OPTIMAL PEEP DETERMINATION

by

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OPTIMAL PEEP DETERMINATION

BEHAVIORAL OBJECTIVES

UPON COMPLETION OF THE READING MATERIAL, THE PRACTITIONER WILL BE ABLE TO:

1. Explain the goals of PEEP administration
2. Explain the indication for PEEP administration.
3. Describe the physiologic effects of PEEP administration.
4. Describe the complications of PEEP.
5. Define 4 methods for determining optimal PEEP.
6. Describe the static compliance method of optimal PEEP determination.
7. State the rationale of using optimal PEEP methods.
8. Apply information gained by completion of a clinical scenario.

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Optimal PEEP Determination

Introduction

Positive End-Expiratory Pressure (PEEP) is utilized in the treatment of acute oxygenation failure or acute hypoxemic respiratory failure Type I, for decades. Utilizing optimal levels of PEEP is a time-tested, and clinically proven method for improving oxygenation, especially in cases of refractory hypoxemia.

The PaO$_2$ is an important monitoring tool, but in the administration of PEEP a more sensitive indicator is needed. Enhanced tissue oxygenation is the ultimate goal of PEEP therapy. There must be adequate perfusion of the tissues coupled with adequate arterial oxygenation to achieve this goal. Inappropriate PEEP levels provide adequate arterial oxygenation while simultaneously decreasing perfusion. This results in an improvement in PaO$_2$ while tissue oxygenation is actually decreased. Therefore, PaO$_2$ as the sole determinant of appropriate PEEP level is very misleading.

The purpose of determining “optimal” PEEP is to maximize arterial oxygenation while maintaining adequate oxygen transport and perfusion of the tissues. This course discusses several ways to determine optimal PEEP. Emphasis is placed on the static compliance method. This method is relatively simple, non-invasive, and correlates well with more accurate but invasive methods.

Optimal PEEP determination is more of a thought process than a procedure. It is a process focusing on providing the patient the correct amount of therapy for their clinical state. Optimal PEEP determination is goal-directed titration of PEEP. It began in 1975 with key treatment principles aimed at achieving specific endpoints.

Some of these endpoints were the achievement of a specific PaO$_2$, FIO$_2$, shunt fraction, or cardiac output. Over the years, different authors have described different endpoints and techniques. To differentiate these techniques, various terms have been used. When static compliance was used, the term was “best” PEEP. If maximum O$_2$ consumption was used, it was “preferred” PEEP. “Appropriate” PEEP uses the PaCO$_2$ - PETCO$_2$ difference. “Least” PEEP uses the lowest PEEP level providing a PaO$_2$ $\geq$ 60 mm Hg with an FIO$_2$ $<$.50 and an adequate cardiac output.

In this course I use the term “optimal” PEEP, regardless of the technique being described. It is more important the practitioner realize the process of PEEP titration is critical, not the term being used. PEEP must be titrated according to the disease severity, progression, and resolution. The primary emphasis in optimal PEEP determination is preventing ventilator-induced lung injury from overdistention.

In the past, PEEP was primarily confined to severely hypoxic patients with stiff lungs. Today, most ventilator patients have a minimum PEEP level regardless of oxygenation, or compliance status. Intubation alone decreases the functional residual capacity (FRC). Recumbency further decreases the FRC. A patient with normal lungs loses approximately 600-1200 ml just going from a sitting to supine position. A minimal PEEP level (approx. 2-5 cm H$_2$O) is recommended.
OPTIMAL PEEP DETERMINATION

for most patients to replace this lost volume. 1

In addition, some patients trap additional air in the lungs following initiation of mechanical ventilation. Rapid rates, inadequate expiratory times, excessive volumes, and certain ventilator modes can result in inadvertent airtrapping. This is evidenced by the development of inadvertent or “auto-PEEP”. The COPD patient is at particular risk of auto-PEEP. A minimal PEEP level can actually decrease auto-PEEP by maintaining small airway and alveolar patency in dependent lung zones. An optimal PEEP determination is unnecessary for these situations utilizing a minimal PEEP level.

EFFECTS OF PEEP

PEEP affects the pulmonary, circulatory and endocrine systems. Some of these effects are positive and some are negative.

There is an increase in alveolar lung volumes as PEEP is increased. This increase in volume is linear up to a point when it plateaus. Further increases in PEEP merely increase pressure, not alveolar volume. The end-expiratory alveolar diameter is increased more than the end-inspiratory alveolar diameter. In rats, alveolar diameter increases linearly to 10 cm H$_2$O and plateaus at 15 cm H$_2$O of PEEP.

