_2O [COPD] and 27 cm H_2O [postoperative], $P < .001$). Initial positive expiratory end pressure (12 cm H_2O vs 7 cm H_2O vs 5 cm H_2O) and fraction of inspired oxygen (F_{IO_2}; 1.0 vs 0.5 vs 0.3) were also higher for ARDS (both $P < .001$); however, only 8% selected a positive expiratory end pressure/F_{IO_2} combination as recommended by ARDSnet. Values of oxygen saturation as measured by pulse oximetry of 97% (ARDS) and 94% (COPD and postoperative) were considered appropriate for F_{IO_2} reduction. The lowest pH was 7.28 vs 7.23 vs 7.26; the highest pH was 7.46 vs 7.44 vs 7.46 ($P < .001$). Partial pressure of carbon dioxide (arterial) of 51 mm Hg (postoperative) to 65 mm Hg (ARDS) was considered acceptable.
Conclusion: Lung protective ventilation was favored, yet distinct differences in ventilator settings were evident. Monitoring targets suggested relatively conservative practices for F_{IO_2} reduction but an understanding of permissive hypercapnia.

1. Introduction

Over the preceding 2 decades, irrefutable evidence demonstrates the potential for mechanical ventilation to cause harm [1]. Volutrauma may occur when tidal volumes (V_T) are applied in a range that overstretches the alveoli resulting in ventilator-associated lung injury [2]. Barotrauma results from excessive transpulmonary pressures, and atelectrauma results from repetitive opening and closing of alveoli exacerbated by low levels of positive expiratory end pressure (PEEP) [3]. Biotrauma, the result of local and systemic inflammatory processes involving both epithelial and endothelial cells, may further aggravate lung injury and contribute to multiple-organ dysfunction syndrome and death [4].

Inappropriately applied mechanical ventilation can increase the severity of existing acute respiratory distress syndrome (ARDS) [5], but also may cause ARDS [6]. Dynamic hyperinflation, a major cause of weaning failure in chronic obstructive pulmonary disease (COPD) [7], may be exacerbated by failure to consider the need for a prolonged expiratory time [8]. For these reasons, it is vital that clinicians caring for ventilated patients have appropriate levels of specialist knowledge and skill to manage patient-ventilator interactions, recognize complications, and intervene appropriately [9]. This requires in-depth

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knowledge of ventilator technology, its clinical application, and the current evidence for effective ventilation strategies.

Despite recognition of the potential injurious effects of inappropriately applied mechanical ventilation, variable adoption of ventilatory strategies proven in patients with ARDS to reduce mortality has been identified [10,11]. Moreover, there is paucity of guidance on the most appropriate settings for initiation of ventilation and acceptable targets for monitoring parameters for indications other than ARDS. This is despite large observational cohort studies indicating that ARDS is one of the *least* common indications for mechanical ventilation [12]. Our objective was to characterize respiratory therapists' (RTs) accepted ventilator settings for initiation of continuous mandatory ventilation and monitoring parameter targets for 3 patient scenarios: postoperative ventilation with no lung pathology, ARDS, and COPD exacerbation. We specifically sought to determine perceived best practices for initiation of ventilation as opposed to actual practice, which is known to be highly variable [13]. These data will inform educational recommendations built-in to a Web-based ventilation simulator and educational assessment tool to evaluate learners' ability to safely initiate mechanical ventilation.

2. Methods

2.1. Study design and sampling frame

We conducted a cross-sectional, self-administered survey of members of the Canadian Society of Respiratory Therapists (CSRT), the national professional association for RTs. Because the CSRT does not collect demographic information about place of work or specialization in the intensive care unit (ICU), we sent the survey to all 2541 CSRT members providing e-mail addresses. Participants were asked to confirm if they were currently working in an adult ICU on survey commencement. The study was approved by the research ethics board of the University of Toronto.

