

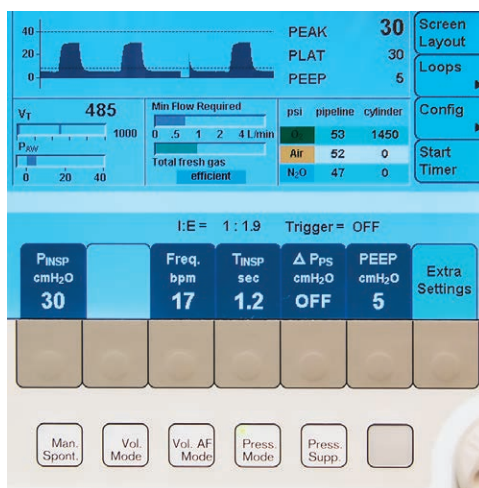
# Lung-protective Ventilation in the Operating Room

## Individualized Positive End-expiratory Pressure Is Needed!

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THE concept of lung-protective ventilation is well established in patients with acute lung injury and is now considered a fundamental approach when managing any patient under mechanical ventilation in an intensive care unit. The concept of lung-protective ventilation in the operating room has taken a little longer to develop, but data establishing the beneficial results of intraoperative lung-protective ventilation are increasing.<sup>1-3</sup> Regardless of location, it has become well accepted that tidal volume ( $V_T$ ) should be maintained between 4 and 8 ml/kg of predicted body weight, that plateau pressure should be maintained at less than 28 cm H<sub>2</sub>O, and that driving pressure (plateau pressure minus end-expiratory pressure [PEEP]) should be maintained at less than 15 cm H<sub>2</sub>O. However, the establishment of guidelines for the setting of PEEP in any of these settings has been very challenging. There are no guidelines for PEEP setting based on the results of randomized controlled trials. In fact, the current literature is nonconclusive. The only established guideline is that patients with moderate-to-severe acute respiratory distress syndrome require “high” PEEP levels, whereas patients with mild adult respiratory distress syndrome require “low” PEEP.

In this issue of the Journal, Pereira *et al.*<sup>4</sup> performed a small physiologic trial to evaluate the ability of titrated PEEP to prevent intraoperative atelectasis using electrical impedance tomography. Optimal PEEP was selected based on the specific response of the given patient's respiratory system. They selected 40 patients without previous lung disease undergoing elective abdominal surgery (20 under laparoscopy and 20 by open abdomen) admitted to the same institution during



***“A small physiologic trial evaluate[d] the ability of titrated PEEP to prevent intraoperative atelectasis.”***

a 21-month period. All patients received a recruitment maneuver using pressure control ventilation to 40 cm H<sub>2</sub>O. Upon completion of the recruitment maneuver and before the initiation of the surgical procedure, the patients were randomized to be ventilated with 4 cm H<sub>2</sub>O PEEP or with the PEEP level that resulted in the least collapse and least overdistension using electrical impedance tomography. At the end of surgical anesthesia, patients in both arms were extubated without any adjustment of PEEP or fractional inspired oxygen tension; within 30 to 60 min of extubation, a chest computed tomography was performed. Compared with the 4 cm H<sub>2</sub>O group, the PEEP by electrical impedance tomography group had a lower intraoperative driving pressure, better oxygenation, and

equivalent hemodynamics. No other postoperative pulmonary complications were recorded, and no adverse events associated with the recruitment maneuver were reported.

Electrical impedance tomography is a portable, radiation-free imaging technique that can easily be used at the bedside. It provides real-time dynamic assessment of gas movement into and out of the respiratory system. As noted, it is very useful in identifying the PEEP level, resulting in minimal collapse and overdistention. The major problem with electrical impedance tomography is its availability. At present, no electrical impedance tomography device is commercially available in the United States. The only techniques that provide comparable information are the titration of PEEP postrecruitment using esophageal manometry or the best dynamic compliance PEEP.<sup>5,6</sup> These techniques require invasive placement of an esophageal balloon or the careful

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Corresponding article on page XXX.

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assessment of compliance as PEEP is decreased. Limited data are available comparing these techniques, but electrical impedance tomography appears more precise in identifying the optimal PEEP level.