PEEP redistributes lung water away from the alveolar area. Interstitial water around gas-exchanging areas is pushed into the areas around airways. This is partly responsible for the improved gas exchange seen with PEEP. Diffusion is improved with this redistribution of lung water.

Different types of lung pathology give different responses to PEEP. Some alveoli increase in size progressively with PEEP. Others reach a critical opening/distending pressure with PEEP before they increase in size. (The classic “recruitment” of collapsed alveoli). Others have no change in size with increasing PEEP (consolidated alveoli).

There is a greater degree of “recruitment” in dependent lung zones. In dependent areas, more alveoli collapse on expiration than in less dependent areas. This gives a biphasic response to PEEP, i.e., no change in size until the alveoli “pops” open and then a linear increase in size. The less dependent areas have a greater increase in size without recruitment and have a more linear response to PEEP.

The effects on the circulatory system are primarily related to a decrease in venous return. Higher PEEP levels increase the incidence of decreased venous return. Normally, there is no significant impairment of the right ventricle with PEEP levels of 15 cm H$_2$O or less. The heart can be compressed with increased levels of PEEP, resulting in smaller ejection volumes. At a PEEP level of 20 cm H$_2$O, right ventricular function decreases.

Left ventricular function may be compromised by transmission of PEEP pressure and
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compression of the ventricle. However, those with left ventricular dysfunction may actually be improved if venous return is decreased. Pressures < 15 cm H₂O may adversely affect those with right ventricular dysfunction. The greatest change in cardiopulmonary function with PEEP is within one minute. No further changes in O₂ delivery take place after 15 minutes. Effects on the endocrine system consist of an increase in antidiuretic hormone (ADH) and a decrease in atrial natriuretic peptide (ANP) and brain natriuretic peptide (BNP). The result is sodium and water retention.

PURPOSE OF PEEP

PEEP is used in acute respiratory failure (ARF) Type I to improve oxygenation. It primarily achieves this by the recruitment of collapsed alveoli into the gas exchange process. As mentioned previously, an improvement in arterial oxygenation does not always result in improved tissue oxygenation. Therefore one should carefully consider and monitor the use of PEEP, if being used to improve oxygenation.

Generally, one considers PEEP when there is evidence of widespread alveolar collapse and toxic levels of FIO₂ are being used. Most commonly, these are conditions that lead to adult respiratory distress syndrome (ARDS). PEEP is used to improve oxygenation in patients with refractory hypoxemia. Refractory hypoxemia exists when the patient’s PaO₂ cannot be maintained above 50 mmHg, with the FIO2 at 50% or higher. Refractory hypoxemia indicates the need for positive pressure ventilation with PEEP. PEEP opens collapsed alveoli, thereby restoring the FRC, and decreasing physiologic shunting. Ideally, this allows the use of lower FIO₂ levels, while maintaining or increasing the PaO₂ to satisfactory levels. Other lung parameters, which show improvement with optimal PEEP levels, are improved lung compliance and decreased Vₐ/Vₜ ratio.

ARDS is characterized by inflammation of the A-C membrane and cell injury. This results in a loss of surfactant. Surfactant is lost either from decreased production or is flushed from the alveoli by massive capillary leakage. Normally, the presence of surfactant prevents alveolar collapse on expiration. Surfactant keeps the alveoli inflated above their critical distending pressure on expiration. This decreases the work of breathing considerably and allows the alveoli to participate in gas exchange throughout the respiratory cycle.

A familiar analogy to a surfactant-deficient alveolus is the inflation of a balloon (Figure 1). Initially, despite considerable effort, nothing happens. Then suddenly, inflation begins. Further inflation requires minimal effort until the balloon nears its stretch limit when it becomes difficult again. If the balloon is allowed to collapse, the same effort must be made to reinflate it. Alveoli, without surfactant, behave in a similar fashion. A collapsed alveolus requires an initially high distending pressure to begin inflation. Once this “critical” distending pressure is achieved, inflation is easy until the stretch limit is approached. If the alveolus collapses on expiration, the same amount of pressure must be generated to overcome the critical distending pressure and inflate the alveolus.

The mechanism by which surfactant prevents collapse is through lowering the surface tension of
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A thin layer of water lining alveolar walls. This layer of water tends to “bead” up. When this occurs, the alveolar walls are pulled in and collapse ensues. Surfactant “floats” on the water (like oil on water) and prevents the beading up. This prevents the alveolus from collapsing completely on expiration.

