Recruitment manoeuvres in acute respiratory distress syndrome: Little evidence for routine use

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The use of alveolar recruitment manoeuvres (RMs) is a topic of uncertainty in the management of the hypoxemic respiratory failure found in acute respiratory distress syndrome (ARDS). An RM is a deliberate application of elevated transpulmonary pressure (airway pressure – pleural pressure) intended to reopen previously collapsed lung units, thus increasing the surface area available for gas exchange. It is also suggested that recruiting collapsed lung tissue enables a more homogeneous distribution of ventilation throughout the lung, reducing ventilator-induced lung injury (1,2). Acutely injured lungs have been shown to consist of heterogeneous regions of aerated and collapsed alveoli. Morphologically, ARDS is characterized by inflammatory atelectasis, causing considerable reduction in functional residual capacity (3) and air-to-tissue ratio. A computed tomography study published in 2000 (3) reported a 17% reduction in end-expired lung volume in ARDS patients versus healthy volunteers. This alveolar collapse (ie, atelectasis) has been attributed to increased interstitial pressure and the compressive forces of the weight of the lung. This atelectasis can be worsened by factors such as obesity, high abdominal pressure, disconnections from the ventilator and mucus suctioning (4).

Furthermore, ventilation of acutely injured lungs with positive pressure leads to the generation of shearing forces at the junctions of aerated (compliant) and nonaerated (noncompliant) lung units, inducing lung injury (1). Recruitment of lung tissue is believed to minimize ventilator-induced lung injury by two mechanisms. First, alveolar recruitment increases the aerated lung mass, thus promoting a homogeneous distribution of ventilation. This minimizes shearing forces at the junctions of inflated and underinflated lung units. Lachmann (5) introduced this notion in a 1992 editorial titled 'Open the lung and keep the lung open', explaining that at a transpulmonary pressure of 30 cmH2O, the shearing forces at the junction of an atelectatic region surrounded by a fully recruited lung region can exceed 140 cmH2O, a pressure very likely to induce barotrauma. Second, obtaining appropriate alveolar recruitment minimizes the cyclic opening and closing of terminal lung units (4).

Recent randomized controlled trials and systematic reviews have been unable to demonstrate a significant benefit to support the routine use of RMs in the management of ARDS (6-9). The most recent systematic review on this topic was published in 2009 (7). A Cochrane Review also published in 2009 (10) concluded there was no evidence that RMs reduce mortality or length of ventilation in ARDS patients. The use of RMs in ARDS patients remains a topic of clinical interest and investigation. The purpose of the present review is to synthesize the literature published since the last systematic review, and identify some of the potential barriers encountered when implementing RMs in clinical practice.

There is an observed variability in the response to RMs in patients with ARDS, and investigation into the cause of such variation is an active area of research. One hypothesis is that the degree of extravascular lung water (pulmonary edema) significantly influences the response to RMs (11). Smetkin et al (11) found that of the 17 patients who received a sustained inflation RM (40 cmH2O for 40 s), only five showed a significant response, defined as a 20% increase in the ratio of partial pressure of oxygen (PaO2)/fraction of inspired oxygen (FiO2) from baseline. Additionally, this response was not sustained in 58% of patients, suggesting alveolar recruitment was short lived. Edema was a predictor of RM response, with patients with pulmonary edema showing no significant response to RMs. Individuals without pulmonary edema demonstrated a 33% increase in PaO2/FiO2 after RMs (11). Lung morphology is also considered to be a significant factor, not only in the response to RM, but in the severity of adverse effects. A recent computed tomography study (12) performed imaging on early ARDS patients at four stages surrounding an RM while identifying the specific lung morphology present. The patients were categorized as having either focal lung morphology ('lobar' loss of aeration predominant) or nonfocal lung morphology (defined as either patchy or diffuse loss of aeration). Lung morphology impacted the response to RM. Only patients with nonfocal lung morphology showed a significant improvement in arterial oxygenation, the chosen...
outcome predictor. Patients with focal lung morphology were found to have a smaller potential for alveolar recruitment, with lung hyperinflation predominant over lung recruitment. A hyperinflated lung can reach up to 24% of total end-expired lung volume in patients with focal lung morphology (this would likely be much greater at end inspiration). Furthermore, the hyperinflated lung can remain elevated at up to 10% of total lung volume after a post-RM steady-state, implying that RM-induced hyperinflation can cause some degree of airspace enlargement secondary to alveolar wall damage (12). This heterogeneity in distribution of recruitment volume has been shown to impact the incidence of complications. In the largest clinical study on RMs to date, Fan et al (13) found that primary focal consolidation was associated with marginal lung recruitability and a higher complication rate when compared with more diffuse morphologies apparent in extrapulmonary processes. This is consistent with animal data showing that RMs are more effective at recruiting collapsed lung tissue in extrapulmonary lung injury than direct pulmonary lung injury (14). The number of RMs applied was also significantly associated with incidence of complications (13). These findings suggest considerable caution be exercised when performing RMs routinely on ARDS patients without knowledge of the baseline morphology. This also seriously questions the application of a ‘one-size-fits-all’ therapeutic intervention to a demonstrably diverse disease population.

