Commentary

Recruit the lung before titrating the right positive end-expiratory pressure to protect it

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Abstract

The optimal level of positive end-expiratory pressure (PEEP) in acute respiratory distress syndrome patients is still controversial and has gained renewed interest in the era of 'lung protective ventilation strategies'. Despite experimental evidence that higher levels of PEEP protect against ventilator-induced lung injury, recent clinical trials have failed to demonstrate clear survival benefits. The open-lung protective ventilation strategy combines lung recruitment maneuvers with a decremental PEEP trial aimed at finding the minimum level of PEEP that prevents the lung from collapsing. This approach to PEEP titration is more likely to exert its protective effects and is clearly different from the one used in previous clinical trials.

In a previous issue of *Critical Care*, the study presented by Huh and colleagues [1] illustrates both the difficulties in applying an open-lung strategy in the clinical setting and the importance of systematically assessing the effects of recruitment and positive end-expiratory pressure (PEEP). The 'open-lung concept' was first described by Lachmann [2] almost two decades ago and later became an integral part of the protective ventilation strategy proposed by Amato and colleagues [3]. It is based on the sequential application of two distinct interventions: (a) an effective initial lung recruitment maneuver that eliminates as much lung collapse as reasonably possible [4] and (b) the stepwise downward titration of PEEP toward a minimum level that stabilizes the previously recruited lung. This final PEEP to be used for the subsequent ventilation therapy is called 'open-lung PEEP' [5]. Such an open-lung PEEP can be determined only after adequate lung recruitment by means of a decremental PEEP trial and certainly not by increasing PEEP from any arbitrary level.

The lack of an effective recruitment precludes a correct estimation of open-lung PEEP, and the inability to set proper open-lung PEEP limits its protective effect. The failure to recognize this close interdependence between recruitment and PEEP has led to disappointing results in numerous clinical studies. In most of these studies, effects of recruitment, mainly assessed by arterial oxygenation, were either mild or short-lasting [6]. On the other hand, those few studies that systematically used maximal recruitment in combination with open-lung PEEP resulted in significant and sustained improvements in oxygenation as well as lung mechanics [7].

However, the clinical implementation of lung protective ventilation strategies remains a difficult task. First, there is no consensus regarding the most appropriate method for safely achieving an 'effective' recruitment. Second, until recently, clinically validated definitions of 'lung recruitment and collapse' were unavailable. This lack of accepted criteria for the success or failure of lung recruitment has precluded the conduct of reproducible clinical trials, rendering any comparison with conventional ventilation strategies difficult. In this respect, Borges and colleagues [4] showed the index arterial partial pressure of oxygen (PaO_2) + arterial partial pressure of carbon dioxide ($PaCO_2$) of greater than or equal to 400 mm Hg (at fraction of inspired oxygen [FiO_2] = 1.0) corresponding to less than 5% collapsed tissue on computed tomography (CT) to be a reliable indicator of maximal lung recruitment in patients with acute respiratory distress syndrome (ARDS). Furthermore, those patients who were recruited successfully according to the above definition also showed, on average, an increase in compliance of more than 15%.

When defining lung collapse, decreases both in oxygenation (first decrease by greater than 10% from a maximum after

ARDS = acute respiratory distress syndrome; CT = computed tomography; FiO_2 = fraction of inspired oxygen; PaO_2 = arterial partial pressure of oxygen; PEEP = positive end-expiratory pressure.

recruitment) [4,8] and in compliance (maximum compliance) [5,9] during a decremental PEEP trial consistently identified the onset of lung collapse, which in turn defines open-lung PEEP as the end-expiratory pressure before this collapse occurred.

In 57 patients with ARDS, Huh and colleagues [1] studied the effectiveness of a ventilation strategy in which PEEP was selected during a decremental PEEP trial after lung recruitment and compared it with the one proposed by the Acute Respiratory Distress Syndrome network (ARDSnet), in which PEEP is set according to a PEEP/FiO_2 table [10]. The primary endpoint was improved oxygenation during the first week of mechanical ventilation. On day one, PaO_2/FiO_2 was only modestly higher in the decremental PEEP group, thereafter remaining at values similar to those of the control group despite daily recruitments. At a mean PEEP of less than 11 cm H_2O in both groups, lung mechanics were comparable, with no more than 2 cm H_2O higher PEEPs in the recruited group. These are surprisingly low PEEP values and minute differences between the treatment arms. The investigators did not find significant differences in 28-day mortality, the secondary endpoint.

Some aspects of this clinical protocol might explain these unsatisfactory results. First, given that the maximal recruitment pressures during the extended sigh as reported previously by the same group [11] never exceeded 40 cm H_2O, they remained significantly below any sufficient pressure to fully recruit the lungs in most patients with ARDS [2,4,8,12]. Unfortunately, maximal inspiratory pressures were not reported and their effectiveness was not assessed. Nonetheless, decreased compliance in conjunction with only modestly improved oxygenation on day one is suggestive of failing recruitment efforts. As previously discussed, incomplete recruitments seriously limit the ability of a decremental PEEP trial to find open-lung PEEP. Furthermore, the investigators used falling oxygen saturation and decaying static compliances to select their PEEP, thereby underestimating the level at which actual lung recollapse occurred. Due to the sigmoid shape of the oxygen saturation curve, it is rather insensitive to lung collapse as large amounts of collapse might already prevail before any change in saturation occurs, especially at high FiO_2. In addition, it has been shown conclusively that, during a decremental PEEP trial, a decrease in compliance from a maximum value indicates lung collapse [5]. The low values of PEEP found in this study most likely reflect such an underestimation of lung collapse. In contrast, studies in which complete recruitment was documented and PEEP titrated downwards until a specified decrease in PaO_2 determined the closing pressure yielded open-lung PEEP values of the order of 18 to 20 cm H_2O [4,8]. These values are similar to the ones reported by Gattinoni and colleagues [13] in the mid-1990s using CT to study the effects of PEEP.

Studies like the one by Huh and colleagues [1] contribute to an improvement in our understanding of the complex physiology behind lung recruitment, PEEP titration, and their interrelation. This accumulating knowledge about lung protective ventilation strategies will hopefully result in better clinical protocols that finally lead to improved patient outcomes.

Competing interests

The authors declare that they have no competing interests.

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