

## Rationale for including PEEP valves in extended care of critically ill casualties

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Under normal circumstances, the pressure in the lung at the end of expiration is equal to the atmospheric pressure. PEEP refers to the application of additional pressure at the end of expiration to maintain pressure in the lung slightly above atmospheric pressure.

Lung volume at end exhalation is determined by the interplay between the elastic recoil of the lung (trying to collapse the lung) and the elastic recoil of the chest wall (acting to pull the lung open). Under normal circumstances these forces are in balance and the lung does not collapse completely when it reaches its smallest volume at end expiration. Many disease processes make the lung stiffer (Physiologically this is known as decreased compliance. Practically speaking it is analogous to a balloon that is very difficult to inflate versus one that is very easy to inflate). This increased lung stiffness makes the lung more prone to collapse completely at the end of expiration. The tendency to collapse is worsened by the fact that the chest wall recoil is also adversely impacted, meaning its ability to pull the lung open is impaired. Anything that increases intra-abdominal pressure will also favor lung collapse at end expiration by pushing up on the diaphragm. This may be gaseous distention of the G.I. tract, hemorrhage, excessive edema of the abdominal wall/abdominal contents, etc. Spontaneously breathing patients may be able to overcome this to some extent by closing the glottis and trapping air inside the lung at end expiration and by engaging their muscles of respiration. These compensatory mechanisms can only go so far, and they are completely inoperable in patients receiving mechanical ventilation via an endotracheal tube.

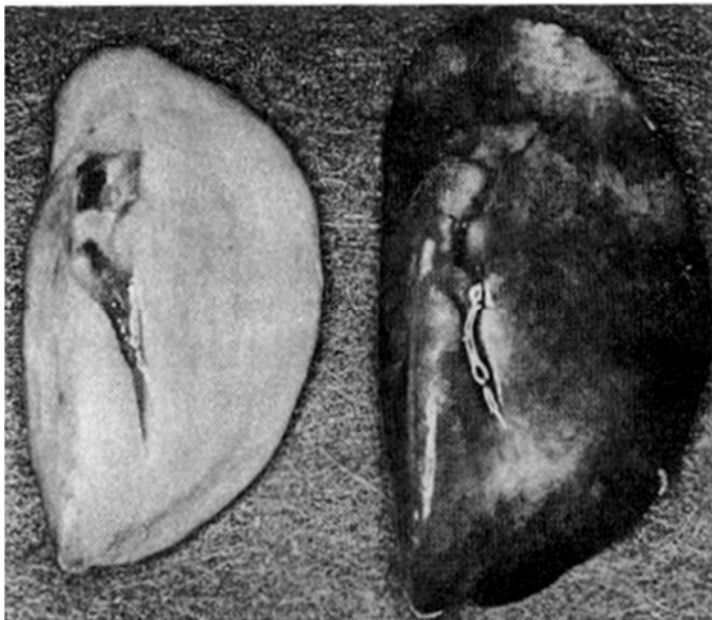
It is important to recall that the lung is composed of approximate 500 million individual alveoli. When I say lung collapse, I do not necessarily mean that the entire lung collapses. It does not behave as a single large balloon. Rather it behaves as 500 million separate individual balloons interconnected by a complicated system of airways. So as the forces favoring collapse become stronger, a larger percentage of the 500 million individual units are collapsed.

**PEEP improves oxygenation** – In order for gas to change to occur, blood and fresh inspired gas must be in close proximity to one another – the gas in the alveoli and the blood in the alveolar capillaries, separated only by a very thin capillary wall that permits gas exchange across it. As these alveoli begin to collapse oxygenation is obviously impaired as there are fewer lung units taking part in gas exchange. The body does have an intrinsic mechanism to direct blood preferentially to non-collapsed alveoli (known as hypoxic pulmonary vasoconstriction). However, this is not a perfect system and cannot overcome widespread alveolar collapse.

