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Year in Review 2014: Mechanical Ventilation

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Mechanical ventilation is an important and ever-evolving component of everyday critical care. Clinicians can struggle to keep up with current literature and descriptions of advancement in a way that they can apply these changes to their bedside patient care. This article serves as a review of important recent findings related to invasive mechanical ventilation and describes their relevance to bedside critical care. *Key words: mechanical ventilation; ARDS; dead-space fraction; HFOV; PEEP; ABCDE bundle; ventilator-associated condition (VAC).* [Respir Care 0;0(0):1–•. © 0 Daedalus Enterprises]

Introduction

Several studies were published during 2013–2014 that are relevant to the daily practice of those involved in critical care and management of invasive mechanical ventilation. The studies that were chosen for this article address selection of PEEP, high-frequency oscillatory ventilation (HFOV), and the association between physiologic dead-space fraction and mortality. Implementation of the awakening and breathing coordination, delirium monitoring/management, and early exercise/mobility (ABCDE) bundle and an overview of the impact and preventability of ventilator-associated conditions (VAC) are also discussed.

Bedside Selection of PEEP

Selecting the appropriate PEEP in patients with severe respiratory failure is a challenge.[1] It is certainly understood that the lungs, with non-homogeneous parenchymal involvement, have regions that are hyperinflated, whereas others are underinflated.[2] Both states are associated with further lung injury. This same heterogeneity makes it more difficult to select the appropriate PEEP as we attempt to avoid further lung injury from volutrauma and atelectrauma.

In a prospective study, Chiumello et al[3] took a close look at what may or may not work best. They investigated 4 methods for evaluating the best PEEP: two methods based on lung mechanics (ExPress)[4] and stress index,[5] one based on end-expiratory transpulmonary pressure via esophageal manometry,[6] and one based on the PEEP/F_{IO_2} table from the Lung Open Ventilation Study.[7] Chiumello

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et al[3] prospectively enrolled 51 subjects at 2 university hospitals in Italy and Germany. Each subject underwent chest computed tomography with 5 cm H_2O and then 45 cm H_2O applied to the lungs during end-inspiratory and end-expiratory pauses to evaluate lung recruitability. Subsequently, each of the 4 described methods for selecting the best PEEP was utilized for each subject. Using the ExPress method, the PEEP was increased until the plateau pressure reached 28–30 cm H_2O. If the plateau pressure did not reach this target when the PEEP was 20 cm H_2O, no further titration was performed. The tidal volume (V_T) was kept at 6 mL/kg ideal body weight. The stress index was evaluated by placing the subjects on volume control ventilation and titrating the PEEP until the pressure-time curve became liner. The third method used esophageal pressure with PEEP titrated until the esophageal pressure and PEEP were equal. Finally, the PEEP was set using a predefined PEEP/F_{IO_2} table with a target of arterial oxygen saturation between 88% and 93%. The authors found that methods of PEEP selection that rely on lung mechanics (ExPress, stress index) or esophageal manometry resulted in PEEP levels that were unrelated to recruitment. Interestingly, the only method in which PEEP selection was related to lung recruitment was based on the PEEP/F_{IO_2} table. Having demonstrated that 3 methods of PEEP titration resulted in similar PEEP levels regardless of ARDS severity, it may be unreasonable to expose patients with mild ARDS (lower recruitability) to higher PEEP to keep open only a small region of the lungs. It is interesting that the PEEP/F_{IO_2} table, which has been dismissed by many, might have value. The beauty of the table is that it is very easy to implement at the bedside.

HFOV in Early ARDS

HFOV has been used in neonatal and pediatric critical care for some time.[8] It has been suggested that the use of HFOV in adult patients with ARDS may have some protective advantages in that the V_T is small and there is low cyclic stretch appreciated by the alveolus.[9] In a multicenter randomized controlled trial, Ferguson et al[10] compared HFOV with controlled ventilation using low V_T and high PEEP. This multi-center study included 39 ICUs in 5 countries. The study was stopped by the Data Safety and Monitoring Board after 548 of an anticipated 1,200 subjects were studied. Inclusion criteria were: respiratory failure with an onset of < 2 weeks, P_{aO_2}/F_{IO_2} of < 200 mm Hg at an F_{IO_2} of 0.5, and bilateral air space opacities on chest radiograph. The study was stopped because outcomes were worse (47% vs 35%) in the study (HFOV) group. There was also a higher use of midazolam, neuromuscular blockade, and vasoactive drugs in the HFOV group. The authors concluded that in adults with moderate to severe ARDS, early application of HFOV compared with a low V_T/high PEEP strategy does not reduce and may in fact increase in-hospital mortality. Prudence is warranted regarding the use of HFOV in patients with ARDS. The appropriate use of HFOV in this patient population deserves additional study.

