We know that the distribution of ventilation and perfusion within the lung is not homogeneous, and related to gravitational and anatomical changes. This heterogeneity increases during mechanical ventilation; even if the lung is "healthy". In "sick" lungs, it is even more exaggerated.

The approach of "optimal PEEP" is based of determination of the pressure value where the alveoli remain open; this approach (albeit with different definitions) is used and recommended during mechanical ventilation.

However: It is very probably, that different regions of the lungs have different "optimal" PEEP's, as been shown in Hedenstierna-school studies during lateral decubitus position. This MAY mean that the "average" (or "global") optimal PEEP is not optimal on the whole lung: In some areas, it may be insufficient to keep the alveoli open; and (maybe more important) in some areas it may lead to overdistension.

Can it be argued that the "optimal PEEP" approach is actually a compromise between the areas with higher and lower levels?

Should "optimal PEEP" be reviewed in this sense; especially in "healthy" lungs?

Mert Şentürk
Editor

Optimum PEEP During Anesthesia and in Intensive Care is a Compromise but is Better than Nothing

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Aerated lung volume is reduced both during anesthesia because of loss of muscle tone (1) and in acute lung injury because of the disease itself (2). Airways will more easily close during expiration and reopen during inspiration or even stay closed throughout the breath. Reduced or absent ventilation of regions behind closed airways will impair gas exchange and cause atelectasis when alveolar gas has been absorbed. The collapsed region may promote an inflammatory reaction (3). This suggests that closed airways and collapsed alveoli should be reopened and kept open during the anesthesia and in the intensive care patient. The benefit of an open lung during anesthesia can be discussed, depending on the duration of the anesthesia and the rationale may not be to optimize gas exchange. An lung kept open by PEEP may sometimes improve oxygenation but not always, due to impeded cardiac output and shift of lung blood flow to dependent regions that may still be collapsed (4). The reason is rather to limit continuous or cyclic airway closure and atelectasis. Moreover, it should be a goal to keep the lung open during the post-operative period (5). Atelectasis may remain for several days in the post-operative period, giving more time for potential negative consequences than during the anesthesia itself (6). Preventing fall in end-expiratory lung volume during the emergence from anesthesia by applying PEEP/CPAP reduces early postoperative atelectasis (7). Recent large number of multicenter studies on "protective ventilation" and postoperative lung complications may not have taken the emergence from anesthesia into sufficient account and have not had any control over lung aeration postoperatively, see e.g. (8, 9). It may not come as a surprise but to recruit the lung in the intensive care patient and to keep it open is even more obvious than during anesthesia.

An open lung can be achieved by a recruitment maneuver with an increase in airway pressure to e.g. 40 cmH_2O or more for a limited time (10, 11). Re-collapse of both airways and alveoli can be prevented by the application of positive end expiratory pressure, PEEP. An "optimum" PEEP will be the lowest pressure needed to keep the lung open and it will vary between patients, depending on body configuration and lung conditions. A lean subject will need less PEEP than an obese one as will a patient with healthy lungs compared to a patient with severely afflicted lungs as in e.g. ARDS. How then to know the correct application of PEEP? To keep dependent airways and alveoli open will require a higher airway (and alveolar) pressure than in non-dependent lung regions. This is a consequence of gravitational forces with a higher (more positive) pleural pressure around dependent lung regions than around upper, non-dependent regions. So what is ideal for dependent regions may be too much in upper regions and the latter may be exposed to pressures that cause over-distension with potential damage as well as decreased ventilation and impeded perfusion. However, to keep dependent lung regions open with the benefit of better ventilation/perfusion relationship and better gas exchange as well as reduced risk of atelectrauma and infection PEEP should,

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according to this author, be high enough to keep the airways open. This can be achieved by a PEEP titration checking for best respiratory compliance or aerated volume by an imaging technique (electric impedance technique, EIT, holds promise as a bedside tool) (12). Best oxygenation is another possibility but requires repeated arterial blood sampling (transcutaneous or percutaneous probes are hardly sufficient). By applying a low driving pressure (end-inspiratory minus end-expiratory airway pressure) over-distension of non-dependent lung regions will be minimized (13). However, balancing between open lung and over-distension is a compromise and present technique of ventilator support has limitations. Can it be better? Revival of high frequency ventilation with tidal volumes of a few ml sounds tempting, but it did not work, why? The answer seems to be gas trapping due to the short expiratory period. Can there be another approach?

If there is a possibility to monitor regional mechanics as well as to distribute ventilation according to regional mechanics, then mechanical ventilation would presumably be more efficient in oxygenating blood and eliminating carbon dioxide and at the same time decrease lung stress and strain and ventilator-induced lung injury. Techniques have been developed to monitor regional respiratory mechanics but can we distribute ventilation according to these mechanics data? This is hardly possible in a supine or prone patient but the lateral position may enable separation of upper and lower lung regions since the non-dependent and the dependent lungs can be ventilated separately with a double lumen endobronchial catheter. Considerable improvement of gas exchange and morphology by reducing or eliminating atelectasis with no over-distention of other lung regions has been achieved both in animal experiments and in clinical studies (14, 15). However, there is an obstacle and that is the need of an double-lumen endobronchial. How feasible the technique is during prolonged ventilation and with the rotation of the patient from side to side is another question. Anyway, having introduced the double lumen catheter, a PEEP can be applied to the lower lung that keeps the lung open by a PEEP titration curve for that particular lung, and a lower PEEP, if any, to the upper lung, also titrated with a PEEP titration curve. Thus, advanced imaging technique is not by itself necessary. It is the opinion of this author that such technique may offer advantages and may be an alternative to extra-corporeal membrane oxygenation and CO_2 removal.

In summary, in the anesthetized patient PEEP may be of limited value if anesthesia is only one or two hours long but may be more important if it lasts for several hours. A PEEP just high enough to keep airways and alveoli open will hardly do any harm and may therefore be used routinely, not for oxygenation but for keeping the lung open. Moreover, efforts should be spent on delivering an open lung to the postoperative ward. In intensive care a PEEP should be applied that is high enough to keep dependent lung regions open. In order to limit over-distension of lung regions, a low tidal volume should be applied so that the driving pressure is kept as low as possible. Techniques to apply airway pressures individually in proportion to regional lung mechanical properties would allow more homogeneous aeration and distribution of ventilation and blood flow. Hopefully, techniques will be further refined, or new ones will be developed, to enable individual ventilation of lung units.

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