Recruitment Maneuvers to the Extreme

Alveolar collapse is a common problem in mechanically ventilated children, particularly those with significant lung disease, such as ARDS. Many different methods are used by clinicians to recruit collapsed alveoli, including sustained inflation or incremental increases in PEEP until recruitment is achieved. These methods have primarily been studied in animal models and adults with varying approaches for the amount and duration of pressure applied. The primary goal of a recruitment maneuver is to open atelectatic alveoli and keep them open by applying PEEP to limit the cyclic alveolar opening and closing that is associated with ventilator-induced lung injury. When and how to perform these maneuvers is controversial, and many clinicians have safety concerns regarding hemodynamic stability and the risk of barotrauma during these maneuvers.[1,2] Some also question the need for recruitment maneuvers because although they usually improve oxygenation, this improvement is often transient, alveolar recruitment may not be sustained unless other adjustments to ventilator settings are made, and little evidence suggests that recruitment maneuvers improve outcomes.[3]

A few small studies have investigated recruitment maneuvers in children with ARDS, finding in general no clinically important effect on either hemodynamic stability or risk of barotrauma.[4-6] Even fewer studies exist on the application of recruitment maneuvers in children without lung disease who are mechanically ventilated for reasons such as general anesthesia.[7] Mechanically ventilated children with normal lungs are also susceptible to atelectasis. These children may be at greater risk of harm due to the creation of high transpulmonary pressures from a recruitment maneuver in the situation of relatively normal pleural pressures.

Gonzalez-Pizarro et al[8] sought to address the safety of recruitment maneuvers in an animal model simulating children with normal lungs, specifically targeting barotrauma in their article in this issue of RESPIRATORY CARE. The authors studied 10 anesthetized neonatal piglets subjected to 2 recruitment maneuver strategies: (1) incremental increases in positive inspiratory pressure (PIP) with no PEEP and (2) incremental increases in PEEP with a fixed driving pressure of 15 cm H_2O (once a PEEP of 50 cm H_2O was reached, PIP was subsequently increased by increasing driving pressure). During the study protocol, pressures were increased until an air leak was noted from chest tubes signifying pneumothorax.

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The authors found that a much higher PIP (mean 90.5 ± 15.7 cm H_2O) than typically used for any type of recruitment maneuver was required to create a pneumothorax with no difference between the 2 strategies. Perhaps more remarkable, by the time pneumothorax occurred, all of the piglets had died (the mean pressure required to cause asystole was approximately 75 cm H_2O). In general, the group with PEEP had less hemodynamic instability (higher blood pressures) at the same PIP than the group with no PEEP. Interestingly, this appeared to become less important with higher PIPs because the PIP for asystole was similar between the strategies. The PIP causing a decrease in mean arterial blood pressure of 20% was within the range of a normal recruitment maneuver for the no PEEP group (mean 37.5 cm H_2O); however, it was higher for the group with PEEP (mean 62.5 cm H_2O). The authors concluded that recruitment maneuvers in newborns without lung disease are safe with regard to pneumothorax but may have significant effects on hemodynamics.

But why was there such a profound effect on hemodynamics before pneumothorax, and why was this more prominent in the group without PEEP? Decreased cardiac output with positive pressure mechanical ventilation is generally related to either decreased venous return or increased right ventricular afterload. Increased right ventricle afterload is caused primarily by alveolar overdistention, which increases pulmonary vascular resistance related to alveolar capillary compression. The higher tolerance of the piglets to the strategy with PEEP versus without PEEP might be explained, as the authors suggest, by accompanying differences in driving pressure. However, rather than influencing venous return as the authors state, the larger driving pressure in the group without PEEP probably had a great influence on right ventricular afterload. Although a high intrathoracic pressure with high PIP during inspira-

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tion will compromise pulmonary perfusion, this would be true for both recruitment strategies. However, a larger driving pressure presumably resulted in larger tidal volumes in the no PEEP strategy. This would lead to alveolar overdistention, compromised pulmonary blood flow, increased pulmonary vascular resistance, and increased right ventricular afterload. Given overall lower mean airway pressure in the group without PEEP, venous return was most likely higher in that group and is unlikely to be the explanation for worse hemodynamic compromise.[9]

It appears that in this experiment, the detrimental effect of higher PEEP on venous return was not as important for hemodynamic instability as the detrimental effect of a high driving pressure. These findings correlate with evidence in the literature emphasizing the importance of driving pressure for right ventricle function.[10,11] Of course, driving pressure has been receiving more attention, given recent published data demonstrating that it is strongly associated with mortality risk in adults with ARDS.[12] Although these effects may be from alveolar overdistention leading to ventilator-induced lung injury, it is possible that some of these effects may in fact be due to right ventricle performance. Unfortunately, tidal volumes, cardiac output, and venous pressures were not measured during this study.

The authors present compelling evidence to suggest that a recruitment maneuver, particularly with an approach of incremental increases in PEEP and fixed driving pressure, should be well tolerated in mechanically ventilated newborns with normal lungs. It is important to note that the findings of this study should not be applied to children with ARDS. Lower transpulmonary pressures, heterogeneous lung disease, and possible baseline right ventricular dysfunction could all significantly affect the net impact on hemodynamics and lung injury during these recruitment maneuvers. Clearly, further studies are required on recruitment maneuvers in children to determine when and how to apply these maneuvers and whether they influence outcomes. However, this study should help clinicians feel more comfortable with the safety of recruitment maneuvers when implemented for management of the mechanically ventilated child with normal lungs.

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