Commentary

Recruitment maneuvers and positive end-expiratory pressure/tidal ventilation titration in acute lung injury/acute respiratory distress syndrome: translating experimental results to clinical practice

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Abstract

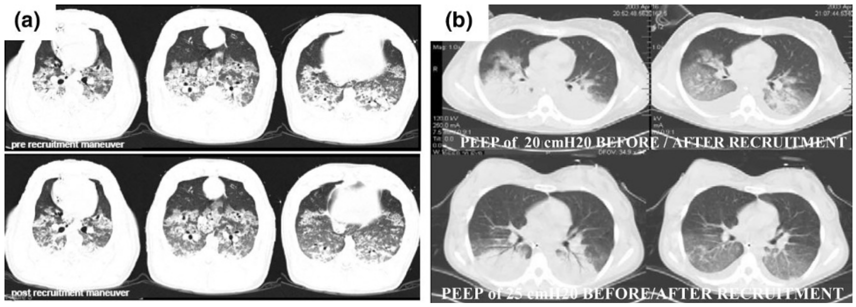
Recruitment maneuvers and positive end-expiratory pressure (PEEP)/tidal ventilation titration in acute lung injury/acute respiratory distress syndrome (ALI/ARDS) are the cornerstone of mechanical ventilatory support. The net result of these possible adjustments in ventilatory parameters is the interaction of the pressure applied in the respiratory system (airway pressure/end expiratory pressure) counterbalanced by chest wall configuration/abdominal pressure along the mechanical ventilatory support duration. Refinements in the ventilatory adjustments in ALI/ARDS are necessary for minimizing the biotrauma in this still life-threatening clinical problem.

It is well known that the main phenomenon of hypoxemia in acute lung injury/acute respiratory distress syndrome (ALI/ARDS) is the high shunt fraction caused by the nonaerated areas of the lungs. During the disease process, the volume of extravascular lung water and the lung weight increase and promote the collapse of peripheral airways and lung parenchyma, mainly in the gravitation-dependent lung regions (Fig. 1). This phenomenon can be exacerbated by anesthesia and conditions of chest wall impairment. The relationship between the nonaerated, poorly aerated, normally aerated and hyperinflated lung regions depends on the degree of heterogeneity of the ALI/ARDS and the net result of the interaction of the pressure applied to the lung parenchyma (airway pressure/end expiratory pressure) and chest wall mechanics, as illustrated in the report by Henzler and colleagues [1] appearing in this issue of *Critical Care*. The most important force is not the airway pressure or tidal volume itself but the stress and strain that this airway pressure/tidal volume generates and the duration of these stresses and strains. At the bedside, the rough equivalent of stress is transpulmonary pressure, and the rough equivalent of the strain is tidal volume/end expiratory lung volume [2].

This modern and complex mechanical ventilatory approach of ALI/ARDS recruitment maneuvers and positive end-expiratory pressure (PEEP)/tidal ventilation titration is a meshwork of interdependent but heterogeneously affected lung subunits that are behave according to different and multiple pressure–volume envelopes of the respiratory system during mechanical ventilation, which in some cases can be represented by respiratory mechanics (depending on the heterogeneity and etiology of the ALI/ARDS and the net results of the mechanical configuration of the respiratory system and the applied inspiratory/expiratory pressure along the mechanical ventilatory support duration) [3]. In 1998, a Brazilian prospective, randomized and controlled trial of mechanical ventilation in patients with ARDS demonstrated that a lung protective ventilation strategy that used recruitment maneuvers (a continuous positive airway pressure of 35 to 45 cmH_2O) for 40 s with a higher PEEP set 2 cmH_2O above the lower inflection point of the pressure–volume curve of the respiratory system and tidal volumes less than 6 mL/kg was associated with a 28-day intensive care survival rate of 62%. This contrasted with a survival rate of only 29% with conventional ventilation (the lowest PEEP necessary for acceptable oxygenation with a tidal volume of 12 mL/kg

ALI = acute lung injury; ARDS = acute respiratory distress syndrome; CT = computed tomography; IL = interleukin; PEEP = positive end-expiratory pressure.

Figure 1



Thoracic tomography of two different models of acute lung injury/acute respiratory distress syndrome (ARDS). **(a)** Computed tomography (CT) scan of pigs after saline lung lavage before and after recruitment maneuvers with 45 cmH_2O of pressure, maintaining a positive end-expiratory pressure (PEEP) of 10 cmH_2O, showing some redistribution of ventilation [1]. **(b)** CT scan of acute respiratory distress syndrome patients before and after a recruitment maneuver with 60 cmH_2O maximal inspiratory pressure maintaining PEEP values of 20 and 25 cmH_2O.

without recruitment maneuvers – number necessary to treat = 3, $P < 0.001$) [4]. In a post hoc analysis, the same group stratified the 53 patients of the trial into quartiles according to PEEP levels and analyzed the 28-day survival rate. A PEEP of more than 12 cmH_2O, and particularly greater than 16 cmH_2O, was significantly correlated with an improved survival rate in these ARDS patients [3]. Ranieri and colleagues corroborated these results by demonstrating that a ventilation strategy involving higher PEEP/low tidal volume significantly decreased bronchoalveolar lavage and systemic blood levels of tumor necrosis factor-α, IL-8 and IL-6 compared with low PEEP/high tidal volume ventilation [5]. More recently, the same Brazilian group showed that when an almost full recruitment is achieved and maintained by means of sufficient applied PEEP levels (in ARDS patients this is about 18 to 26 cmH_2O of PEEP), a partial arterial oxygen tension plus partial arterial CO_2 tension of more than 400 mmHg at a fraction of inspired oxygen of 100% is well correlated with less than 5% of lung collapse as shown on a thoracic computed tomography (CT) scan, ensuring more homogeneous ventilation (Fig. 1) [3].

Recruitment maneuvers, PEEP and tidal ventilation titration in ALI/ARDS exert varied effects on airway caliber, the ventilation:perfusion ratio distribution, cardiac output and many as yet incompletely understood effects on the macromechanical and micromechanical properties of the diseased lung parenchyma [6-8]. The history of mechanical ventilation in previous breaths and the applied PEEP level strongly determine the working envelope in the present breath and the chances of promoting intratidal recruitment during mechanical ventilation in ARDS patients. Overdistension and the opening and closing of alveoli during tidal ventilation are important issues in ventilator-induced lung injury [9]. Airspace collapse as shown by a thoracic CT scan is associated with hypoxemia in early ALI/ARDS [1,3] and can be reversed with a maximum lung recruitment strategy that can be applied to critically ill patients and may lead to better pulmonary function at hospital discharge [3]. So, careful studies of the mechanical, gas-exchange and hemodynamic consequences of mechanical ventilatory support in the experimental and clinical critical care settings of ALI/ARDS are still necessary for a better understanding of the extremely complex issues involved in improving the prognosis of this still life-threatening clinical problem.

More intriguing are the recent results showing that dead space fractions were elevated early in the course of ARDS patients and that the dead space fraction is an independent risk factor for death [10]. Corroborating these results are the observations that ALI/ARDS patients who had a decreased partial arterial CO_2 tension during a prone-position protocol had improved survival compared with the nonresponders [11]. So, respiratory mechanics, gas exchange and hemodynamic parameters as well as medical treatment for the etiology of ALI/ARDS (for example viral infections, bacterial infections, pancreatitis or gastric aspiration) are important issues that have to be kept in the mind of the critical care physicians when treating a patient with ARDS in the intensive care unit.

Competing interests

The author(s) declare that they have no competing interests.

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