Intraoperative Positive End-expiratory Pressure for Obese Patients: A Step Forward, a Long Road Still Ahead

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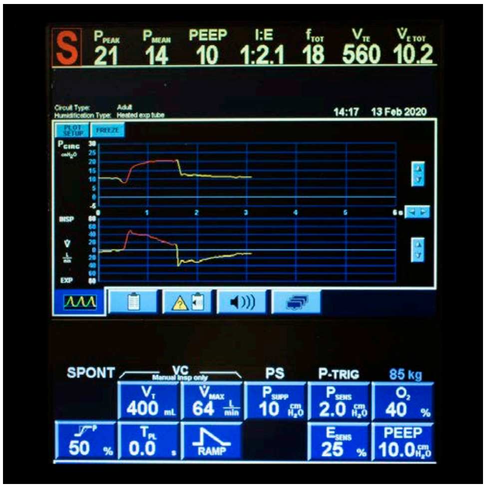
The ideal positive end-expiratory pressure (PEEP) management during surgery is still elusive. In the current issue of Anesthesiology, Simon *et al.*[1] and the PROVEnet investigators provide another step forward on the long road of searching for a physiology-supported PEEP strategy. Such a PEEP strategy aims to optimize alveolar patency, minimize lung strain, and improve gas exchange, but the ideal long-term goal of any intraoperative management would be to reduce postoperative pulmonary complications (*e.g.*, atelectasis, pneumonia) and improve overall clinical outcomes. Pursuing the appropriate PEEP strategy is even more imperative in obese patients because of their known reduced expiratory reserve volume and functional residual capacity and increased risk of atelectasis and hypoxemia. For an in-depth review of the consequences of obesity on the respiratory system, we refer the reader to excellent available reviews on this topic.[2,3]



"…should we attempt using PEEP levels greater than 10 to 12 cm H_2O for obese surgical patients? It is not yet clear."

Clinical investigations focused on intraoperative PEEP management have traditionally compared two fixed levels of PEEP, typically 0 to 5 cm H_2O *versus* a higher PEEP level, variable depending on the surgical population and the procedure studied. The Protective intraoperative ventilation with higher *versus* lower levels of positive end-expiratory pressure in obese patients (PROBESE) study,[4] the largest multicenter trial focused on obese patients during abdominal surgery, randomized them to receive either a fixed 4 cm H_2O PEEP without recruitment maneuvers or intermittent recruitment maneuvers with a constant PEEP of 12 cm H_2O. The 12 cm H_2O PEEP ventilatory strategy was not associated with significantly fewer postoperative pulmonary complications within 5 days after surgery, compared to 4 cm H_2O PEEP.[4] An increasingly popular concept for protective mechanical ventilation is that of "best PEEP," "optimal PEEP," or "individualized PEEP," as opposed to preselected PEEP levels. An individualized PEEP protocol refers to selecting a PEEP level that optimizes a specific respiratory parameter for individual surgical patients at a particular time point. Respiratory parameters that have been used to identify individualized PEEP levels in surgical patients are related to respiratory system mechanics (*e.g.*, respiratory system compliance, driving pressure, transpulmonary pressure), lung aeration (assessed with lung ultrasound), or changes in lung volume calculated from ventilation-induced fluctuations in impedance (assessed with electrical impedance tomography; fig. 1).

Simon *et al.*[1] present a secondary analysis of two previously published prospective studies focused on PEEP management in obese patients undergoing laparoscopic abdominal surgery. They compared parameters of gas exchange, respiratory system mechanics, and electrical impedance tomography dorsal-ventral ventilation distribution from three groups of patients receiving care at the same institution: (1) those receiving intermittent recruitment maneuvers with constant intraoperative PEEP 12 cm H_2O participating in the PROBESE study (n = 21), (2) those from the PROBESE study receiving a constant PEEP 4 cm H_2O combined with patients from patients receiving a fixed PEEP 5 cm H_2O without recruitment maneuvers from a comparable single-center study by Nestler *et al.*[5] (n = 44), and (3) those patients from the single-center study[5] receiving a recruitment maneuver, performed before pneumoperitoneum insufflation, followed by an electrical

