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Mini Review

Mechanical Ventilation in the Operating Room: Evidence and Current Practice

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Abstract

General anaesthesia is an integral part of a standard operating practice. Ventilation strategy during general anaesthesia, despite being a key parameter determining peri-operative success, is the often neglected and comes as a least important anaesthetic consideration in contemporary practice.

Keywords: Ventilation; Operating Room; Surgery; Anaesthesia

Introduction

Mechanical ventilation: past and present

The concept of mechanical ventilation has been evolved drastically in last few decades. Under the effect of muscle paralyzing agent, when lungs are actively ventilated with the help of a ventilator, it never simulates a spontaneous breathing pattern. The positive pressure breathing has multiple negative impacts on human physiology. The stress and strain from inflation of pressurized gas into the alveoli causes ventilator induced lung injury. The power of the mechanical ventilator [1] is the main determining factor in the process of mechanical damage to lung parenchyma. Mechanical power of the ventilator depends on tidal volume, respiratory rate, inspiratory-to-expiratory time ratio, applied PEEP, resistance and elastase of respiratory system. Each of the above parameter has deleterious effect on the pulmonary physiology. Lung protective ventilation is the only ventilatory strategy prevent ventilator induced lung injury to some extent. Although tidal volume 6 - 8 ml/kg predicted body weight remains a fundamental aspect of lung protective ventilation, other components like application of PEEP as open lung strategy, limiting plateau pressure and driving pressure to prevent overdistension injury, recruitment manoeuvre to prevent atelectasis, and titration of fiO2 and I:E ratio are also important aspects as part of ventilation strategy.

Evidence of lung protective ventilation in OR

Traditionally, tidal volume of 10 - 12 ml/kg body weight was encouraged during general anaesthesia, especially for abdominal and thoracic procedures as it showed to have lesser atelectasis and improved oxygenation compared to low tidal ventilation [2] Concept of lung protective ventilation (LPV) became popular in intensive care medicine field after a landmark trial [3], that showed significant mortality benefit in patients with ARDS. The practice soon became a standard of care in ICU practice after publication of numerous articles showing its benefit in non-ARDS patients in terms of mortality, lung infection [4], development of pulmonary complications [5], and ventilator free days [6]. Soon interest grew among the clinicians, to evaluate whether same benefit leaches during mechanical ventilation in patients with healthy lung in operating room (OR). The most important complication of induction of general anaesthesia in healthy individual is development of atelectasis [7] and post-operative pulmonary complication (PPC) [8]. The ventilator strategy plays significant impact on this two issues as a part of comprehensive peri-operative care. There are number of randomised and non-randomised trials published in last two decades showing physiological and clinical benefit of LPV during general anaesthesia. Most of these studies were conducted in the setting of major abdominal surgery. Two major recent RCTs

[9,10], showed lesser pulmonary and extra pulmonary complications associated with LPV in intra-operative period when followed up 5 - 7 days post-operative period. Similar benefits were seen in extra-abdominal surgeries as well. Using LPV during intraoperative period was associated with better post-operative pulmonary function [11] and fewer post-operative hypoxia [12] when used in cardiopulmonary bypass. In patients undergoing thoracic surgery, low tidal volume ventilation was found to be associated with lesser post-operative pulmonary dysfunction [13], duration of mechanical ventilation [14] and better post-operative oxygenation index [15]. Another RCT conducted on high risk elderly patients (ASA 2 and 3) undergoing spinal fusion surgery [16] showed better perioperative oxygenation and accelerated recovery of respiratory function with LPV when followed up for three days post-operative period. There are some physiological trials as well which showed lesser release of pro-inflammatory cytokines and procoagulant factors when LPV used in peri-operative period [17-19], that may or may not translated into clinical benefit in the given study setting. Meta-analysis on this topic [20,21], also majorly speaks on behalf of benefits of LPV over conventional high tidal volume ventilation in terms of clinically significant pulmonary outcome and length of hospital stay.