PEEP functions similar to an artificial surfactant. PEEP causes air trapping much the same way surfactant “traps” air. Both surfactant and PEEP allow the patient to have an FRC of trapped air. The presence of an FRC makes breathing relatively effortless by keeping alveoli above their critical distending pressure. The presence of an FRC also prevents shunting of blood past atelectatic units.

![Diagram showing normal alveoli with surfactant, surfactant deficiency causing alveolar collapse, and PEEP reversing collapse and keeping alveoli patent.]

A. Normal alveoli with surfactant.
B. Surfactant deficiency causes alveolar collapse.
C. PEEP reverses collapse and keeps alveoli patent.

Figure 1

Excluding the minimal baseline PEEP recommended by many, one can say the primary indication for PEEP is severe hypoxia due to a decreased or absent FRC. A general clinical indication for consideration of PEEP is when $\text{PaO}_2$ is less than 50 mm Hg and $\text{FiO}_2$ is more than 50%. One considers PEEP at this point to avoid the dangers of $\text{O}_2$ toxicity. A goal of PEEP at this point is to minimize the amount of $\text{O}_2$ needed for adequate oxygenation.

COMPLICATIONS OF PEEP

The complications of PEEP are numerous. All the normal complications of positive pressure breathing (reduced venous return, hypotension, decreased cardiac output, fluid retention, etc.) are intensified with PEEP. PEEP raises the mean intrathoracic pressure resulting in decreased venous return to the right heart. If severe enough, this decreases cardiac output and blood pressure. (Should cardiac output decrease due to PEEP, it can usually be
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returned to its previous level through intravascular volume expansion.) Kidney perfusion pressure also may decrease with resultant fluid retention. An increase in antidiuretic hormone (ADH) occurs and contributes to fluid retention. If the addition of PEEP raises the peak inspiratory pressure high enough, barotrauma (pneumothorax and other air leaks) can occur. However, alveolar rupture is more likely related to excessive volume rather than excessive pressure (volutrauma).

The fact that the patient’s lungs are stiff offers some security against complications. A uniformly stiff lung resists rupture. A stiff lung transmits less pressure to the pulmonary vasculature so cardiac output may not decrease. In some cases, cardiac output may be increased. If PEEP results in increased myocardial oxygenation, cardiac output may actually increase.

![Diagram of lung units with different levels of PEEP]

The same level of PEEP can cause significantly different amounts of distention in adjacent lung units. This shifts blood flow to the poorly ventilated units and can cause alveolar rupture.

Figure 2

Unfortunately, the lung is rarely in a state of uniform “stiffness”. Even in severe ARDS one finds normal alveoli interspersed throughout diseased alveoli. The same amount of PEEP in adjacent lung units can therefore produce differing amounts of inflation (Figure 2). The same level of PEEP needed to recruit diseased alveoli causes overdistention of normal alveoli. If a lung unit becomes overdistended adverse effects are possible, such as, alveolar rupture. Overdistention also causes blood vessels to be compressed and shifts blood flow to poorly ventilated alveoli. This actually lowers PaO₂. This is a distinct possibility if PEEP is not titrated as the patient improves.²
**OPTIMAL PEEP DETERMINATION**

A. Correct PEEP provides adequate alveolar distention.
B. Excessive PEEP overdistends alveoli.
C. When patient improves and surfactant returns, low levels of PEEP can cause overdistention and a decrease in \( \text{PaO}_2 \).

**Figure 3**

PEEP must be reduced as compliance increases to minimize overdistention. If not, the same level of PEEP begins to overdistend alveoli (Figure 3). Should the level not be readjusted, the \( \text{PaO}_2 \) may fall. A drop in \( \text{PaO}_2 \) after the patient has shown improvement may be the first indication that overdistention has occurred. Serial monitoring of compliance detects overdistension before \( \text{PaO}_2 \) decreases. If compliance is not being monitored, a drop in \( \text{PaO}_2 \) may trigger one to increase PEEP and worsen the problem. Proper titration avoids most complications of PEEP.

**METHODS OF OPTIMAL PEEP DETERMINATION**

As stated earlier, there are many ways to determine optimal PEEP. The first of these is rather simple. One draws an ABG on each successive increment of PEEP and the PEEP that gives the highest \( \text{PaO}_2 \) is considered optimal. Unfortunately, the highest \( \text{PaO}_2 \) does not necessarily reflect optimal tissue oxygenation. As PEEP is increased, there is a decrease in the amount of shunting and a proportional rise in \( \text{PaO}_2 \) occurs. However, there also may be a proportional decrease in venous return and cardiac output. If this occurs, tissue oxygenation actually decreases despite the rise in \( \text{PaO}_2 \). Determining and monitoring optimal PEEP via ABG’s is expensive, invasive, and does not accurately reflect delivery of \( \text{O}_2 \) to the tissues. An ABG should be drawn to verify adequate arterial oxygenation but should not be used as the determinant of optimal PEEP.