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impedance tomography-guided PEEP level that was then maintained throughout surgery (individualized PEEP; n = 25). The secondary analysis[1] found that electrical impedance tomography-guided PEEP resulted in greater oxygenation (Pa_{O_2}/ F_{IO_2}) before extubation, better intraoperative respiratory system mechanics (lower median driving pressure, greater respiratory system dynamic compliance), and greater tidal volume redistribution to the dependent areas of the lung, compared to both PEEP 4 to 5 cm H_2O and PEEP 12 cm H_2O patients.

The observed PEEP levels that produced the most homogeneous ventilation (lowest regional ventilatory delay index by electrical impedance tomography) are remarkable: the median PEEP was 18 cm H_2O (interquartile range, 16 to 22 cm H_2O) with a range from 10 to 26 cm H_2O. These values are quite similar to the optimal electrical impedance tomography-guided PEEP (means ± SD) of 15 ± 1 cm H_2O (range, 13 to 17 cm H_2O) found by Erlandsson *et al.*[6] during laparoscopic gastric bypass. In contrast to obese patients,[1,6] optimal respiratory system mechanics were achieved with lower PEEP (median [interquartile range], 10 [8 to 15] cm H_2O; range, 2 to 20 cm H_2O) in nonobese patients undergoing abdominal surgery.[7] Of note, the optimal PEEP observed by Simon *et al.*[1] in obese patients was higher than in the PROBESE PEEP 12 cm H_2O group.[4] It remains unknown whether the lack of improved clinical outcomes in the PROBESE PEEP 12 cm H_2O group could be related to the possibility that PEEP 12 cm H_2O was inadequate to achieve an "optimal PEEP" in some patients. Furthermore, implementing certain high PEEP values as reported in the study by Simon *et al.*[1] may be faced with technical difficulties, because widely used anesthesia machines (*e.g.*, Draeger Apollo) cannot achieve PEEP levels beyond 20 cm H_2O.

So, should we attempt using PEEP levels greater than 10 to 12 cm H_2O for obese surgical patients? It is not yet clear. The findings by Simon *et al.*[1] have several limitations that currently prevent introduction of this approach to clinical practice. First, although electrical impedance tomography data confirmed greater ventilation of dorsal lung regions and this can explain higher oxygenation, it is not a clinical tool routinely available at the bedside. Second, Simon *et al.*[1] only explored ventilation distribution at the third/fourth intercostal space level, which may not be representative of the global lung ventilation distribution or even the lung bases that are more at risk of atelectasis. Third, electrical impedance tomography-guided individualized PEEP was associated with greater oxygenation, suggesting a better ventilation-perfusion matching, compared to fixed PEEP, but multiple studies have shown that this is a temporary physiologic outcome that disappears after tracheal extubation. To some extent, a focus on intraoperative oxygenation is obsolete and no longer sufficient to be promoted as an outcome, by itself, in any ventilatory approach. Instead, we must confirm that individualized PEEP improves relevant clinical outcomes beyond purely physiologic parameters before its routine use can be recommended. A higher PEEP may optimize respiratory system mechanics, but it may simultaneously pose a cardiocirculatory challenge. In this and other studies, patients receiving higher PEEP may be more likely to have bradycardic

