Lung-protective perioperative mechanical ventilation

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Chapter 9

Positive end-expiratory pressure during surgery - Authors’ reply

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With great interest, I read the Article by PROVE Network Investigators (Aug 9, p 495)\(^1\) and the accompanying Comment.\(^2\) Some of the study limitations that might have obscured any treatment effect (e.g., protocol deviations, infrequent recruitment manoeuvres, and a high positive end-expiratory pressure [PEEP] level in the higher PEEP group) have been addressed in the accompanying Comment.\(^2\) Several additional factors might have negated any potential treatment effect.

39% of patients in both groups had received thoracic epidural analgesia. Compared with systemic analgesia, thoracic epidural analgesia can be expected to improve the postoperative pulmonary outcome in patients undergoing abdominal surgery.\(^3\) At the same time, the combination of thoracic epidural analgesia, general anesthesia, and mechanical ventilation frequently causes hypotension, which requires therapy.\(^4\) Any possible difference in pulmonary outcome between groups might have been obscured by the beneficial pulmonary effects of thoracic epidural analgesia. Similarly, the higher incidence of intraoperative hypotension and increased need for vasoactive drugs in the high compared with the low PEEP group might not have mainly been caused by the high PEEP per se but instead by the combination of high PEEP, thoracic epidural analgesia, and general anaesthesia. To compare the primary and secondary outcome variables between patients with and without thoracic epidural analgesia would be relevant. Combined abrupt withdrawal of 12 cmH\(_2\)O PEEP and restoration of spontaneous respiration at the time of extubation will have acutely increased venous return and, in turn, right and left ventricular preload. This might have increased lung water in patients with left ventricular dysfunction with unpredictable subsequent adverse pulmonary sequelae.

All patients had received intermediate long acting muscle relaxants. Residual neuromuscular blockade must be expected at the end of surgery in up to 80% of cases.\(^5\) Residual neuromuscular blockade is associated with impaired postoperative lung function and postoperative pulmonary morbidity.\(^5,6\) Because the detrimental effect of residual neuromuscular blockade on postoperative pulmonary outcome might have obscured any potential treatment effects, we need to know whether neuromuscular function was quantitatively assessed before extubation. Extubation during an inspired oxygen fraction (FiO\(_2\)) of 1.0 is associated with worse postextubation atelectasis and oxygenation compared with extubation at a lower FiO\(_2\).\(^7\) Use of a FiO\(_2\) of 1.0 at the time of extubation in all patients might partly explain the absence of difference in postoperative atelectasis.
References

Positive end-expiratory pressure during surgery – Comments
Farouk Mike Elkhatib, Mohamad Khatib (Department of Anesthesiology, School of Medicine (FME), American University of Beirut, Beirut, Lebanon)

We read with interest the PROVHILO study\(^1\) comparing high with low positive end-expiratory pressure (PEEP) during general anaesthesia for open abdominal surgery. The researchers concluded that high PEEP and recruitment manoeuvres during open abdominal surgery do not protect against postoperative pulmonary complications.\(^1\) We commend the investigators for providing such highly needed data; however, we believe that a major contributing factor that could have masked the potential benefit of high PEEP is the fact that peak inspiratory pressure was significantly higher in patients exposed to high PEEP than those exposed to low PEEP. The fact that high-peak airway and alveolar pressures per se are associated with ventilator-induced lung injury secondary to alveolar overdistention is well known.\(^2\)

The PROVHILO study\(^1\) should have considered decreasing the tidal volume (VT) in the high-PEEP group to whatever level is needed to achieve in the high-PEEP group a peak airway pressure that is similar to that of the low-PEEP group. As such, one would expect higher PEEP with lower VT to maintain the same peak airway pressure that might result in improved lung compliance secondary to enhanced alveolar recruitment with high PEEP while preventing hyperinflation or overdistention in non-dependent lung units by the decrease in VT.\(^3\) Furthermore, reduction in peak airway pressure in the high PEEP group will lead to a decrease in mean airway pressure and potentially less haemodynamic impairment in the high-PEEP group.\(^4\) Perhaps only prevention of all forms of ventilator-induced lung injury (ie, cyclic opening and closing of alveoli and alveolar overdistention) can reduce or eliminate complications in mechanically ventilated patients.\(^5\)

References
5. Melo MF, Eikermann M. Protect the lungs during abdominal surgery: it may change the postoperative outcome. \textit{Anesthesiology} 2013; 118: 1254–57
Authors’ reply
Emmanuel Futier,1 Farouk Mike Elkathib and Mohamad Kathib, and Hans-Joachim Priebe’s comments about the results of PROVHILO2 raise relevant issues that deserve consideration.

