Dräger

Technology for Life

Individualizing intraop ventilation using EIT

Supporting the individualized open lung approach

As of 2025, and despite more than a decade of research into postoperative pulmonary complications (PPCs) and lung-protective ventilation (LPV) in the perioperative setting, PPCs continue to represent the second most common complication after surgery, with an incidence of approximately 23 %, surpassed only by wound infection. While it is current best practice and recommended by international consensus to apply low tidal volumes, the application of positive end-expiratory pressure (PEEP) and recruitment manoeuvres (RM) are still a matter of discussion. High quality evidence appears to be scarce. When discussing PEEP and reviewing the latest literature, it seems that PEEP is not so much a matter of a fixed value or low versus high PEEP. Rather, it seems to be a matter of tailoring the PEEP to the needs of each patient.[1] There are various approaches to PEEP titration. From intensive care ventilation we learned that titrating PEEP to achieve a lower driving pressure improves outcomes. Serpa Neto and colleagues identified driving pressure as the only statistically significant mediator in the prevention of PPCs, while Park and colleagues reported an independent association between driving pressure and the development of major morbidities. Various strategies to titrate PEEP have been described, incremental and decremental PEEP titration being prominent examples. However, reports suggest that PEEP titration using a decremental PEEP approach in combination with a recruitment manoeuvre is potentially superior since compliance may increase and driving pressure is reduced correspondingly.[2]

Laparoscopic Surgery

As laparoscopic surgery becomes increasingly common for well-recognised reasons, it is important to acknowledge that pneumoperitoneum and the Trendelenburg position reduce pulmonary compliance and residual functional capacity, thereby increasing the risk of PPCs. While low tidal volumes, PEEP and RMs are among the potentially beneficial parameters to counteract PPCs, PEEP and RMs remain controversial in this context. A systematic review and meta-analysis by Pei and colleagues found that RM improved respiratory mechanics, such as static lung compliance, driving pressure, intraoperative oxygenation index and oxygenation index on PACU compared to performing no recruitment intraoperatively. Furthermore, RMs combined with PEEP was found to result in fewer PPCs compared to RMs without PEEP (ZEEP), while RMs were found not to significantly impact haemodynamics (MAP & HR). This suggests that neither PEEP alone nor RMs alone were fully effective, indicating that only the combination achieves the maximum effect.[3]

