Editorial

Intraoperative lung-protective ventilation in cardiothoracic surgeries: Paradigm and practices

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Pulmonary dysfunction is a recognised complication of cardiothoracic surgeries, with its spectrum ranging from atelectasis in mild cases to acute respiratory distress syndrome (ARDS) in severe cases and having complex and multifactorial aetiology.[1,2] The alterations in the pulmonary mechanics are the combined effect of anaesthesia, surgical incision (affecting the integrity of chest wall), cardiopulmonary bypass (CPB) (through proinflammatory and proapoptotic pathway activation), blood transfusions, postoperative pain (preventing deep inspiration) and diaphragmatic dysfunction. Prevention of pulmonary complications includes various strategies like lung-protective ventilation (LPV), pharmacological protection (inhaled prostacyclins, phosphodiesterase inhibitors and nitric oxide), CPB modification (heparin coating, leucocyte removal), and surgical techniques (off pump coronary artery bypass graft). Additionally, postoperative non-invasive ventilation and physiotherapy have been recommended to minimise postoperative pulmonary complications (PPCs). Among these, appropriate intraoperative mechanical ventilation management is a predictable factor in preventing PPCs and improving respiratory and extra-pulmonary outcomes. Initially employed in managing patients with ARDS, the scope of LPV strategies encompassed a wide variety of surgeries including cardiac surgeries.

Mechanical ventilation is an established injurious process associated with barotrauma, volutrauma and atelectotrauma, accentuated by general anaesthesia-induced reduction in muscular tone and reduced lung volume, alteration in ventilation/perfusion ratio and the onset of atelectasis. Repetitive over-distension and collapse of the alveoli induce lung injury; preventing both overdistension using lower tidal volume (VT) and alveolar collapse using positive end-expiratory pressure (PEEP) has remained the cornerstone for the LPV strategies. Patients undergoing cardiac surgery represent a vulnerable subset because of the prolonged duration of surgery, comorbidities, proinflammatory processes due to CPB, ischemic reperfusion injuries and complete collapse of lung parenchyma secondary to interruption of ventilation during cardiac surgeries with CPB. In the chronology of events, CPB-related systemic inflammatory response syndrome represents a crucial first hit for lung injury, and injurious (or non-protective) ventilation represents the second hit that worsens the lung damage. Additionally, during CPB, lungs are often under-perfused, non-ventilated or under low continuous positive airway pressure (CPAP). A growing interest in LPV strategies has been witnessed in the past few years though the evidence is insufficient, and there are no universal guidelines in this regard.[3]

The intraoperative LPV strategy is a relatively new concept in surgeries performed under general anaesthesia. LPV is not limited to tidal volume (VT)

reduction. The significant components of ventilatory management include assist-controlled mechanical ventilation with low VT (6–8 mL kg^{-1} of predicted body weight) associated with higher PEEP (depending upon the compliance and other factors) limitation of the fraction of inspired oxygen (FiO_2), ventilation maintenance during CPB and, finally, recruitment manoeuvres. Optimal FiO_2 and duration of oxygen exposure are important as excessive production of reactive oxygen species may lead to oxidative stress, which can have adverse effects.[3,4] Regarding FiO_2 management, a recent review concluded that moderate hyperoxia (50 − 80% FiO_2) confers benefits of reduced surgical-site infections and absence of clinical drawbacks.[5] Among the ventilation strategies, low VT and high PEEP were advocated; however, other modalities require investigation. The present issue of Indian Journal of Anaesthesia (IJA) features the clinical investigation by Adabala *et al*.[6] They investigated the role of inverse ratio ventilation (IRV) in patients undergoing laparoscopic cholecystectomy. IRV increases the inspiratory time and mean airway pressure without increasing the peak and plateau pressure that forms the basis for lung protection. Patients were allocated to either the conventional ventilation (VT 8 ml/kg, RR-12/min, I: E-1:2) group or IRV group (I: E-2:1). They did not observe any difference in the postoperative pulmonary function; however, the airway pressures were considerably reduced in the IRV group. Moreover, there were no differences in lung function parameters, indicating the ventilation strategy's usefulness only when the lungs are injured. In the presence of normal lungs, LPV, IRV or conventional ventilation strategy may not make an appreciable difference. Interestingly, the usage of PEEP has not been discussed elaborately by the authors. In the IRV group, the authors remarked that they did not use any extrinsic PEEP, contributing to atelectasis. It would have been interesting to know the results if PEEP had been applied.