So we need a method to help prevent lung collapse at the end of expiration in critically ill mechanically ventilated patients. This mechanism is PEEP, or positive end-expiratory pressure. In its simplest terms this involves keeping a small amount of pressure in the lung at the end of expiration rather than letting it return to atmospheric pressure. This pressure trapped inside the lungs acts as a force pushing outward on the alveoli and holding them open. It increases the volume of gas inside the lung at the end of expiration- or increases Functional Residual Capacity (FRC) in physiological terms. PEEP is a simple basic setting on most mechanical ventilators. When using a bag valve ventilation device it can be

accomplished by applying a small PEEP valve to the expiratory port on the device. A PEEP valve is simply a spring loaded valve that the patient exhales against.

**PEEP prevents ventilator induced lung injury** – The loss of lung units taking part in gas exchange as a result of collapse at end expiration impairs oxygenation. Some of these lung units remain collapsed during the next inspiration while others may collapse in expiration only to be reopened again when the next breath is delivered. This is known as recruitment-derecruitment of the lung. The repetitive collapse and re-expansion of alveoli occurring with every breath is now widely recognized to contribute to the development of ARDS. Prevention of collapse at the end expiration by the application of PEEP is an effective method to counteract this process. The picture below shows two rat lungs that were ventilated outside of the chest. The inspiratory pressure was the same for both while one had PEEP applied and one did not. As you can see the lung with zero PEEP is enlarged edematous and swollen while the other has a more normal appearance. This is an old the very classic experiment demonstrating the harm of repetitive collapse and re-expansion of lungs with mechanical ventilation (recruitment-derecruitment). The advantage of ventilating the lungs outside of the chest like this as that they are able to swell and makes the point much clearer.



**PEEP = 10**  
**PIP = 45**

**PEEP = 0**  
**PIP = 45**

**Adverse effects of PEEP** – The predominant adverse effect of PEEP is a decrease in venous return to the heart leading to decreased cardiac output. At low levels of PEEP (up to 5, maybe 8) this effect is fairly minimal and can be largely ignored. Other adverse effects of PEEP including over inflation and worsening barotrauma are less relevant overall and are also negligible at the low levels of PEEP that will be applied in the field.

## Additional resources for interested parties

The two links below will take you to some very interesting videos on YouTube that are worth watching – it will only take a few minutes.

<http://www.youtube.com/watch?v=hOa7zO1llmI>

<http://www.youtube.com/watch?v=iuUSDR4ocCY>

They are both videos of animal lungs (rabbit and pig I believe) that are being ventilated outside of the chest. In both videos the operator is steadily increasing PEEP while the lungs are inflated and deflated. Note that in the video of the smaller lungs when the narrator says ZEEP he is referring to zero PEEP- the pressure in the lung at end exhalation is equal to atmospheric pressure. As you can see the lungs become very collapsed at the end of exhalation on each breath when there is no PEEP applied. As PEEP is gradually increased you notice that the lungs slowly begin to expand and they do not completely collapse again at the end of expiration. It is interesting how this happens bit by bit – you can see some areas that are collapsed and slowly inflate over time. Once the lungs are exposed to ZEEP again (only shown in the first video), all of this lung recruitment is lost almost immediately and the process must begin all over again. This is what happens at the end of each and every breath in a mechanically ventilated patient with no PEEP applied. To be fair, lungs that are ventilated outside the chest behave slightly differently and are much more prone to collapse at end expiration than lungs that are tethered within the chest as they no longer have the elastic recoil of the chest wall to keep them open. However, this is not much different than diseased lungs that are very stiff and highly prone to collapse. I think this is a good visual depiction of how PEEP maintains lung recruitment which is critical to maintain oxygenation. A very inexpensive PEEP valve goes a long way towards preventing this when ventilating with an ambubag.

### KEY POINTS

PEEP – prevents the lung from collapsing at end-exhalation.

PEEP makes oxygen saturation (SpO<sub>2</sub>) increase and reduces lung damage.

In early injury 5-10 cm H<sub>2</sub>O of PEEP is sufficient to prevent lung collapse.

If PEEP is too high it can cause blood pressure to fall.