Decremental PEEP Titration: A Step Away From the Table

The setting of PEEP in patients with ARDS has become a standard of practice for nearly 46 years.[1] One of the more widely used methods in current practice for PEEP selection is the ARDS Network PEEP/F_{IO_2} table.[2] This table guides the clinician to increase or decrease PEEP and F_{IO_2} based on oxygenation. The low-to-modest levels of PEEP utilized throughout the table have been challenged in 2 studies that randomized patients to receive mechanical ventilation with 6 mL/kg of tidal volume (V_T) with the traditional PEEP table or a higher PEEP table.[3,4] These studies failed to demonstrate an improvement in clinical outcomes. A systematic review and meta-analysis of high PEEP in ARDS published in Respiratory Care found no improvement in 28 day mortality.[5] The meta-analysis raised some interesting points related to PEEP selection methods used in the included studies; most intriguing is that perhaps using a table to set PEEP has the potential to worsen ventilator-induced lung injury in some patients, rather than provide benefit. Currently, the appropriate level and best methods to select PEEP for ARDS remain unclear. This uncertainty should not discourage PEEP studies, rather it should encourage clinicians to study methods of selecting PEEP based on variables other than oxygenation guided by a table.

Decremental PEEP Titration

The study by Rodriguez and colleagues in this issue of Respiratory Care monitored P_{aO_2}, ratio of dead space (V_D) to V_T, respiratory-system compliance (C_{RS}), and transpulmonary pressure (P_{tp}) during a decremental PEEP titration.[6] The goal of the decremental PEEP titration is to determine the level of PEEP required to maintain an open lung after lung recruitment. This is not a new approach to determining an optimal level of PEEP.[7-12] However, a quick look at the available evidence may leave clinicians questioning the usefulness of this method. In the provided Table of decremental PEEP studies there are noticeable differences in titration methods, monitored values, methods for prior recruitment, as well as what the "optimal" level of PEEP should be post procedure. Also, only one randomized controlled trial was powered for mortality, and there was no difference in clinical outcomes.[9] It should be noted that the timing between PEEP changes in the randomized controlled trial was 30 seconds, which was shorter than any other study in the table. When gas exchange is the target for optimizing PEEP, the time spent at each level becomes increasingly important.[13] The study by Rodriguez and colleagues titrated PEEP every 3 min; it is discussed as a potential limitation to the study.[6]

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Transpulmonary Pressure and PEEP

The use of transpulmonary pressure to set PEEP is an interesting concept, with encouraging data, but requires further study. It uses the esophageal pressure as a surrogate for pleural pressure. Luckily, the methods for measurement are very consistent in the literature, and despite its potential limitations, it appears to be a valuable tool.[14-17] One concern that is frequently mentioned is the positional artifact associated with measurements. Previous work has demonstrated a difference in esophageal pressure between upright and supine positions.[18] This was done with healthy volunteers, and for this reason positional artifact was not compensated for in this study. We also do not compensate for position in our ICU for this reason.

Transpulmonary Pressure-Inspiratory

The level of inspiratory P_{tp} (lung stress) that occurs during a decremental PEEP titration, as observed in this study, is of particular concern. These values, combined with the length of time required to perform such maneuver, may influence your use of this approach for setting PEEP. However, the starting PEEP level in this study was 30 cm H_2O. Another point of interest for some may be the finding that the level of airway pressure with the highest sensitivity and specificity for excessive inspiratory P_{tp} (lung stress) was 37 cm H_2O. Other research supports the notion that airway pressure is an inadequate surrogate for lung stress and strain.[19] This is important because many protocols related to mechanical ventilation aimed at an absolute limit of 30 cm H_2O of plateau pressure may lead to unnecessary use of rescue therapies with patients.[20] An end-inspiratory $P_{tp} > 18$ cm H_2O significantly increased V_D/V_T in this study, regardless of airway pressure. Although a