Problem statement

Despite having overwhelming number of clinical articles stating benefit of LPV in OR, the strict adherence of LPV is still uncommon [22] among the anaesthesiologists. Two recent observational studies [23,24] on the practice of mechanical ventilation in operating room shows a large number of patients receive tidal volume greater than 10ml/kg body weight and no PEEP in operating room, and incidence is highest in patients with obesity and short height. The main reason for nonadherence is not disinterest but "lack of knowledge in concept [25]. One reason for apathy may be that, with short duration of conventional ventilation during GA, complications may be clinically inapparent. Short-term nonprotective mechanical ventilation for ≥ 5 hr) found to promote local bronchoalveolar inflammatory changes and activate coagulation in patients without pre-existing lung injury [19,26]. In clinical studies, even 2 hrs of non-protective ventilation has found to have significant post-operative pulmonary complications [10]. Moreover, it should be emphasized that, there is no physiological rationale supporting not to use LPV in OR.

Second factor may be that in contemporary clinical trials demonstrating benefit of LPV in OR, the parameters aspect in terms of use of PEEP, recruitment maneuvers, FiO_2 setting was extremely heterogenous. The most consistent parameter was low tidal volume ventilation (6 - 8 ml/kg BW). The prominent effect of decreasing tidal volume is probably decreasing driving pressure that has found to be independently associated with PPC even in normal healthy lung ventilation in operative setting [27-29]. Another hospital based registry study in USA, over 69265 enrolled patients requiring GA with ET intubation, intraoperative protective ventilation was found to be associated with lesser risk of post-operative pulmonary complication with PEEP 5 and median plateau pressure of 16 associated with lowest risk [30].

Zero positive expiratory pressure (ZEEP) causes reduction in end expiratory lung volume (EELV) under anaesthesia and increases area of atelectasis, decrease static lung compliance and induces over-inflation injury in in aerated lung tissue [31]. Application of PEEP universally improve intraoperative oxygenation, but the beneficial effect dissipates after extubating. Effect of PEEP in clinical trials have been found to be heterogenous, and optimal level of PEEP along with low tidal volume ventilation remains a matter of debate. Moreover, higher level of PEEP may adversely affect the hemodynamic parameter in the setting of hypovolemia. Two recent multicentric RCTs [32,33], (PROVHILO and PROBESE) showed no beneficial effect of setting higher PEEP during anaesthesia on post-operative pulmonary outcome. An Expert panel based consensus recommendation [34] advocates PEEP of 5 cm of H_2O to use initially, and to individualise in case of obese patients, in prone and Trendelenburg position and during pneumoperitoneum avoiding increase in driving pressure.

Regarding the use of recruitment maneuver, studies are inconclusive. While it prevents atelectasis, but is associated with adverse hemodynamic disturbance and the effect is ill sustained.

FiO_2 is another potentially modifiable factor. Intraoperative FiO_2 should be titrated to prevent hyperoxia as it may increase oxidative stress, induce coronary artery vasoconstriction and increase absorption atelectasis and PPC [35] Goal should be to maintain normoxia with target SpO2 > 94% and preferable FiO_2 < 0.4% [34]. During hypoxia aim should to find out the cause of gas exchange impairment and improve lung compliance rather to indiscriminate increase in FiO_2.

I:E ratio during mechanical ventilation is a potentially contributing factor in mechanical power concept. This parameter is less well studied, but prolongation of inspiratory time has been associated with increase mean airway pressure to improve oxygenation and to provide "balanced stress versus time product" associated with attenuation if lung injury [36].

Conclusion

Future trend and best practice strategy

On the basis of above discussion, it can be clearly stated that protective lung ventilation to be universally accepted for all patients undergoing general endotracheal anaesthesia. The component of the strategy may be individualised case by case basis, keeping driving pressure within limit. Intra operative LPV should be an essential part of perioperative bundle of care for improvement of surgical outcome.

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Conflict of Interest

None.

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