Cardiothoracic surgeries need special consideration regarding ventilation. Firstly, VT and PEEP management during one-lung ventilation (OLV) is a special requirement during many thoracic surgeries. PEEP to the ventilated lung, CPAP to the non-ventilated lung, intermittent recruitment manoeuvres and lung insufflations; all of them have been advocated to prevent hypoxaemia.[7] The role of LPV in OLV remains elusive. Blank RS *et al*.[8] retrospectively evaluated 1019 patients' data and found that VT is inversely related to the incidence of PPCs. The authors also found that low VT alone cannot prevent PPCs without adequate PEEP. The Pulmonary Surgery with Protective Ventilation (PPV) trial also employed intermittent lung recruitment in addition to low VT and PEEP and echoed similar results.[9] Secondly, ventilation modalities during CPB include no ventilation, CPAP, low VT and PEEP-based ventilation with minimal respiratory rate.[4] Meta-analysis has shown that lung ventilation during CPB improves oxygenation during the immediate bypass period, but not the PPCs significantly.[10] The CPBVENT 2014 trial result might put some more light into the matter in the coming days.[11] The third point to be considered is the ventilation strategy following intracardiac repair in patients with severe pulmonary hypertension. The study conducted by Bates DM *et al*.[12] in patients with chronic thromboembolic pulmonary hypertension undergoing thromboendarterectomy and reperfusion lung injury whose clinical outcomes did find a significantly favourable outcome for LPV. Finally, hyperventilation and ventilation with increased FiO2 are standard of practice after surgical repair of congenital cardiac defects such as a ventricular septal defect in children with pulmonary hypertension.[13] LPV might play a better role in this coronavirus disease of 2019 (COVID-19) pandemic and post-pandemic period as the virus affects the lung parenchyma. The Indian Society of Anaesthesiologists advisory and position statement on COVID-19 also advocates the use of LPV.[14] The IRV strategy can be explored as one of the strategies for intraoperative lung protection, possibly in those patients whose plateau pressure reaches 30 cm H_2O with conventional ventilation. The usage of PEEP with IRV is also one of the areas that can be explored during intraoperative ventilation. Nevertheless, wide variations exist between the practices among different centres and clinicians, and this heterogenicity has been acknowledged; therefore, focusing on current scientific evidence, standards of care need to be established concerning the ventilation of patients during cardiac surgery.[15] Implementing specific perioperative ventilatory strategies in patients undergoing cardiac surgery is expected to improve the postoperative outcome. However, for such strategies to be fully effective, they should be integrated into a multimodal approach beginning from the induction and continuing over the postoperative period.

Although postoperative pain management is not the focus of this editorial, one should appreciate that surgery on the chest is one of the most painful surgical procedures and compromises respiratory function. Untreated acute pain can have undesired sequelae like chronic postsurgical pain and posttraumatic stress

disorder.[16] High thoracic epidural analgesia (HTEA) with bupivacaine and fentanyl infusion is hugely effective (gold standard);[17] nevertheless, it is fraught with the risk of developing a thoracic epidural haematoma.[18] Multimodal analgesia regimens comprising intravenous opioids and acetaminophen and regional analgesia techniques (especially under ultrasound guidance) are preferred as they provide safe and effective analgesia. They have been shown to suppress stress response, decreased myocardial ischaemia, rapid recovery of spontaneous respiration and extubation, better peak expiratory flow rate, increased functional residual capacity, improved coughing and decreased postoperative arrhythmias. Certain novel regional anaesthetic techniques have proven their effectiveness in postoperative pain management of cardiothoracic procedures, including paravertebral block, serratus anterior plane block, erector spinae block, pectoral nerve block, etc.[19-21] Bilateral pectoral nerve block has been shown to reduce the duration of ventilation, resting pain, pain on coughing in patients with mid-sternotomy.[18]

Evolution and adaptation to change are essential attributes for any speciality to flourish and diversify. As the academic wealth of anaesthesiology continues to evolve and adapt in the face of challenges of modern medicine, the inculcation of newer techniques and strategies and their pragmatic application will help our speciality to adjust according to the demands of increasing patient care, safety and satisfaction.

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