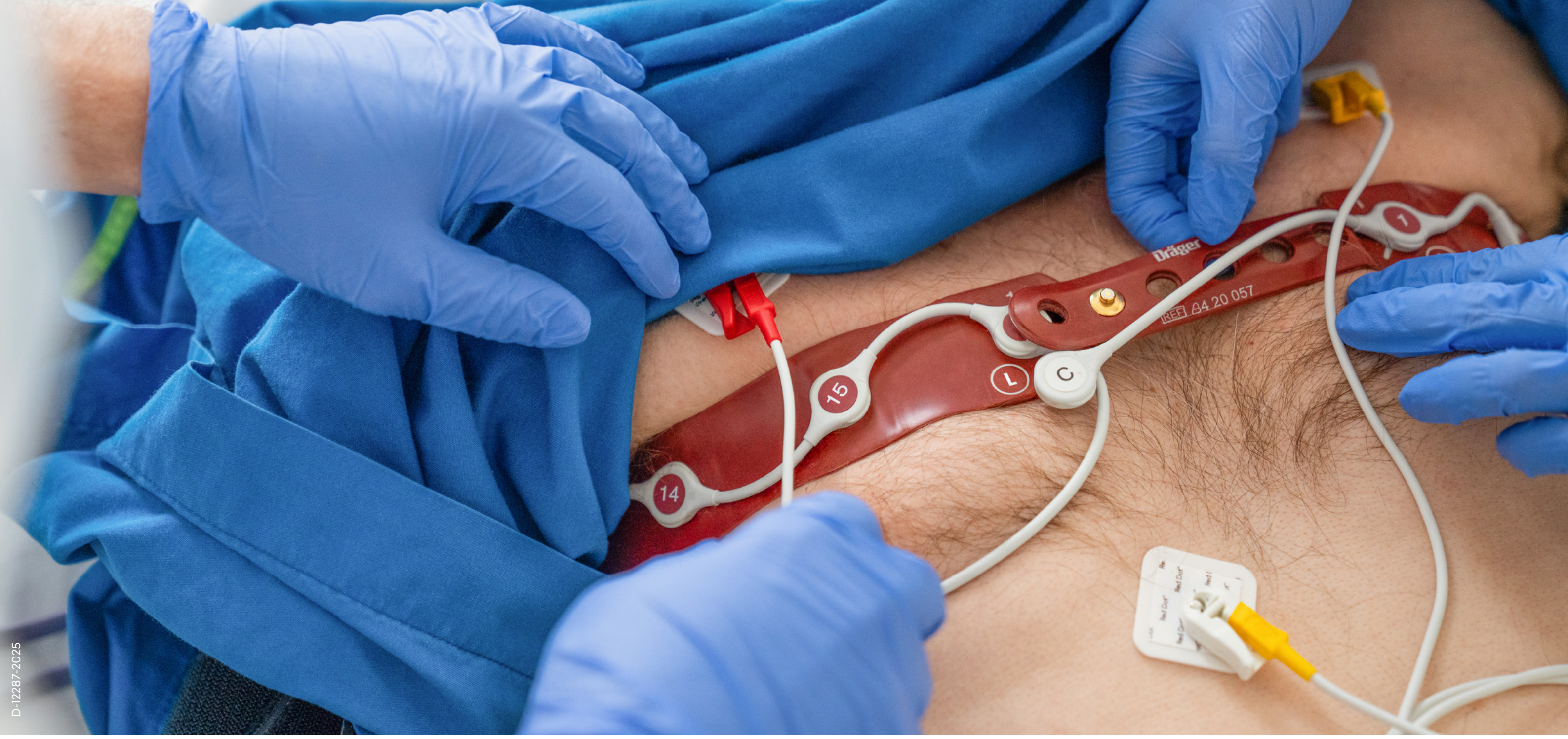
The finding of an improved oxygenation index is particularly interesting, given that an increase in respiratory rate is a common response to deteriorating oxygenation. However, bearing in mind the potential negative effects of mechanical ventilation with respect to stress and strain and mechanical power, an increased frequency may also exacerbate these effects.[2] In addition, a recent posthoc individual patient-level analysis by Nasa and colleagues found that low intraoperative $etCO_2$ levels, a potential effect of increased respiratory rate, are associated with an increased rate of PPCs, even when LPV was used. This confirmed the inverse dose-dependent relationship previously found in a posthoc analysis of the LAS VEGAS trial.[4] Therefore, applying RM alongside adequate PEEP appears to be an effective and protective approach to improving oxygenation.

PEEP individualised and machine driven

Now, PEEP is recommended not to remain static, but to be adapted after RM to keep alveoli open. It has been shown that both together achieve greater homogeneity in local ventilation during laparoscopic surgery and improve oxygenation and respiratory mechanics, as demonstrated by electrical impedance tomography (EIT). However, RMs should be performed using the ventilator rather than 'just squeezing the bag', to avoid alveoli re-collapsing after changing from manual/spontaneous mode to mechanical ventilation.[3]

As mentioned above, it appears beneficial to titrate PEEP for each patient individually. Hennessey and colleagues recommend selecting and titrating ventilatory parameters based on close monitoring of targeted physiological variables and individualised goals, especially when dealing with critically ill patients in the perioperative setting. Advanced monitoring tools like EIT and esophageal manometry should be considered during surgical procedures that affect respiratory mechanics. Since EIT provides imaging of breath-by-breath changes in ventilation distribution, it can be used intraoperatively to optimise ventilator settings dynamically. EIT measurements of tidal volume (V_t). and ventilation distribution have been validated as being as accurate as CT scans and nitrogen washout. They can also identify regional ventilation heterogeneity, overdistension, and atelectasis that would otherwise be undetectable using traditional bedside metrics.[5]

In 2022, Dargvainis and colleagues investigated the level of PEEP required to minimise alveolar collapse, termed open-lung PEEP, and the level of PEEP that results in an equal amount of overdistension and collapse, termed best-compromise PEEP. Their study was conducted in patients undergoing laparoscopic surgery, comparing the supine and Trendelenburg positions with capnoperitoneum, using EIT analysis. They found that both, 'open lung PEEP' and 'best compromise PEEP', were significantly higher in Trendelenburg position with capnoperitoneum as compared to supine position without capnoperitoneum. While in Trendelenburg positon 'open lung PEEP' was 18 (18-20) cmH_2O and 'best compromise PEEP' was 18 (16-20) cmH_2O, PEEP levels were significantly lower in supine position without capnoperitoneum ('open lung PEEP' 12 (12-14)cmH_2O and 'best compromise PEEP' 8 (6.5 – 10) cmH_2O). All being significantly higher than conservative PEEP levels of 5cmH_2O or less, which are typically used for ventilation in both open abdominal and laparoscopic surgery. They also mentioned that intra-individual variation of both PEEP values can occur, mandating intraoperative monitoring of regional ventilation with EIT on an individual basis could contribute the improvement of lung-protective ventilation strategies. However, considering the cost -benefit ratio, this approach may be more feasible in high-risk patients undergoing surgery in unfavourable body positions rather than in those at-low risk of PPCs.[6]