Alveolar recruitment can be achieved using a variety of techniques, and lack of standardization in this regard acts as a barrier to widespread use in critical care. The ideal technique would provide sustainable alveolar recruitment to correct and prevent hypoxemia, and improve lung mechanics (improving ventilation) while having a low incidence of complications/adverse effects. Additionally, to increase the potential for widespread implementation, an ideal RM would not be complicated and time consuming to perform. The most prevalent technique is the sustained inflation (SI) RM, which uses a sustained elevation of plateau pressure in a continuous positive airway pressure with pressure support mode. The pressure support is set to zero and increase the potential for widespread implementation, an ideal RM with marginal lung recruitability and a higher complication rate when compared with more diffuse morphologies apparent in extrapulmonary processes. This is consistent with animal data showing that RMs are more effective at recruiting collapsed lung tissue in extrapulmonary lung injury than direct pulmonary lung injury (14). The number of RMs applied was also significantly associated with incidence of complications (13). These findings suggest considerable caution be exercised when performing RMs routinely on ARDS patients without knowledge of the baseline morphology. This also seriously questions the application of a ‘one-size-fits-all’ therapeutic intervention to a demonstrably diverse disease population.

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surpass. The present review has shown that the literature pertaining to SI manoeuvres has essentially shown no impact on mortality. Perhaps, then, the implementation of a different technique of potentially greater benefit is positive. More institutions adopting SRMs would, at minimum, provide a platform for more widespread investigation of the technique, potentially providing the data needed to support SRM use. The present literature search did not find any articles that addressed the increased time factor associated with performing SRM over SI manoeuvres. When performed appropriately, the SRM can take up to 25 min for the clinician (likely a respiratory therapist) to perform, potentially necessitating greater staffing. Clinicians should also familiarize themselves with the data regarding who may benefit from the manoeuvres and, importantly, who will experience a worsened lung injury. Larger randomized controlled trials that are powered to demonstrate clinically relevant outcomes (mortality) are warranted based on recent evidence. Smaller studies have shown promising trends toward such outcomes, but have not had the quantity of data required to achieve statistical significance (20,21).

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SUMMARY
The key messages of the present review are that recruitment of the atelectatic lung tissue of ARDS is based on the degree of transpulmonary pressure applied. High pleural pressure reduces transpulmonary pressure at a given airway pressure, reducing recruitment. Tools, such as esophageal balloon measurement, can be used to accurately predict pleural pressure, allowing for more individualized PEEP application. Maintenance of recruitment after effective lung inflation is paramount to protective ventilation and recruitment without attempt to obtain optimal PEEP has only shown short-lived improvements. At this time, the routine use of RM in the management of ARDS remains unsupported by evidence.

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