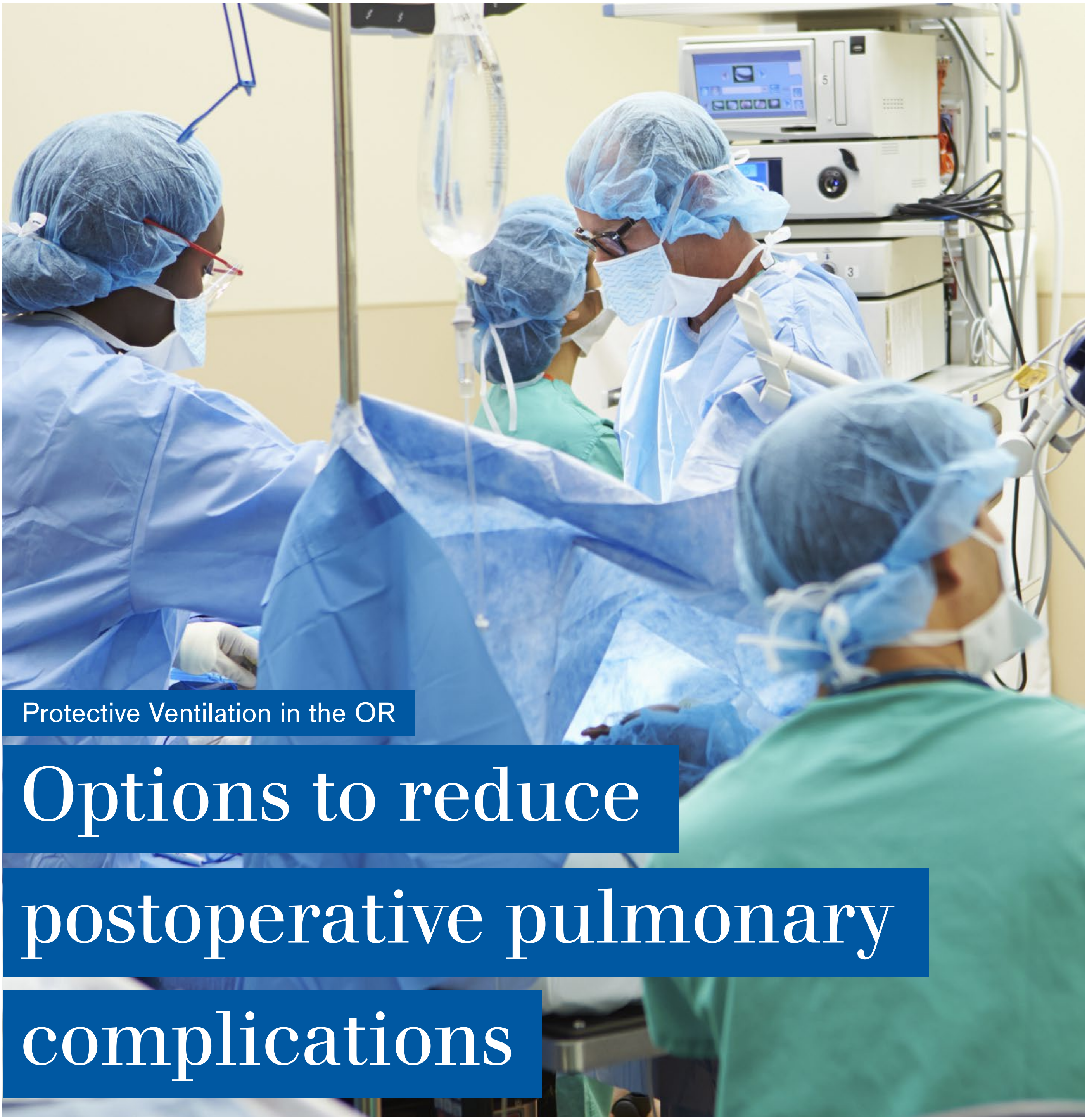

Protective Ventilation in the OR

Options to reduce postoperative pulmonary complications

This article explores the current discussion on intraoperative lung protective ventilation strategies. It provides condensed background information and an overview of current literature-based recommendations to reduce postoperative pulmonary complications.

The discussion on how to ventilate surgical patients intraoperatively to minimize postoperative pulmonary complications has been lively in the past years. Various randomized controlled trials (RTCs) and reviews have been conducted to shed light. However, research has not fully restored clinical balance. Some parameters of ventilation are proven as levers for protecting patients' lungs during surgery, some remain unclear and require further research. However, all in all it seems to be common sense that general anesthesia impairs lung function and ventilation plays a significant role in causing these impairments. Although results from research conducted on this topic are ambiguous, the evidence gained during the past years mandate the use of lung protective strategies in surgical patients even though not all questions have been sufficiently answered yet.