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This was confirmed by a recently published study by Scaramuzzo and colleagues. They investigated the additional impact of laparoscopy on lung overdistension and collapse in obese patients undergoing laparoscopic surgery in the Trendelenburg position. More specifically, they aimed to quantify the difference in PEEP levels that could minimise both collapse and overdistension, as evaluated using EIT, after anaesthesia induction and during laparoscopy. Furthermore, they evaluated the differences in regional lung mechanics caused by laparoscopy, as well as the main factors influencing these differences, such as intra-abdominal pressure and trunk inclination. Best PEEP was determined in two ways: first, using PEEP titration based on lung mechanics, e.g. lowest driving pressure; second, using EIT to monitor regional ventilation distribution and to determine the point of best relation (the crossing point) between overdistension and collapse.

They found that higher PEEP levels were required during laparoscopy; however, this was primarily due to the degree of trunk inclination rather than increased intra-abdominal pressure. Additionally, the PEEP requirement was not constant but rather changed significantly, with a maximum increase of 7 cm H_2O. Interestingly, the optimal PEEP level according to lung mechanics was consistently lower than that defined by EIT.[7]

There is much to suggest that EIT may be considered an integral part of intraoperative ventilation, in order to tailor ventilation to the individual needs of patients — especially those at high risk of postoperative pulmonary complications.

However, patients undergoing laparoscopic surgery may not be the only ones to benefit from ventilation settings personalised using EIT. In general, patients with inhomogeneous lungs appear to have a higher risk of PPCs and may benefit from individualized ventilation based on EIT findings. Iwata and colleagues found that approx. 60% of patients undergoing major surgery had an inhomogeneous distribution of ventilation and described distinct phenotypes based on ventilation patterns. Two of these phenotypes showed more PPCs during hospital stay and experienced delayed weaning from oxygen use. While chest radiograph did not identify postoperative patients with major PPCs, EIT was successful in identifying postoperative patients at risk of poor clinical outcomes in early stages during the perioperative path.[8]

In addition to EIT being potentially beneficial for a broader set of patients, it is to be assumed that more beneficial application of EIT will be identified that go beyond guiding individualization of mechanical ventilation during general anaesthesia. Rauseo and colleagues described the use of EIT in confirming the correct positioning of double lumen endotracheal tubes (DLTs) allowing the clinicians to non-invasively identify any misplacement of DLTs in the contralateral main bronchus by accurately displaying left and right lung ventilation.[9]

Also, after extubation EIT might come with distinct benefits. Closely monitoring patients after after extubation is advised due to the abrupt discontinuation of mechanical ventilation and loss of respiratory monitoring by the anaesthesia machine while being at risk of persisting consequences of sedation. These may include muscle weakness, reduced inspiratory effort and transpulmonary pressure, impaired cough reflex and impaired ability to clear secretion due to residual paralysis. All this can contribute to an increased risk of PPCs. EIT might be help in identifying patients being at risk of PPCs by continuing respiratory monitoring in the postoperative phase identifying patients at risk.[9]

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Corporate Headquarters
Drägerwerk AG & Co. KGaA
Moislinger Allee 53–55
23558 Lübeck, Germany

www.draeger.com

Manufacturer:
Drägerwerk AG & Co. KGaA
Moislinger Allee 53–55
23542 Lübeck, Germany

Region Europe
Dräger Safety AG & Co. KGaA
Revalstraße 1
23560 Lübeck, Germany
+49 451 882 0
+49 451 882 2080
info@draeger.com

Region Middle East, Africa
Dräger Safety AG & Co. KGaA
Branch Office
P.O. Box 505108
Dubai, United Arab Emirates
+971 4 4294 600
+971 4 4294 699
contactuae@draeger.com

Region Asia Pacific
Draeger Singapore Pte. Ltd.
61 Science Park Road
The Galen #04-01
Singapore 117525
+65 6872 9288
+65 6259 0398

Region Central and South America
Dräger Indústria e Comércio Ltda.
Al. Pucurui - 51 - Tamboré
06460-100 - Barueri - São Paulo
+55 (11) 4689-4900
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