Table. Decremental PEEP Studies

First Author	Year	*n*	Starting PEEP	Decremental Titration	Value Monitored	Optimal PEEP	Results
Borges[7]	2006	26	25 cm H_2O Prior recruitment using a stepwise increase of pressure control to a maximum of 60 cm H_2O	2 cm H_2O every 4 min	$P_{aCO_2} + P_{aO_2}$	Lowest level maintaining $P_{aCO_2} + P_{aO_2} \geq 400$ mm Hg	Oxygenation benefit was maintained or increased at 6 h
Girgis[8]	2006	20	20 cm H_2O Prior recruitment using sustained inflation of 40 s	2 cm H_2O every 15–20 min	S_{pO_2}	PEEP level above the level that caused a decrease in S_{pO_2} to $< 90\%$	Sustained oxygenation improvement for 4 h
Gernoth[9]	2009	12	20 cm H_2O Prior recruitment using pressure control to a maximum of 50 cm H_2O	2 cm H_2O every 2 min	Dynamic compliance	Best dynamic compliance + 2 cm H_2O	Better oxygenation and lung compliance; improved right-ventricular function
Huh[10] RCT	2008	57	20 cm H_2O Prior recruitment using pressure control to a maximum of 55 cm H_2O	1 cm H_2O every 30 s	S_{pO_2} and static compliance	PEEP level above the level that caused an S_{pO_2} decrease of 2% and a decrease in static compliance	Initial improvement in oxygenation; no difference in respiratory mechanics and patient outcomes
Hodgson[11] RCT	2011	20	25 cm H_2O Prior recruitment using pressure control to a maximum of 50 cm H_2O	2.5 cm H_2O every 3 min	S_{pO_2}	2.5 cm H_2O above the level where S_{pO_2} decreased by $\geq 1\%$ of maximum	Greater amelioration in some systemic cytokines; improved oxygenation and lung compliance over 7 days; no difference in other clinical outcomes
Fengmei[12]	2011	23	20 cm H_2O Prior recruitment using sustained inflation of 40 cm H_2O for 30 s	2 cm H_2O every 20 min	P_{aO_2}/F_{IO_2}, V_D/V_T, static compliance	Optimal considered the highest level of compliance combined with the lowest V_D/V_T	Observations only during PEEP titration; best compliance was slightly lower than lowest V_D/V_T

RCT = randomized controlled trial
V_D/V_T = ratio of dead space to tidal volume

P_{tp} limit of 25–27 cm H_2O has been suggested in current literature,[15,19] perhaps a P_{tp} limit of 20 cm H_2O is more appropriate?

Gas Exchange

The observation made by Rodriguez and colleagues,[6] of a good correlation between expiratory P_{tp} and best C_{RS} related to P_{aO_2}, suggests a benefit to using this approach, but best C_{RS} resulted in a negative P_{tp} in 4 patients, which significantly decreased P_{aO_2}. When looking at the individual patient data, it seems that even the addition of 2 cm H_2O above the level of best C_{RS} (as described in some of the methods from the above Table[9,11]) would still result in a negative P_{tp} for 3 out of the 4 patients.

The V_D/V_T at best C_{RS} and optimal end-expiratory P_{tp} was highly correlated. It may appear that setting PEEP according to best C_{RS} may result in a lower P_{aO_2} with a negative P_{tp} leaving the patient at risk of atelectasis, but most likely would not cause overdistention (worsening V_D/V_T). Should we be worried about a lower P_{aO_2}? It is well known that better oxygenation does not imply improved outcomes.[2-4]

In a recent study published in RESPIRATORY CARE, P_{aO_2}/F_{IO_2}, V_D/V_T, and C_{RS} were monitored during a decremental PEEP titration (methods listed in the above Table[12]). There was a significant improvement in P_{aO_2}/F_{IO_2} at the starting PEEP of 20 cm H_2O, which steadily declined but maintained significance at the same level that V_D/V_T and C_{RS} significantly improved (mean PEEP level of 12 cm H_2O). Significant improvement in P_{aO_2}/F_{IO_2} and V_D/V_T was lost at a mean PEEP level of 10 cm H_2O, whereas C_{RS} continued to improve. However, PEEP was adjusted every 20 min, which may yield different results. Compared to the current study by Rodriguez and colleagues, V_D/V_T and C_{RS} trended similarly, whereas P_{aO_2} trended slightly differently, most likely due to the starting PEEP of 30 cm H_2O used in the study. Regardless of trending differently, both studies demonstrated that the best C_{RS} did not result in the best oxygenation.

Future Direction

The use of esophageal pressure measurements as a guide for mechanical ventilation is a relatively new concept, requires the insertion of a catheter, and staff must be trained to interpret the observations made with the catheter. The technique for esophageal pressure measurement is well described and consistent with current research. This is feasible in an ICU environment with proper education and supportive staff. The decremental PEEP titration seems more attractive, as it requires only the ability to monitor compliance over time, of which all modern ventilators are capable, and requires less experience to perform properly. However, the question still remains: which method for performing the decremental PEEP titration is best?

Future randomized controlled studies powered for demonstrating a mortality benefit need to be done to determine once and for all whether these methods to individualize ventilation will improve outcomes in patients with ARDS, compared to current standards of practice. The decremental PEEP titration method has become fragmented in the literature, and could also benefit from observational research comparing methods. What seems to be promising is the desire to look up from under the "table," and move forward toward an individualized approach to mechanical ventilation.

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