REVIEW: POSITIVE END EXPIRATORY PRESSURE (PEEP)

by David Wheeler RRT, NPS

Positive End Expiratory Pressure, (PEEP), remains an essential component in the care of critically ill patients who require mechanical ventilation. The application of PEEP is expected to enhance both lung mechanics and gas exchange as it recruits lung units. I realize the discussion of PEEP will, to some, seem rather mundane and banal. I trust that the frequent reader will understand that my return to this very fundamental topic reflects my desire to keep the knowledge base of my audience contemporary and clinically relevant.

Positive End Expiratory Pressure, (PEEP), is the application and maintenance of supra-atmospheric or positive airway pressure through the expiratory phase of a mechanical breath. The application of PEEP will increase both peak and mean airway pressures as well as the FRC. PEEP is primarily utilized to increase the PaO2, maintain alveolar integrity, facilitate patient-ventilator synchrony, enhance ventilator triggering and recruit alveolar units.

The application of PEEP is expected to increase PaO2 through the primary mechanisms of increased functional residual capacity, improved alveolar recruitment, redistribution of extravascular lung water and improved ventilation-perfusion matching. The optimal method of clinically applying PEEP remains a very contentious topic.

The main effect of augmenting PEEP is the recruitment of alveolar units that were previously collapsed. This additional recruitment allows tidal volume to be distributed to more alveoli, peak airway pressure to be reduced and compliance to be increased. In the acute lung injury, depending on the severity of lung disease, PEEP may clearly alter the compliance of the lung through the mechanism of alveolar recruitment. However, there are insufficient studies to advise a universal approach for the use of PEEP in patients with acute lung injury (ALI) and acute respiratory distress syndrome (ARDS). Yet, there is sufficient evidence to strongly suggest the use of moderate to higher levels of PEEP in an attempt to stabilize and recruit lung units in ALI and ARDS.

In patients with acute lung injury, high levels of positive end-expiratory pressure (PEEP) may be necessary to sustain or restore adequate oxygenation, despite the fact that mechanical ventilation may affect cardiac function in a capricious fashion. However, there is increasing clinical evidence that ventilating ARDS patients with comparatively lower tidal volumes and high levels of PEEP is clinically beneficial and perhaps an optimum strategy.

Indeed, in patients with severe ARDS a mechanical ventilation strategy employing a smaller tidal volume and PEEP set at greater than Pflex yields a striking improvement in mortality compared with a mechanical ventilation strategy that uses higher tidal volume and lower PEEP.

However, there are patients with ARDS in whom an increase in PEEP cannot produce alveolar recruitment because there is very little lung with "potential for recruitment". In this patient population the use of PEEP may amplify ventilator-induced lung injury by enhancing pulmonary overdistention. Thus, the use of greater PEEP levels in these patients may impair the desired clinical outcome. One must remain cognizant that patients with a greater percentage of potential for lung recruitment will have more severe primary lung injury. Bear in mind the effect of PEEP on lung recruitment is coupled with the percentage of potentially recruitable lung and the percentage of potentially recruitable lung is decidedly linked with the overall severity of lung injury.

In light of the previous paragraph I feel compelled to comment briefly of the type of injury associated with the underutilization of adequate PEEP levels.

Repetitive Alveolar Collapse & Expansion, (RACE), is a form of VILI described as a product of alveolar instability that is non-homogenous. The inflation / deflation pattern in the acutely injured lung causes this form of VILI. Healthy alveoli with stable properties adjacent to very unstable alveoli collapse and / or are injured as a result of sheer stress and incongruent opening and clos-

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ing times. Non-homogenous time constants result in a rocking or tearing stress motion. Altered alveolar mechanics render inflection point measurements suspect and perhaps useless in this form of lung injury.

This repetitive cycle of alveolar collapse and re-recruitment has been associated with worsening and very severe lung injury. The extent of this lung injury has been reduced or eliminated through the use of PEEP. PEEP intensities that prevent derecruitment at end-expiration will augment the recruitment of previously collapsed alveoli. Furthermore lung regions recruited with PEEP may not completely collapse at end-expiration. There is evidence to strongly suggest improved survival when a strategy involving a low tidal volume was used in combination with high PEEP levels in order to prevent derecruitment.

In mechanically ventilated patients with ARDS, the ratio of potentially recruitable lung varies dramatically and is strongly coupled with the individual lung units response to PEEP. The percentage of potentially recruitable lung varies widely and is decidedly associated with the percentage of lung tissue in which aeration is maintained after the application of PEEP. Patients with a higher percentage of potentially recruitable lung have greater total lung weights, poorer oxygenation, poorer respiratory compliance and higher rates of death.

Recent findings suggest that a wet or "sponge lung" is produced by a "core," consolidated lung unit from which a general lung edema will spread. This proliferation, through an inflammatory reaction, is decisive in the determination of the collapsed and potentially recruitable lung.

As stated previously the magnitude of potentially recruitable lung vacillates in the ARDS lung. This comprehension is indispensable for a rational PEEP setting because the amount of lung tissue maintained, recruited and aerated via PEEP is intimately connected and linearly related to the amount of recruitable lung. The judicious clinician would limit the use of PEEP levels of greater than 15 cm of water to patients with a higher percentage of potentially recruitable lung and utilize PEEP levels below 10 cm of water to those with a lower percentage of potentially recruitable lung.

If PEEP is to have lung protective efficacy in mechanically ventilated ARDS patients then it must increase the end-expiratory lung volume through alveolar recruitment while avoiding alveolar overdistention. The optimal PEEP strategy remains a subject for further debate and investigation. Indeed, the technique for the establishment of "optimal" PEEP levels remains elusive. However, there is some strong evidence that that the use of PEEP equal to the Pflex + 2 cm H_2O with a lower tidal volume demonstrates the maximum impact on patient outcomes in ARDS.

The potential for recruiting collapsed lung units varies greatly among patients with ARDS. The informed clinician will be reminded that an important effect of PEEP is lung recruitment or the preservation of alveolar recruitment after a lung-recruitment. It is the responsibility of every clinician to establish in an evidence based; assessment driven fashion the most advantageous clinical strategy for our patients. I trust the comprehensive therapist will employ clinical practices that will attenuate the suffering of the patient entrusted to their care and I hope that this column is helpful. PEEP on.

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