mysafety insight

Lung Protective Ventilation during Anaesthesia

Clinical Information Leaflet

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The burden of postoperative pulmonary complications (PPCs)

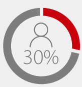
What are PPCs?

Every year, more than 230 million major surgical procedures requiring general or regional anaesthesia are undertaken worldwide [1]. According to LAS VEGAS study, for patients who underwent general anaesthesia and received mechanical ventilation, 10% of them will develop postoperative pulmonary complications (PPCs). This rate can be even higher for high-risk patients (19.2%) [2]. For cardiac and thoracic surgeries or or obese patients, the incidence may be higher than 30% [3].

PPCs are defined as unplanned supplementary oxygen, new or prolonged invasive ventilation, respiratory failure, acute respiratory distress syndrome (ARDS), and pneumonia, which may seriously affect patient outcome. Especially for severe PPCs like postoperative respiratory failure, the 30-day mortality goes up to 25.62%, whereas the mortality in patients without postoperative respiratory failure is only 0.98 % [4].

Did you know?

10% of patients who undergo general anaesthesia and mechanical ventilation will develop postoperative pulmonary complications (PPCs).[1]



For cardiac and thoracic surgeries or obese patients, the incidence of postoperative pulmonary complications (PPCs) may be higher than 30%.[3]

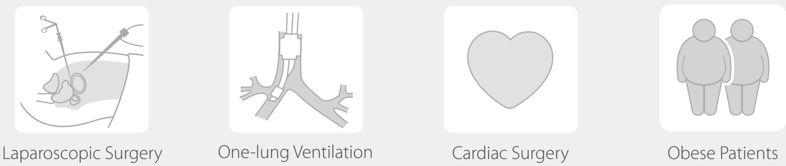
Causes and impact of PPCs

Multiple factors can increase the risks of PPCs, including the patient's condition, surgery incision and intraoperative anaesthesia management. During the intraoperative stage, while initiating anaesthesia, the patient's respiratory system will significantly change. Initially, patients will lose consciousness and the central respiratory drive will be depressed. Then, the use of neuromuscular blocking drugs will paralyze the respiratory muscles, which can lead to a significant decrease of Functional Residual Capacity (FRC) of 15-20% [5]. Decrease of FRC frequently causes atelectasis and is one of the most common respiratory changes contributing to PPCs during general anaesthesia.

Atelectasis may develop in nearly 90% of patients under general anaesthesia and can persist throughout the postoperative period and even up to several days after surgery [6]. The pathophysiological changes of atelectasis develop in two stages during an operation: Firstly, during the anaesthesia induction stage, a high concentration of FiO_2 (80-100%) is delivered to the patient, therefore, the decrease of nitrogen will cause inadequate surface tension to prevent the collapse of the alveoli, which will consequently cause absorption atelectasis. Subsequently, during the maintenance stage of anaesthesia, the decreased movements of the dependent side lung will cause compression atelectasis due to inactivity of the diaphragm and the gravity of lung tissue .

To prevent atelectasis, at times a higher tidal volume is used to recruit collapsed alveoli, however, this may lead to overdistension or even volutrauma [7,8]. Furthermore, injury of shearing forces from the repetitive opening and collapse of the alveoli, called "atelectrauma", can induce or worsen existing lung injuries.

High-risk of atelectasis under general anesthesia



Ventilatory Strategies to protect lungs during anaesthesia procedure

Epidemiologic data shows that PPCs rarely present shortly after surgery, but in a subset of patients at increased risk, PPCs develop over a period of days, with considerable impact on outcome [9,10]. Because of the 234 million surgical procedures performed annually, the current rate of PPCs remains an issue for patient outcome. Therefore, to improve the outcome for surgical patients, a better strategy is to prevent PPCs rather than providing treatments once they occur [11].

Lung protective ventilation is widely recognized as an effective strategy to keep the alveoli open while avoiding barotrauma.

Intraoperative lung protective mechanical ventilation using :

- Low tidal volume
- Optimal positive end-expiratory pressure (PEEP)
- Recruitment maneuvers

Commonly used strategies include low-tidal volume, optimal PEEP titration, and lung recruitment maneuvers [12,13].

The low tidal volume strategy could help prevent alveolar overdistention, benefiting critically ill patients with or without acute respiratory distress syndrome (ARDS) [14,15]. In addition, a lower driving pressure is also considered in decreasing the risk of PPCs in patients undergoing mechanical ventilation for general anaesthesia [16]. Mechanical ventilation with higher levels of positive end-expiratory pressure (PEEP) with or without recruitment maneuvers is suggested to prevent repetitive opening and closing of alveoli in patients with severe ARDS [17].