2.2. Survey development and testing

Scenarios and survey items were generated by the study investigators and revised iteratively based on consultation with RTs in ICU practice leadership positions and intensivists with expertise in mechanical ventilation. We devised 3 scenarios: postoperative ventilation in a patient with no lung pathology, severe ARDS with refractory hypoxemia, and COPD exacerbation failing a trial of noninvasive ventilation (see Electronic Supplemental Material for scenarios). We selected postoperative ventilation with no lung pathology because this is the most common indication for mechanical ventilation [12], with little evidence to guide clinicians on appropriate ventilator settings on ICU admission. Also, this scenario provided a comparison for 2 other scenarios of patients with significant lung pathology. We selected ARDS because lung protective ventilation comprising 4 to 6 mL/kg of predicted body weight is considered the standard of care [14], yet observational studies of practice continue to indicate variable adoption [15]. Ventilation of patients with COPD poses a challenge because of dynamic hyperinflation, yet we were unable to identify evidence-based recommendations for ventilator settings on initiation of invasive ventilation that would inform our development of a Web-based ventilation simulator and educational assessment tool. For each scenario, we clearly specified the primary indication for initiation of mechanical ventilation to avoid any uncertainty about the patient's diagnosis. Patient variables such as sex, age, height, and weight were kept consistent across the 3 scenarios.

Ten clinicians (RTs and physicians) rated the survey on 5-point Likert scales for face and content validity, discriminability, utility, and clarity (clinical sensibility [16]). Means scores ranged from 3.33 to 4.5, resulting in further survey refinement based on provided comments. The final survey was then formatted in Survey Monkey™, which enables programming of skip logic required for directing participants to questions based on selection of pressure (PV) or volume ventilation (VV) as their preferred mode for each scenario.

In the final survey, for each scenario, respondents were asked to select either PV or VV as opposed to a specific ventilator mode, and then to identify values of ventilator parameters they would set or target when commencing mechanical ventilation. If selecting PV, ventilator parameters included the following: target V_T (in milliliters per kilogram), maximal acceptable plateau pressure, set respiratory rate, inspiratory time, PEEP, and fraction of inspired oxygen (F_{IO_2}). If selecting VV, respondents identified set V_T and maximal acceptable peak inspiratory pressure in addition to the parameters listed for PV. For each scenario, respondents also identified lowest acceptable oxygen saturation as measured by pulse oximetry (Sp_{O_2}), the Sp_{O_2} at which they would reduce F_{IO_2}, lowest and highest acceptable pH, and partial pressure of carbon dioxide (arterial; Pa_{CO_2}). Response formats provided a range of categorical responses for each ventilator and monitoring parameter; respondents were asked to select one. Respondents were invited to provide textual comments on their selection of ventilator parameters and monitoring targets for each scenario. In the demographics section of the survey, respondents were asked about years of ICU experience, hospital type (academic or community), and number of hospital and ICU beds.

2.3. Data collection

The survey was sent by the CSRT via e-mail link with 2 reminders sent at 2-week intervals in March and April 2011. The CSRT also promoted the survey on its Web site. Potential participants were advised that survey completion was voluntary.

2.4. Statistical methods

We included data from incomplete questionnaires; therefore, survey item denominators vary. We summarized categorical variables such as preferred ventilator mode using frequency counts and proportions and ventilator settings and monitoring targets as means and SDs or medians and interquartile ranges (IQRs), depending on data distribution. We log transformed data and generated linear regression models examining ventilator settings and monitoring targets across the 3 scenarios and pairwise comparisons, taking into account correlation among observations from the same subject. We compared the proportion of respondents selecting $V_T \geq 8$ and ≥ 10 mL/kg using McNemar tests. All tests were 2 sided with a significance threshold of $P \leq .05$. No assumptions were made regarding missing data. All analyses were performed by an independent statistician using SAS 9.2 (SAS Institute, Cary, NC).

3. Results

We received 438 responses (17% response rate) comprising 51 respondents indicating that they did not work in ICU and 387 questionnaires. We were unable to calculate a true survey response rate because of inability to confirm the number of CSRT members working in critical care. We excluded 24 questionnaires because of failure to respond to any items in all 3 patient scenarios, resulting in 363 questionnaires providing responses to scenario 1 (postoperative ventilation with no lung pathology), 344 to scenario 2 (ARDS), and 333 to scenario 3 (COPD). Respondents had a range of years of ICU experience, and most (230; 63%) worked in community hospitals (Table 1).

More participants selected PV as the preferred mode for ARDS (265/344; 77%) as opposed to COPD exacerbation (167/333; 50%) and postoperative ventilation (115/363; 32%) ($P < .001$; Fig. 1). The mean