The question is how current approaches can be implemented effectively. Various other clinical procedures have shown that, although striking evidence is in place, recommendations and even guidelines are not fully applied on a routine basis in clinical practice.

Discussion on specific parameters

In the discussion on intraoperative lung protection, research focusses on specific parameters that are expected to have an influence on the incidence of postoperative pulmonary complications, either individually or in conjunction with each other. Under discussion is the size of tidal volumes (Vt), the use and the level of positive end-expiratory pressure (PEEP), the applied oxygen fraction[2], recruitment maneuvers and recently the plateau- and driving pressures[3].

Tip: For further technical background information, see our "technology insights" e-book.

Tidal volume

High Vt has already been described for quite some time to be particularly dangerous for ARDS patients and low Vt ventilation has become a standard of care for these patients in the ICU as evidence demonstrated a clear reduction of mortality. But evidence has not only demonstrated the benefits of low Vt for ARDS patients, but also for critically ill patients without lung injury. But for these patients, low Vt strategies have not yet become a standard of care[2].

In the OR, clinical trials have suggested that lung protective strategies encompassing reduced Vt have a positive effect on lung function and the incidence of postoperative pulmonary complications (PPCs). Three RCTs have demonstrated positive effects of low Vt in patients undergoing abdominal surgery and spinal surgery. Tidal volumes in these trials were as low as 6-7ml/kg predicted bodyweight (PBW)[2]. The two large European trials, known as IMPROVE and PROVHILO, have both advocated that lung protective ventilation in the OR should include low Vt, but showed contradicting results with respect to other components of lung protection, namely PEEP and recruitment maneuvers (RM)[4, 5]. A recent meta-analysis stated the harmful effects of high Vt even under short-term ventilation for general anesthesia for surgery advocating relatively low Vt of 6-8ml/kg PBW[6]. A very recent RCT on lung protective ventilation further suggests this approach for healthy patients undergoing laparoscopic surgery[7].

TIDAL VOLUME AND PREDICTED BODY WEIGHT

It is well known that tidal volumes should not be calculated based on actual but on predicted or ideal body weight, as suggested. This is important as the application of tidal volumes as low as 6-8ml/kg result in tidal volumes that may appear very low, probably lower than many would expect. In addition, there seems to be no agreement on a uniform way to calculate the PBW. The equations found in literature are inconsistent and result in markedly different tidal volumes. An actual article listed and compared various equations and recommended the NIH/NHLBI ARDSNet definition[8]:

- Women: 45.5 + 0.905 x ([height in cm] – 152.4)
- Men: 50.0 + 0,905 x ([height in cm] – 152.4)

PEEP

Whereas most research seems to be unambiguous with respect to tidal volumes, the use and the benefit of PEEP appears to be still controversial. For patients with moderate to severe ARDS, a meta-analysis has suggested a benefit from higher PEEP levels. But three independent RCTs failed to demonstrate definitive benefit. In critically ill patients without ARDS one study showed a benefit of a PEEP of 5 - 8 cmH_2O compared to zero PEEP (ZEEP) with regards to the incidence of ventilator-associated pneumonia and the risk of hypoxemia, but not with respect to outcomes. Another trial could not demonstrate a positive effect of a PEEP of 8 cmH_2O on the occurrence of ARDS or other associated complications. But another RCT found an independent association between higher PEEP levels and the development of lung injury when comparing Vt of 6 and 10 ml/kg PBW in the critically ill patient without ARDS.[2, 12, 13, 14, 15, 16, 17, 18.]

For the perioperative ventilation, the available research does not give a clear answer on an ideal PEEP. The above mentioned three RCTs compared bundles of lung protective measures, also including different levels of PEEP. This made it almost impossible to draw any conclusion about the individual effect of this parameter[2]. PEEP was also the controversial point when comparing the two big European trials, PROVHILO and IMPROVE[4, 5]. While IMPROVE recommended a moderate PEEP level to keep recruited lungs open and to prevent further collapse, the PROVHILO trial could not demonstrate any benefit from higher PEEP levels of 12 cmH_2O compared to low PEEP levels of 2 cmH_2O, but high PEEP levels produced more intraoperative hypotension and a higher need for vasoactive drugs[4, 5]. The above mentioned meta-analysis cites recent findings that also suggest that higher levels of PEEP (10 - 12 cmH_2O) do not protect against PPCs and may even cause harm, at least in the non-obese patient[6]. The above mentioned recent RCT on lung protective ventilation in patients undergoing laparoscopic surgery found that low Vt with a moderate PEEP of 5 cmH_2O was associated with less incidences of pulmonary complications compared to conventional ventilation approaches with high Vt with RM and no PEEP[7]. So the discussion currently appears to tend toward moderate to low PEEPs[3, 11].

