Hemodynamic effects of alveolar recruitment maneuvres in the operating room: Proceed with caution

Atelectasis occurs in 100% of subjects undergoing general anesthesia, leading to impairment in oxygenation even in patients with normal lungs.[1] The main mechanisms for the development of atelectasis under general anesthesia, are compression atelectasis, absorption atelectasis and impaired surfactant function.[2,3] General anesthesia and neuromuscular blockade restrict the movement of the diaphragm, leading to collapse of dependent lung regions. When the flux of oxygen enters the blood from the alveoli faster than nitrogen returns to the alveoli, (as oxygen diffuses faster than nitrogen), the alveoli shrink and collapse. This is exacerbated by high concentrations of oxygen. Surfactant impairment may be due to injurious mechanical ventilation settings and some anesthetic agents. In addition, the sigh reflex is abolished under anesthesia, resulting in loss of the inherent ability to mitigate atelectasis.[3-5]

Atelectasis produces adverse consequences including, decreased compliance, intrapulmonary shunting and increases the susceptibility to lung injury. It is a major cause of postoperative hypoxemia, respiratory failure and pneumonia, and is associated with a prolonged ICU and hospital stay.[4,6] Therefore, intraoperative strategies to prevent or reduce atelectasis may improve perioperative outcomes.

The use of positive end expiratory pressure (PEEP), lower FiO_2 and alveolar recruitment maneuvres (ARMs) are effective in preventing atelectasis. The use of higher tidal volume (TV), high plateau pressures and no PEEP, are associated with lung injury even in patients with healthy lungs.[5]Futier *et al*. in a randomized study in 400 patient undergoing abdominal surgery, showed a significant reduction in postoperative pulmonary complications (PPCs) when patients receiving intraoperative lung protective ventilation (IOLPV) using TV6-8 mL/kg; PEEP 6-8 cm H_2O and anARM were compared to TV of 10-12 mL/kg with no PEEP or ARM.[7]The PROVHILO trial, a randomised multicenter in 900 patients undergoing abdominal surgery, found no difference in PPCs when 12 cm H_2O PEEP was compared to 2 cm H_2O or lower PEEP.[8]The optimal PEEP level is probably somewhere between these values and further studies should address this.

The effects of an ARM leading to recruitment of collapsed alveoli and improvement of arterial oxygenation are short lived, as atelectasis may recur within 40 minutes.[9] Thus, the benefits of ARMs may be prolonged by performing repeated manoeuvres. A systematic review concluded that ARMs followed by the use of PEEP should be routinely used following induction, during maintenance of general anesthesia and when oxygen saturation falls.[4] In patients undergoing robotic prostatectomy, the incidence of intraoperative oxygen desaturation and postoperative atelectasis reduced in patients ventilated with TV 6-8 mL/kg and a PEEP 5 cm, with the use of ARMs compared to without ARM.[10]ARMs combined with conventional ventilation (TV 10 mL/kg; PEEP 0 cm H2O) are associated with more PPCs compared to ventilation with TV 6 mL/kg and PEEP 5 cm H2O without ARMs.[11] These studies show that RMs confer a benefit when used as part of IOLPV package, but not when used alone or with conventional ventilation.

Although ARMs improve oxygenation, there can be adverse cardiovascular effects inflicted by the increased intrathoracic pressures which decreases the venous return, leading to a decrease in the left ventricular end-diastolic areas and stroke volume (SV).[12] These hemodynamic effects of ARMs depended both on the level and type of ARM applied and on the lung properties.[13] Broadly there are two ways of performing an ARM: sustained inflation of the lungs up to 40 seconds to a defined peak inspiratory pressure or by a stepwise increment in PEEP.[4] The hemodynamic outcomes of ARM in anesthetised patients have not been much studied. Two studies in hemodynamically stable cardiac patients, using ARM with sustained lung inflation, showed a significant reduction in cardiac output and left ventricular end-diastolic area.[14,15] In obese patients under general anesthesia, a strategy of higher PEEP with ARMs versus lower PEEP did not show any difference in PPCs. However, intraoperative hypotension was more frequent in the high PEEP group, suggesting that some amount of permissive atelectasis should be accepted.[16] Biais *et al*. showed that the magnitude of SV decrease (20% versus 43%) during an ARM could predict preload responsiveness in mechanically ventilated patients in the operating room.[17]This study indirectly shows that the hemodynamic effects of ARM may be more pronounced in preload dependent patients. The cardiovascular effects of different ARMs have not been compared.

In the current issue of the journal, Hanouz JL, *et al*. conducted a single centre observational study to compare hemodynamic effects of CPAP (ARM_{CPAP}) and stepwise increase and decrease in PEEP (ARM_{PEEP}) on the SV in 37 adult patients undergoing vascular surgery who were fluid non-responders. The patients were ventilated using a controlled ventilation mode with TV of 6 to 8 ml.kg^{-1}and PEEP +5 cmH_2O. The changes in SV measured during ARMs were more pronounced in the ARM_{CPAP} group (−39 ± 20%) as compared to the ARM_{PEEP} group (−15 ± 22%; $P = 0.002$).[18] This is the first study which compares the hemodynamic effects of two different ARMs in patients under general anesthesia. The main limitations of the study are the small sample size and that it was not randomized. In addition, echocardiography was not performed to determine the effect of the ARMs on the ventricular function. The findings of this pilot study are important, because they highlight that the magnitude of hemodynamic effects are different with different ARMs. These findings should prompt randomized studies comparing the hemodynamic effects of different ARMs in patients under anesthesia.

In conclusion, ARMs are useful in preventing atelectasis. The benefit of ARMs is not when used alone, rather when incorporated into a package of IOLPV. Adverse hemodynamic effects of intraoperative ARMs should be anticipated. These effects are more marked in preload-dependent patients; hence, preload optimisation should be considered before performing an ARM. The decrease in SV was more pronounced during ARM using brief CPAP than using stepwise increase and decrease in PEEP in this pilot study. Future studies should help identify which ARM produces lesser hemodynamic effects and their impact on short- and long-term outcomes. Until such time, ARMs in the operating room should be performed with extreme caution, under close monitoring.

Sheila N. Myatra

Department of Anesthesiology, Critical Care and Pain, Tata Memorial Hospital, Homi Bhabha National Institute, Mumbai, Maharashtra, India

Address for correspondence: Prof. Sheila N. Myatra, Department of Anesthesiology, Critical Care and Pain, Tata Memorial Hospital, Dr. Ernest Borges Road, Parel, Mumbai - 400 012, Maharashtra, India.

E-mail: sheila150@hotmail.com

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