Dead-Space Fraction and Mortality in ARDS

Physiologic dead space and elevated ratios of dead-space volume to V_T (V_D/V_T) are common characteristics of ARDS.[11] Volumetric capnography can be utilized to measure and calculate the severity of V_D/V_T.[12] In an observational study of subjects who were enrolled in a separate clinical trial, Kallet et al[13] assessed the feasibility of using volumetric capnography at the bedside for subjects meeting ARDS criteria. They also investigated the correlation between dead-space fraction and mortality. This study was carried out in 24 hospitals affiliated with the National Heart, Lung, and Blood Institute (ARDS Network) and included all subjects (at least 18 y old) who met the American-European Consensus Conference criteria for ARDS and had P_{aO_2}/F_{IO_2} of ≤ 300, bilateral infiltrates on chest radiograph, and normal left atrial pressures. V_D/V_T was measured within 4 h of enrollment and on study days 1 and 2 if arterial blood gas sampling was indicated for clinical management. The instrument used for volumetric capnography had been previously validated. Early and sustained elevations in V_D/V_T were associated with higher mortality in subjects with ARDS. This study also demonstrated that bedside measurement of V_D/V_T was practical and may provide information that may be valuable in developing clinical trials to identify those patients who are at high risk of dying. Use of V_D/V_T in the care of patients with ARDS is likely underutilized. This is an area in which respiratory therapists might add value.

Effectiveness and Safety of the ABCDE Bundle

In a prospective cohort study, Balas et al[14] evaluated the efficacy and impact of the ABCDE bundle. The study was conducted over an 18-month period and included subjects in 5 adult ICUs, one step-down unit, and one hematology/oncology unit of a 624-bed tertiary medical center. The study included 296 subjects (146 before the bundle was implemented and 150 subjects after) who were ≥ 19 y of age and who were being managed by the center's critical care services. Chart reviews were performed pre-bundle and post-bundle implementation. Comparison of the 2 groups showed reduced time on the ventilator, less delirium, more time spent out of bed, and lower mortality after the ABCDE bundle was implemented. These improvements were achieved despite little difference in medication and incomplete adherence to bundle guidelines. The ABCDE bundle appears to be a valuable tool in the manage-

ment of critically ill patients. Respiratory therapists make an important contribution to the bundle by performing spontaneous breathing trials. This study adds additional evidence supporting the awakening and breathing trial, suggesting that a bundle also addressing agents for sedation, delirium monitoring, and early mobility improves outcomes.

Clinical Impact and Preventability of VAC

The newest surveillance parameters developed by the Centers for Disease Control and Prevention (CDC) are VAC and infection-related VAC (IVAC). The clinical impact and preventability of VAC and IVAC and their relationship to ventilator-associated pneumonia (VAP) are unclear.

In a retrospective analysis of a prospective multi-center study, Muscedere et al[15] investigated the clinical impact of the implementation of VAP clinical guidelines and the relationship between VAC and IVAC. Over 24 months, data were collected from 11 centers (10 in Canada and one in the United States) from medical, surgical, and trauma ICUs. There were 4 data collection periods (baseline and 6, 15, and 24 months). The study enrolled 330 subjects in each data collection period for a total of 1,320 subjects. Subjects $>$ 16 y of age and who were mechanically ventilated for $>$ 48 h were enrolled. Research coordinators collected data by either direct observation or chart review for concordance with each of the CDC guideline recommendations. Outcomes were evaluated as well. Rates of VAC, IVAC, and VAP over time were recorded. Agreement between definitions, associated morbidity/mortality, and independent risk factors for each were determined. Of 1,320 subjects, 139 (10.5%) developed VAC, 65 (4.9%) developed IVAC, and 148 (11.2%) developed VAP. The agreement between VAP and VAC was 0.18, and that between VAP and IVAC was 0.19. Subjects who later developed VAC or IVAC had significantly more ventilator and hospital days. These subjects also received more antibiotics and had higher hospital mortality rates than those who developed VAC or IVAC. Moreover, increased concordance with VAP prevention guidelines during the study was associated with decreased VAP and VAC rates, but no change in IVAC rates. These data suggest that VAC includes complications in addition to VAP. Interestingly, whereas VAC and IVAC appear to have an associated mortality risk, the results of this study suggest that VAP might not have an attributable mortality.

Summary

In this article, I reviewed a handful of recent important studies that pertain to mechanical ventilation. It is my intent to have summarized relevant literature pertaining to this topic in a way that bedside clinicians can quickly familiarize themselves with what is new and important to their practice.

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