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Forced oscillation technique: an alternative tool to define the optimal PEEP?

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In the inhomogeneous airspace environment of acute respiratory distress syndrome (ARDS) patients, inappropriate application of tidal volume (VT) and positive end-expiratory pressure (PEEP) has been demonstrated to further worsen lung injury [1–3]. Ventilator-induced lung injury (VILI) may take place at lung volumes that induce over-distention of alveolar units (volutrauma) or cause

repeated recruitment and de-recruitment (atelectrauma) [1, 3, 4]. Numerous human and animal studies addressing the mechanisms of VILI culminated in the ARMA trial of the ARDS Network [5], demonstrating that a lung-protective ventilation strategy based on low tidal volume (6 mL/PBW) and plateau pressures ($P_{\text{plat}} < 30 \text{ cmH}_2\text{O}$) is able to reduce ARDS-associated mortality.

The subsequent attempts to further minimize VILI and improve the prognosis of ARDS patients by using higher PEEP levels have been disappointing in at least three recent clinical trials [6–8] named ALVEOLI, LOVS and EXPRESS, where high versus low PEEP levels were applied in conjunction with low tidal volume ventilation. There may be several reasons to explain the lack of beneficial or even harmful effects of using inappropriate PEEP levels: (1) acute lung injury (ALI)/ARDS patients show great variability of alveolar recruitment in response to PEEP [12]; (2) A fixed combination of PEEP/ FiO_2 ratio may have induced alveolar over-distension in some patients [9]; and (3) The use of P_{plat} -guided protective ventilation may not be an appropriate approach because of alterations of transpulmonary pressure due to chest wall impairment [10]. On the other hand, the use of low PEEP levels combined with low tidal volume ventilation has been demonstrated to cause lung injury by repeated alveolar collapse and re-opening [4]. The application of adequate levels of PEEP in the management of ARDS patients remains a critical issue for further investigation [11]. A large portion of potentially recruitable lung units seems to be an independent risk factor for mortality in ARDS [12], thus the benefit of reducing tidal recruitment by increasing PEEP levels may prevail over the effect of increasing alveolar over-distension in this subgroup of patients [13]. A reliable tool at bedside to set desirable PEEP and VT is critical [11]. Traditional methods to tailor and monitor mechanical ventilation such as using pressure–volume curve, static compliance and stress index have shown drawbacks especially when the

compliance of chest wall is altered. Toward this end, computed tomography (CT) scan is a powerful tool for mapping the distribution of gas volume in the lung compartments under different combinations of PEEP and VT; however, CT scan is yet to be a part of bedside technology.

Forced oscillation technique (FOT) is based on the application of very small lung volume changes with a very short time period (i.e., 0.2 s for a forcing frequency of 5 Hz) in order to measure the oscillatory respiratory system compliance [14]. FOT may offer several potential advantages over traditional methods: (1) it applies very small volume displacement, and minimizes artifacts resulting from non-linearity of the respiratory system; (2) it does not require deep sedation and muscle paralysis; and (3) it can be integrated into currently available ventilator circuits at bedside.

The study by Dellacà and colleagues [15] in the June 2011 issue of *Intensive Care Medicine* attempted to optimize the level of PEEP by applying FOT in a porcine model of ARDS induced by surfactant depletion. The investigators performed incremental and decremental PEEP trials, and measured both conventional and FOT-derived respiratory system compliance at each step of PEEP changes. CT scan analysis was also performed as a gold standard of monitoring lung compartments at end expiration. The used FOT was able to detect the minimal PEEP value to keep the lung open, and this was in good agreement with CT scan analysis with respect to sensitivity and specificity. On the contrary, changes in dynamic

compliance and partial pressures of arterial oxygen (PaO_2) and carbon dioxide (PaCO_2) were less sensitive compared with FOT. These results suggest that FOT may have potential value to define adequate levels of PEEP to prevent/reduce the occurrence of de-recruitment.

There are some limitations in this study: (1) unlike previous studies [16, 17] using a similar model, the authors failed to identify significant hyperinflated area even at high levels of PEEP ($\sim 13 \text{ cmH}_2\text{O}$), which is an important contributor to VILI [18, 19]. This discrepancy should be addressed in future studies to validate the FOT and CT settings that should be sensitive enough for both de-recruitment and over-distension of alveolar units; (2) The CT scan analysis of the lung compartments was performed at the end expiration; it would be interesting in future studies to compare FOT with CT at the end of the inspiratory phase to detect tidal hyperinflation that can contribute to VILI [18, 19]; and (3) The surfactant depletion model used in this study is not accompanied with abnormal chest wall compliance, so that the validation of FOT to detect the extent of recruitment/de-recruitment and hyperinflation remains to be determined in more complicated clinical situations.

In conclusion, the application of FOT appears to be feasible and sensitive to define adequate levels of PEEP in a porcine model of ARDS. Further studies are warranted to determine whether PEEP levels can be individualized to strengthen protective ventilatory strategies by using FOT in preclinical models before clinical studies in humans.

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