Of concern is the fact that the results of the study by Pereira *et al.*<sup>4</sup> seem to differ from the recently published Spanish study by Ferrando *et al.*<sup>7</sup> The Spanish study did not find a difference in postoperative complications among groups.<sup>7</sup> The design of the Spanish study at first glance is similar to that of Pereira *et al.*<sup>4</sup> except (1) they enrolled 1,012 patients with healthy lungs scheduled for abdominal surgery in 21 hospitals during a 16-month period; (2) patients were randomly assigned to four arms, each evaluating different operative and postoperative ventilatory support strategies; and (3) the PEEP level in the control group was 5 cm H<sub>2</sub>O, although 69 patients in the control group had their PEEP adjusted during surgery. Of interest is the fact that one of the groups had essentially the same intraoperative protocol as the recruitment maneuver used by Pereira *et al.*<sup>4</sup> followed by a decremental PEEP trial identifying optimal PEEP by best dynamic compliance. As we noted above, this should establish approximately the same PEEP level as with electrical impedance tomography. However, the PEEP levels applied to the open lung groups after the recruitment maneuver were different: median PEEP of 10 cm H<sub>2</sub>O (interquartile range, 8 to 12 cm H<sub>2</sub>O) in the Ferrando *et al.*<sup>7</sup> study (n = 479) *versus* the median PEEP of 12 cm H<sub>2</sub>O (interquartile range, 10 to 14 cm H<sub>2</sub>O) in the study by Pereira *et al.*<sup>4</sup> (n = 20). In addition, 50% of patients in the study by Pereira *et al.*<sup>4</sup> (n = 20) had laparoscopic surgery and 50% (n = 20) had open-abdomen surgery, whereas in the study by Ferrando *et al.*<sup>7</sup> 60% of patients (n = 580) had open-abdomen surgery, and 40% (n = 364) had laparoscopic surgery. Of note, Ferrando *et al.*<sup>7</sup> reported the main surgical procedures performed in their study population, whereas Pereira *et al.*<sup>4</sup> did not.

The major difference between the two studies is that the primary outcome of interest in the study by Ferrando *et al.*<sup>7</sup> was the combined prevalence of pulmonary and systemic postoperative complications, not just postextubation atelectasis. In fact, their list of pulmonary complications included aspiration, pneumonitis, atelectasis, bronchospasm, dyspnea, pleural effusion, hypoxemia, pneumothorax, pneumonia, adult respiratory distress syndrome, and the need for reintubation and mechanical ventilation. In addition, they included surgical-site infection, anastomotic dehiscence, sepsis, cardiac failure, renal failure, and need for surgical reintervention. All of this was determined over the first 7 days after extubation. In the study by Pereira *et al.*<sup>4</sup> patients had a computerized tomography scan performed 30 to 60 min after extubation, and the primary outcome of interest was the level of atelectasis postextubation. Pereira *et al.*<sup>4</sup> did not follow patients beyond the immediate postoperative period, and Ferrando *et al.*<sup>7</sup> only provided composite data, although as a secondary outcome, they found that the

recruitment maneuver group had a significantly lower prevalence of combined pulmonary complications than the control PEEP groups. As a result, it is impossible to compare the outcomes of these two studies, and their outcome may have been the same if their primary outcomes were the same. We hope that in a future secondary analysis, Ferrando *et al.*<sup>7</sup> will provide detailed analysis on each individual complication for comparison.

On the basis of current available literature and the study of Pereira *et al.*<sup>4</sup> recruitment maneuvers with peak airway pressure of 40 cm H<sub>2</sub>O are safe. The two primary concerns with recruitment maneuvers are pneumothorax and hemodynamic instability. The peak airway pressure obtained with bag mask ventilation can easily exceed 40 cm H<sub>2</sub>O. Clinicians often do not precisely control and monitor airway pressure when they perform mask ventilation. Consequently, air pressures exceeding 40 cm H<sub>2</sub>O in adults are common. Pneumothorax have only been reported occurring in association with recruitment maneuvers when peak airway pressures are 55 cm H<sub>2</sub>O or more.<sup>8,9</sup> When peak recruitment maneuver airway pressures are 50 cm H<sub>2</sub>O or less and patients are passively ventilated during the recruitment maneuver, pneumothorax is an extreme rarity. In the five most recent randomized controlled trials<sup>4,7,8,10,11</sup> in which recruitment maneuvers were used, pneumothorax was only associated with recruitment maneuvers in one of the trials,<sup>8</sup> and in that trial, recruitment maneuver peak pressure was set at 60 cm H<sub>2</sub>O. Hemodynamic instability is another issue. Any patient may develop hemodynamic instability during a recruitment maneuver. Before the recruitment maneuver, hemodynamic stability should be assured. However, even in the most hemodynamically stable patient, problems can occur. Clinicians must be ready to abort the recruitment maneuver and provide fluid or vasopressors to stabilize the patient unable to tolerate the recruitment maneuver. However, in a recent randomized controlled trial by Leme *et al.*,<sup>11</sup> the investigators found that recruitment maneuvers were well tolerated by postoperative cardiac surgical patients and had a positive effect on postoperative pulmonary complications and patient outcomes.

Pereira *et al.*<sup>4</sup> have examined the importance of an individualized approach to setting PEEP in abdominal surgery patients. However, the patients enrolled in their study were relatively homogenous. It is interesting to note that they indeed found a correlation between the body mass index and PEEP by electrical impedance tomography in spite of the range of body mass index in the studied patients being relatively small (29.5 ± 4.3). It is likely that the variation of PEEP by electrical impedance tomography in a patient population with greater body mass index is much larger. In addition, certain positioning may lead to higher and more variable PEEP by electrical impedance tomography, for instance during surgery of robotic assisted laparoscopic prostatectomy where abdominal insufflation and steep Trendelenburg position are applied. Although not the end of the story of setting PEEP in the operating room, their results provide essential

pilot data for the development of future trials assessing the use of PEEP in the operating room. Most importantly, they have found that recruitment maneuvers and high levels of PEEP can be safely used in the operating room and may have a positive impact on patient outcome.

## Competing Interests

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