Firstly, PROVHILO is the only trial of intraoperative ventilation that compared different levels of positive end-expiratory level (PEEP) in low tidal volume ventilation, which is now the standard of care.3,4 Notably, results from one metaanalysis5 show that the benefit from lung-protective ventilation is better explained by the use of low tidal volumes than the use of high levels of PEEP. A simultaneous reduction in tidal volume size in the high PEEP group in PROVHILO, to limit peak airway pressures, would not only have contradicted current practice but also have made identification of the individual role of high levels of PEEP impossible. Although we agree that high airway pressures could lead to increased ventilator-induced lung injury, mean peak inspiratory pressures were 23 cm H2O in the high PEEP group, i.e. below the commonly accepted safety limit.

Differently from the claim by Futier,1 several trials show that an intraoperative PEEP level of 10 cmH2O or more is necessary to avoid lung volume loss, and is not associated with overdistension.6 In PROVHILO, dynamic compliance improved in the high PEEP group, suggesting effective lung recruitment without relevant overdistension. Furthermore, periodic recruitment manoeuvres7 are not considered essential to keep lungs open when appropriate levels of PEEP are used, even with use of high inspiratory oxygen concentrations.8 Also, the suggestion that high oxygen concentrations during extubation could induce postoperative atelectasis has recently been challenged.9 We also do not ascribe pulmonary complications to abrupt changes in intrathoracic pressures during extubation, as a stepwise and gentle approach was used in which the mean airway pressure was reduced first, before resuming spontaneous breathing—a strategy that lasted several minutes, as usual in clinical practice.

Several additional analyses were requested. In an analysis of patients who received high levels of PEEP and received recruitment manoeuvres after intubation, after disconnection of the ventilator and before extubation (363 patients), versus patients who received low levels of PEEP without recruitment manoeuvres at any time (441 patients), the occurrence of postoperative pulmonary complications was not different (35% vs 36%; p=0.80). Likewise, in the 445 patients without thoracic epidural anaesthesia, the incidence of postoperative pulmonary complications did not differ between PEEP groups (48 vs 42%; p=0.26). Finally, in 265 patients who were monitored for and showed no residual neuromuscular blockade, the occurrence of postoperative pulmonary complications was independent of the level of PEEP (50% vs 45%; p=0.13).

Differently from a recent retrospective, one-centre study,4 results from PROVHILO1 convincingly showed that in non-obese patients undergoing open abdominal surgery, a low tidal volume strategy combined with low levels of PEEP is not associated with any disadvantage in terms of clinical outcome. In fact, use of high levels of PEEP was associated with impaired hemodynamics, mandating the increased use of fluids and vasoactive drugs in the intraoperative period.

PROVHILO clearly answers Futier’s question “positive end-expiratory pressure in surgery: good or bad?” in the patient group being studied. When a low tidal volume strategy is used, a low
PEEP level without recruitment manoeuvres does not increase the incidence of postoperative pulmonary complications and is associated with less haemodynamic impairment compared with high PEEP with recruitment manoeuvres. These results need to be confirmed in morbidly obese patients and in patients undergoing thoracic surgery. We hope that beliefs and myths regarding PEEP during general anaesthesia will soon give place to the evidence of large randomised controlled trials.

References
4. Levin MA, McCormick P1, Lin HM, Hosseinian L, Fischer GW. Low intraoperative tidal volume ventilation with minimal PEEP is associated with increased mortality. *Br J Anaesth* 2014; 113: 97–108