Committee News

Using PEEP in the OR and ICU

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Although the use of positive end expiratory pressure (PEEP) for pulmonary edema was described by Barach in 1938, PEEP did not enter routine clinical practice until the late 1960s, when it was used by Gregory and colleagues in neonates with respiratory distress (*Crit Care Clin* 2007;23:251-61; *N Engl J Med* 1971;284:1333-40). The use of PEEP then expanded to adults, with reports of improved oxygenation in adult respiratory distress syndrome (ARDS) (*N Engl J Med* 1970;283:1430-6). Today, PEEP is a standard component of mechanical ventilation (*ScientificWorldJournal* 2014;2014:852356).

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PEEP is the airway pressure above atmosphere that exists at the end of expiration. In intubated patients, 5 cm PEEP ("physiologic PEEP") prevents atelectasis and results in normal FRC. PEEP is a critical component in management of severe hypoxemic respiratory failure in ARDS. In ARDS, the lungs are filled with exudative fluid due to cytokine damage to the endothelial-capillary interface in the alveoli (*Chest* 1980;77:636-42). Decreased surfactant level and function results in decreased lung compliance and alveolar collapse. PEEP produces alveolar recruitment, improving oxygenation and decreasing pulmonary shunting and work of breathing. PEEP can be used during noninvasive ventilation (CPAP or BiPAP) to keep alveoli open and prevent derecruitment, but high levels of PEEP may not be tolerated in spontaneously breathing patients (*Am J Respir Crit Care Med* 1999;159:872-80). The adverse effects of PEEP include increased intrathoracic pressure, which decreases venous return and cardiac output. Overdistension of normal alveoli can cause barotrauma, ventilator-induced lung injury (VILI), and shunt blood to diseased alveoli, worsening hypoxemia (*Am J Respir Crit Care Med* 2001;164:131-40). Finally, by increasing thoracic pressure, PEEP may increase intracranial pressure.

In ARDS, decreased lung compliance requires higher airway pressures to open the alveoli, so higher levels of PEEP are needed to prevent atelectasis and shunting (*Anesthesiology* 2014;121:572-81). Lung protective ventilation (LPV) using low tidal volumes (4-8 ml/kg predicted body weight) and limiting inspiratory plateau pressures (<30 cm) improves outcome. There are several methods for determining best PEEP, including pressure volume loops and esophageal balloon (*Intensive Care Med* 2017;43:603-11). A meta-analysis demonstrated that patients with moderate to severe ARDS (PaO_2/FiO_2<200) benefited from a higher PEEP strategy (*JAMA* 2010;303:865-73). However, high PEEP levels may require sedation or paralysis. It is important to individualize treatment with PEEP in ARDS by considering lung mechanics, which can change over time.

Intraoperative use of PEEP

Postoperative pulmonary complications (PPCs) such as pneumonia and hypoxemic respiratory failure are common after major surgery (*Anesthesiology* 2015;123:692-713; *Anesth Analg* 2020;131:1721-9; *J Clin Med* 2021;10:2656). General anesthesia produces atelectasis, which can cause PPCs (*Anesthesiology* 2022;136:181-205). Ventilation with high tidal volumes prevents atelectasis but produces alveolar overdistention, resulting in VILI. Low tidal volumes (6-8 ml/kg PBW) minimize VILI but increase atelectasis when used without PEEP. The addition of PEEP as part of LPV in surgical patients prevents atelectasis and decreases PPCs, so most authors recommend moderate levels of PEEP (5-8 cm) (*Minerva Anestesiol* 2018;84:229-35). Higher levels of PEEP can recruit additional atelectatic lung and improve gas exchange but can produce hypotension due to decreased venous return and increased right ventricular afterload, and it may increase VILI due to overdistention of alveoli during inspiration. There remains controversy on whether there is benefit from higher levels of PEEP, especially in patients who are obese (*Lancet* 2014;384:495-503; *JAMA* 2019;321:2292-2305).

Studies have therefore examined whether the ideal level of PEEP can be determined in an individual surgical patient. The goal of PEEP is to recruit atelectatic alveoli without producing overdistention. The ideal PEEP may therefore correspond to the best lung compliance. At a fixed tidal volume, driving pressure (inspiratory plateau pressure minus PEEP) is inversely proportional to pulmonary compliance, so titrating PEEP to the lowest driving pressure has been used to optimize the level of PEEP (*Lancet Respir Med* 2016;4:272-80). The iPROVE study demonstrated a nonsignificant trend toward decreased complications with individually titrated PEEP, but no differences in overall outcome (*Lancet Respir Med* 2018;6:193-203).

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At the current time, most evidence suggests that moderate levels of PEEP are appropriate for the majority of patients undergoing general anesthesia. Individualized PEEP may be beneficial during one-lung ventilation in thoracic surgery (*Medicine* 2021;100:e26638). Multiple studies have demonstrated benefits of postoperative PEEP (CPAP) in patients with abnormal gas exchange following major abdominal surgery (*Cochrane Database Syst Rev* 2014;2014:CD008930). Ongoing studies will determine whether higher levels of PEEP are beneficial in specific patient populations such as patients who are obese, patients who have undergone thoracic surgery, patients undergoing laparoscopic surgery, patients in Trendelenburg position, and patients with risk factors for PPCs (*Curr Opin Crit Care* 2018;24:560-7; *Anesthesiology* 2018;129:1070-81). In addition, studies are using lung ultrasound imaging or electrical impedance tomography to determine the level of PEEP that reverses atelectasis without causing overdistention in individual patients. ■