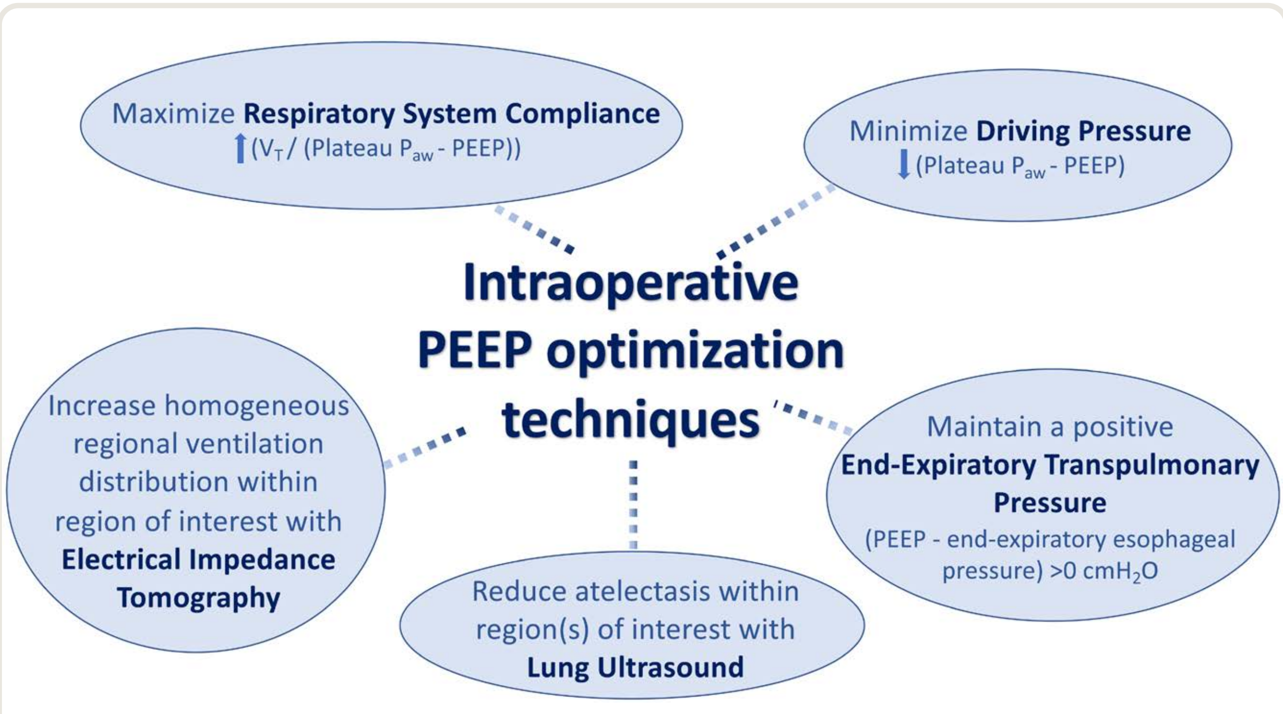

Fig. 1. Techniques used for intraoperative positive end-expiratory pressure (PEEP) optimization. Plateau P_{aw}, plateau airway pressure; V_T, tidal volume.

or hypotensive episodes or require higher fluid infusion rates or vasopressor doses.[1,4] Excessive PEEP may also induce inhomogeneous alveolar overdistention, which could lead to increased alveolar capillary permeability and lung edema.[8] The use of very high PEEP and its interplay with the tidal volume may overcome the physiologic limits of lung expansion, lose the intended "lung protection" effect, and instead become harmful.[9] Therefore, short-term benefits (*e.g.*, improved oxygenation) related to management with individualized PEEP may be offset by adverse postoperative outcomes.

The study presented by Simon *et al.*[1] takes us a step forward on the long road of understanding PEEP selection to improve intraoperative respiratory mechanics and oxygenation in obese patients. Unfortunately, the key question remains unanswered: how to select the physiologically sound PEEP as part of protective ventilatory strategy that improves postoperative pulmonary outcomes. This ventilation should be achieved without negatively affecting intraoperative hemodynamics and with resources widely available to anesthesia providers in the operating room. Future clinical trials on obese patients will be required to address the complex interaction between optimal intraoperative PEEP and reduction of postoperative pulmonary complications. For now, Simon *et al.*[1] have shown that individualized electrical impedance tomography-guided high levels of PEEP were associated with better intraoperative respiratory mechanics and oxygenation in the obese patients undergoing laparoscopic abdominal surgery included in their study. We believe that very high PEEP levels, as used for some patients in the Simon *et al.*[1] study, should not be routinely implemented in clinical practice before we obtain more definitive evidence that this ventilation approach is associated with improved pulmonary outcomes.

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Competing Interests

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