In fact, the protective ventilation strategies have not been fully recognized. According to a multicenter study during anaesthesia ventilation, about 18% of patients have a tidal volume of greater than 10ml/kg, while approximately 69% of patients are ventilated without PEEP [18].

Protective Ventilation Strategies applied to anaesthesia system

Lower tidal volume

Experimental and observational studies show that high tidal volumes may cause alveolar distension and ventilator-associated lung injury (VALI). The IMPROVED clinical trial suggested that protective lung ventilation and non-protective ventilation have different tidal volume settings of 6-8ml/kg versus 10-12 ml/kg. In retrospect, the lung protective ventilation group has a lower risk of PPCs with lower levels of ventilation support required and shorter hospital stays after surgery [19].

However, in a recent randomized clinical trial among adults undergoing major surgery, low tidal volume strategy did not significantly reduce PPCs within the first 7 days after surgery if the PEEP setting is fixed to 5 cmH_2O, suggesting clinical outcomes may not improve with only low tidal volume strategy [20].

Vt/IBW Indicator in A9/A8

The Mindray A9/A8 anaesthesia system can set Vt/IBW to its volume control mode to guide the default tidal volume based on a patient's ideal body weight. Additionally, when the clinician adjusts the tidal volume, a clear Vt/IBW indicator is displayed simultaneously to guide lower tidal volume strategy.

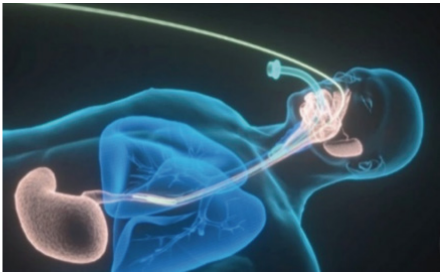
Optimal PEEP for individualized patient care

CT scans show that atelectasis can develop on the gravity-dependent area. By applying 10 cmH_2O of PEEP, the area of the collapsed lung shows drastic improvements on CT imaging [22], meaning that the application of adequate PEEP can prevent atelectasis. However, evidence suggests that a single-fixed value of PEEP is unlikely to fit all patient, as different PEEP settings are required for individual patient characteristics, such as chest wall shape, abdominal content, positioning, and pleural pressures [23]. A study on patients with a high risk of atelectasis, such as those who have undergone laparoscopic abdominal surgery, shows that individualized PEEP setting could reduce postoperative atelectasis while improving intraoperative oxygenation with minimum side effects [24,25]. The same result can be seen in obese patients, who require higher PEEP to keep the lungs open due to higher abdominal pressure [26].

Therefore, optimal PEEP titration during anaesthesia is recommended to improve lung function during and after surgery. The optimal PEEP is defined as the PEEP setting that leads to the lowest intrapulmonary shunt without compromising cardiac output [21]. But how is optimal PEEP titration for individual patients done?

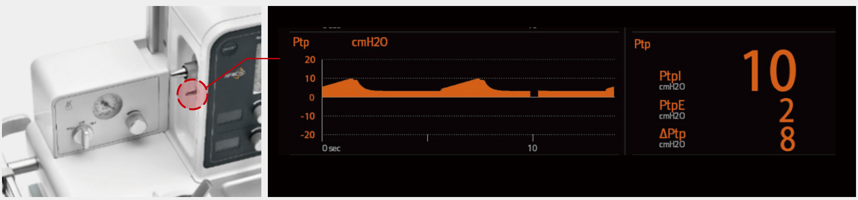
There are several PEEP titration methods commonly used by clinicians, including: pulmonary compliance directed methods, best oxygenation, Vds/Vt guided technique based on imaging, and transpulmonary pressure directed procedures [23, 24, 25].

Transpulmonary pressure is defined as the actual pressure distending the lung, which means the difference between the airway pressure and the pleural pressure(Paw - Ppl). Some evidence shows that transpulmonary pressure can be effectively used to guide PEEP setting. By keeping a positive end expiratory transpulmonary pressure, the transpulmonary pressure PEEP titration method allows for assuring the adequate PEEP without alveolar collapse and over-distention. It is recommended to limit the transpulmonary pressure less than 20-25 cmH_2O at the end of inspiratory to reduce lung strain from overstretching of the alveoli [27,28].



Transpulmonary pressure monitoring in A9/A8

Mindray's A9/A8 anaesthesia system can provide an auxiliary pressure channel, allowing real-time measurement of the esophageal pressure through a balloon catheter. The transpulmonary pressure can be accurately calculated by esophageal pressure and thus help efficiently guide the optimal PEEP setting. Waveforms and parameters such as end-inspiratory transpulmonary pressure, end-expiratory transpulmonary pressure, and transpulmonary driving pressure are shown simultaneously, to help optimize ventilation settings for individual patients, allowing for clinical decision-making with more confidence.