Some authors mention that an appropriate PEEP has to be chosen, but leave the question open on an appropriate PEEP setting. In a recent commentary, Pelosi and Ball have asked the question as to whether it is time to talk about tailored protective ventilation, and demand further studies in particular on the role of patient-tailored PEEP settings[3]. This is also backed by a recent comprehensive review stating that PEEP should be chosen according to the patient's particular characteristics, to specifics of the surgical approach and the patients' position[11]. From a clinical routine perspective, Dr. Chris Thompson, Senior Staff Specialist at Royal Prince Alfred Hospital, Clinical Lecturer at the University of Sydney, Australia, has commented on this topic in his lecture at the ANZCA Congress 2015 in Australia. In his lecture, he gave practical insights into his approaches to protective ventilation including patient individual PEEP titration[10].

You can watch the lecture on youtube (Link).

Plateau pressure and driving pressure

Two parameters have seldom appeared in the discussion on protective ventilation: plateau pressure and driving pressure, which is defined as plateau pressure minus PEEP. A recent hospital based registry study analyzing 69,265 consecutive patients undergoing non-cardiac surgery (2007 – 2014) with general anesthesia and endotracheal intubation found that there is a moderate, statistically significant dose dependent relation between the risk of respiratory complications and the level of plateau pressure. The driving pressure was stated to have an effect on the occurrence of respiratory complication comparable to the plateau pressure. A median plateau pressure of less than 16 cmH_2O was identified as being protective and resulting in no increased risk of ventilator associated postoperative respiratory complications. A very interesting finding was that there was no significant statistical association between Vt and the incidence of PPCs[9].

Ball and Pelosi, whose earlier mentioned comment refers to this study, stated that this finding suggests that the harmful effect of tidal volume dynamic strain might be mediated by an increase in plateau pressure linked to lung compliance, possibly reflecting lung stress[3].

Fraction of inspired oxygen (FiO_2)

Traditionally a high FiO_2 was expected to improve oxygenation and reduce the incidence of PONV as well as surgical site infections. But in the past years a more critical discussion has developed around the fraction of inspired oxygen that puts a question mark behind the afore mentioned traditional opinion. Part of this discussion is the assumption that high FiO_2 may induce pulmonary dysfunction, e.g. by induction of resorption atelectasis in unstable aveoli, and pulmonary injury, at least in part caused by oxidative stress via increased levels of reactive oxygen-derived free radicals that can overcharge natural antioxidant defenses and injure cellular structures. Furthermore, evidence suggests that high FiO_2 in conjunction with high blood oxygen is associated with increased mortality in critically ill patients[2].

For intraoperative ventilation, Güldner et al recommend to use an FiO_2 of ≥0.4 to keep SpO_2 ≥92% and increase FiO_2 first in case of hypoxemia (if other reasons are ruled out)[11]. This applies to non-obese, healthy patients. There may be good reasons for higher oxygen fractions depending on the patient or the surgical procedure.

Recruitment

Most studies cited herein have not specifically studied how, when and for which patients to best apply recruitment. However, PEEP has been described as being most effective when a recruitment maneuver has been carried out before. Güldner et al recommend to do so during tidal ventilation using an incremental approach with pressure controlled ventilation keeping driving pressure constant at 15 - 20 cmH_2O and gradually increasing PEEP to 20 cmH_2O in steps of 5 cmH_2O at 30-60 seconds per step. PEEP and tidal volume are adjusted to desired levels after up to 5 breaths at the PEEP level that achieves the targeted inspiratory pressure. Recruitment of atelectatic lung areas may require airway pressures of 40 mbar or even higher[11]. This approach shows similarities with the above mentioned approach to PEEP titration suggested by Chris Thompson[10].

However, as we believe recruitment is a quite important topic in the discussion on intraoperative lung protection, we will provide you with a separate review of literature at a later point in time.

RECOMMENDATIONS FROM LITERATURE

Based on current evidence, Ball and Pelosi suggest the following parameters to be included into a protective ventilation strategy which is largely backed by recommendations by Filho & Serpa Neto published in a recent commentary[1, 3] and Güldner et al published in their recent Review[11]:

– Low tidal volumes of 6-8ml/kg PBW[1, 3, 11]
– Plateau pressure (<16cmH_2O) and low driving pressure, whenever possible[1, 3]
– low PEEP ≤ 5 cmH_2O[3] or even ≤ 2 cmH_2O[11] without recruitment[3, 11]
– PEEP between 5 - 10cmH_2O to be considered in obese patients and for patients undergoing laparoscopic surgery in Trendelenburg position for >4h[3]
– FiO_2 ≥0.4 to keep SpO_2 ≥ 92 %[11]
– No recruitment maneuver as initial measure[11]
– In case of hypoxemia (if other causes are ruled out and if not contraindicated), FiO_2 should be increased first, followed by increase of PEEP and incremental recruitment maneuver[11].

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