Optimal PEEP - What We Can Learn from Neonates

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PEEP - positive end-expiratory pressure – has its well-established place in the arsenal available today for treating critically ill patients. However, the clinical usefulness of PEEP may be more arguable in mechanical ventilation during general anesthesia, particularly in perioperative lung recruitment.

There are many aspects to PEEP and every clinician should therefore understand its effects: how it modifies pulmonary function and hemodynamic performance, and what its "safe" levels are.

This is illustrated by observing the pulmonary physiology of pediatric patients (1). In acute respiratory failure, neonates can be particularly sensitive to the prejudicial effects of high PEEP(2). Similarly, both adults and small children may demonstrate hemodynamic disturbances due to high PEEP, particularly in the case of diminished preload (3,4).

PEEP and pulmonary mechanics

PEEP is a continuous positive counter-pressure throughout the expiratory period. Extrinsic PEEP is when the origin of the pressure is outside the patient, and intrinsic or auto-PEEP when its cause originates from inside the patient's airway. Total PEEP is then the sum of auto-PEEP and extrinsic PEEP.

The term "hidden PEEP" is sometimes used for intrinsic PEEP generated as a consequence of "air trapping" in the alveoli, as in asthmatic patients. During forced expiration, a transmural pressure gradient across the smallest of the airways increases and tends to keep the alveoli open, simultaneously with dynamic compression of the airways. In fact "hidden PEEP" can cause a misunderstanding as some authors use it as a synonym for auto-PEEP (7,8).

PEEP is not only a straightforward impediment to expiration; it also increases Functional Residual Capacity (FRC), or the volume of air remaining in the lung at the end of expiration (7,8). The closing volume is the minimum volume that the lungs need to retain so that they do not collapse (9). It is affected by many conditions including the patient's age or pulmonary pathology.

At induction of anesthesia, the difference between the closing volume and FRC can be taken as a sort of safety margin: when patients become apneic they still maintain their normal oxygen saturation for a while. Hence we talk about "apnoeic oxygenation time", i.e. the duration from induced apnea to the point when the peripheral oxygen saturation decreases below 91% (7).

In general anesthesia many factors diminish FRC. Some of the reasons may be physiological, as in the case of neonates or pregnant women. Obesity, supine position and anesthetic drugs also have an influence, and hence the lungs are prone to atelectasis during general anesthesia (7,8,9).

How do newborns avoid atelectasis?

It is standard textbook knowledge that neonates may have a closing volume larger than their FRC. This means that at the end of normal expiration, newborn lungs would collapse and a neonate would need to recruit the lungs again at each inspiration.

Clearly, such a situation would not be physiologically sustainable. With the enormous respiratory effort required, the newborn's breathing would fail after the first few breaths – which can in fact happen when neonates have a deficit of pulmonary surfactant.

"Behind the Window: recruiting lungs at the age of two minutes" (Photo©Kalli-06)

The very first breath at delivery is a great effort for the newborn. It may generate inspiratory pressures of 80-90 cm H2O (5). Hence, to avoid lung collapse, a newborn utilizes a glottic closure reflex. Closing the vocal chords at end expiration prevents some of the air leaving the lungs, which raises FRC above the lung closing volume. The neonate thus avoids atelectasis in normal breathing , as that effect can be equivalent to 2-3 cm H2O of PEEP. Consequently, in a situation where there is an inhibited glottic closure reflex, such as at anesthesia induction, neonates rapidly become hypoxemic. (6).

The low systemic arterial pressures and low right side filling pressures of neonates make them more sensitive to PEEP than adults, but the glottic closure reflex of 2-3 cm H2O does not seem to cause significant hemodynamic alterations (3).

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Clinical usefulness of PEEP

In general, it is unlikely that a PEEP lower than 5 cm H2O would generate hemodynamic deterioration, assuming a normal preload condition. Neither does it cause barotrauma or dynamic overdistension to the lung. In the case of the neonate, PEEP levels that low are physiological and necessary (7).

A PEEP of between 5-10 cm H2O should only be used in patients in whom the pulmonary closing volume is very close to their FRC. A PEEP over 5 cm H2O may or may not generate hemodynamic deterioration; that will depend on the elasticity or rigidity of the lung tissue, which in turn affects the way PEEP-mediated intrathoracic and transpulmonary pressures behave.

Clinically significant hemodynamic effects start appearing at levels greater than 10 cm H2O. Here, they affect the preload of the right ventricle and also the pulmonary vascular resistances (3, 4). Hence the likelihood of barotrauma, dynamic overdistension or hemodynamic deterioration increases.

A high level of PEEP should only be used in patients with deteriorated lungs, i.e. diminished compliance. In this case, high PEEP is the only way of keeping the alveoli open once they have been opened with pulmonary recruitment maneuvers (8,9).

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