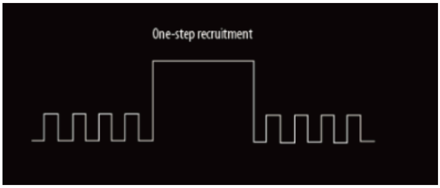


Recruitment maneuvers

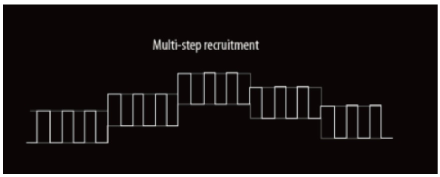
A study in morbidly obese patients shows recruitment maneuvers followed by adequate PEEP setting can reduce atelectasis and improve oxygenation, whereas PEEP or a recruitment maneuver alone does not [29]. Recruitment maneuver is a strategy aimed at re-expanding collapsed alveoli and augmenting the exchange surface at the alveoli-capillary membrane, to avoid intra-and postoperative lung complications [30].

So how is lung recruitment commonly done in the operating room? A wide variety of recruitment maneuvers have been reported and used in practice, including sustained inflation, stepwise increase of tidal volume ventilation, incremental PEEP procedure, etc. The best recruitment maneuver technique may vary according to the specific patients and circumstances [12, 31].

The sustained inflation technique is frequently used during surgery, in which a continuous pressure of 40 cmH_2O is applied to the airway for 30-60 seconds. Most commonly, this maneuver is performed by "bag squeezing" using the airway pressure-limiting (APL) valve of the anaesthesia machine. However, sometimes the airway pressure can be difficult to control during manual operation and may possibly result in overpressure.



The stepwise PEEP procedure is the process of increasing PEEP step-by-step (incremental), sustaining several breath cycles in each step, then decreasing PEEP step-by-step (decremental) to a normal level. In this maneuver, the maximum inspiratory pressure must be carefully limited, and a constant driving pressure is recommended. During the decremental phase, optimal PEEP can be titrated by monitoring the best pulmonary oxygenation or compliance. Some research recommend after finding the optimal PEEP, a recruitment maneuver should be repeated to re-open the lung, then the PEEP should be set to the optimal level as done previously [32].

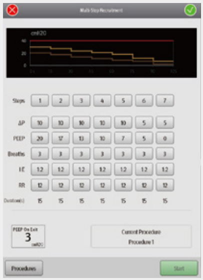


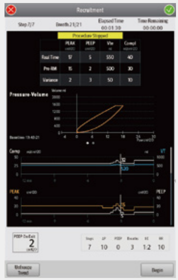
Recruitment Pro Tool in the A9/A8

Mindray's A9/A8 anaesthesia systems are equipped with powerful lung recruitment tools. There are two commonly used recruitment maneuvers in A9/A8: the sustained inflation (one-step) and the stepwise PEEP (multi-step) maneuver, allowing clinicians to choose the most suitable tool according to the specific requirements of the patient. Both maneuvers can be started and stopped with one key, without adjusting lots of control parameters or squeezing the bag manually.

- In the one-step recruitment tool, the sustained pressure and duration can be customized. Additionally, the recruitment can be repeated automatically at a preset interval, such as 30 minutes, allowing more effective recruitment during long-term surgery.

- In the multi-step recruitment tool, up to 5 procedures can be customized and saved to make the lung recruitment process quick and easy. Lots of information is displayed on the [Recruitment] menu to help evaluate the effect of recruitment and guide the titration of optimal PEEP for individual patients, including real-time values and trends of tidal volume, compliance, pressure, and loops.

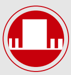




Lung protective ventilation strategy

Low tidal volume

Optimal PEEP titration



Recruitment maneuvers

What Mindray can offer

1 Vt/IBW indicator

Vt/IBW can be calculated as the tidal volume changes, offering clinicians clear indication of appropriate tidal volume settings.

2 Transpulmonary pressure monitoring

Independent monitoring for esophageal pressure, to support customized ventilation settings for individual patients.

3 Recruitment Pro Tool

- Two optional maneuvers: stepwise PEEP or sustained inflation.
- Multiple criteria to evaluate recruitment effectiveness.
- A scheduled recruitment can be performed automatically.

Striving for best practices towards patient safety in anaesthesia settings, Mindray incorporates various protective ventilation tools in the A8/A9 anaesthesia systems, which contributes to safer patient management by reducing the risk of PPCs and improving patient outcomes.

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