Several techniques of optimal PEEP determination require the insertion of an indwelling
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flow-directed pulmonary artery (PA) catheter. PA catheters allow for measurement of cardiac output and sampling of mixed-venous blood. If the equipment and personnel are available, cardiac output (C.O.) may be measured on each successive increase in PEEP. Optimal PEEP is considered to be the level that gives acceptable arterial oxygenation with no disruption of cardiac output.

The presence of a PA catheter also enables the clinician to calculate oxygen transport using the equation: C.O. X CaO$_2$ = oxygen transport. For example, a C.O. of 5000 ml/min and CaO$_2$ of 20 ml O$_2$/dl yields an oxygen transport of 1000 ml O$_2$/min. The oxygen transport value illustrates the relationship between cardiac output, arterial oxygenation, and hematocrit very well. If available, it is an excellent monitor of tissue oxygenation. Unfortunately, it is not available on all patients.

If direct measurement of cardiac output is not possible, it may be inferred from the A-V O$_2$ content difference. This requires the simultaneous sampling of arterial and mixed-venous blood on each successive increase in PEEP level. The O$_2$ content is calculated for each sample and the arterial to venous O$_2$ content difference is compared. Normally, the difference is 5 ml O$_2$/dl. If cardiac output falls, the difference increases since the tissues extract more O$_2$. When an increase in PEEP results in an increase in the difference, it indicates cardiac output is being impaired. Optimal PEEP is the level that gives the smallest difference between the arterial and venous O$_2$ content.

A simpler version of this is to monitor the mixed venous PO$_2$ and/or % saturation. The mixed-venous PO$_2$ and % saturation are a reflection of both oxygen supply and demand. As mentioned above, if cardiac output decreases, the tissues extract more oxygen. This results in a decrease in the mixed-venous PO$_2$ and % saturation. Therefore, the PEEP level that gives the highest mixed venous PO$_2$ or % saturation is considered optimal. All of the above techniques are useful and accurate representations of optimal PEEP. However, they are expensive, invasive, and not available for all patients.

The static compliance method of optimal PEEP determination correlates well with the above techniques. But it does not require elaborate equipment, blood samples, or the insertion of a PA catheter. This technique requires only the measurement and calculation of static compliance on each increase in the PEEP level. Static compliance is a reflection of the elastic resistance (or stretchability) of the lungs. Since PEEP tends to decrease the amount of elastic resistance (via improved FRC) the value of serial static compliance measurements is obvious. Optimal PEEP is considered to be the level that provides the lowest elastic resistance, i.e., the greatest static compliance. The greatest static compliance correlates well with adequate cardiac output, mixed venous PO$_2$ and tissue oxygenation.

Prior to PEEP administration, static compliance is calculated. At this point, assuming the patient does in fact need PEEP, the elastic resistance is greatest due to a decrease in FRC. Consequently, a low static compliance is obtained. As PEEP is increased, FRC increases, elastic resistance decreases, and static compliance increases. Theoretically, there comes a point at which the PEEP level returns the patient to their normal FRC. This point should give the
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greatest static compliance. Increasing PEEP further results in overdistention and static compliance falls. The patient should be placed on the level providing the greatest static compliance.

Static compliance should not only be used for initial optimal PEEP determination but also for maintaining optimal PEEP. PEEP should be increased as the patient’s condition deteriorates and decreased as the condition improves. This latter condition of patient improvement can be overlooked if monitoring is being done by ABG’s alone. All too often PEEP is initially set at the level that gives an adequate PaO$_2$. The patient is then left at this level until weaning is well under way or the patient deteriorates. This is an incorrect therapeutic pathway for the following reasons:

Initially, PEEP results in an improved PaO$_2$ and a return to a normal FRC. As the patient improves and the lung becomes more compliant, the same PEEP level expands the alveoli to a greater degree. This compresses pulmonary capillaries, shifts blood flow to non-ventilated areas, and causes a drop in PaO$_2$. This drop in PaO$_2$ is often perceived as a deterioration rather than an improvement and PEEP may actually be increased in response. Static compliance measurements would reveal that the PEEP level should be lowered rather than increased since a lower PEEP level is now revealed to be optimal. A drop in PaO$_2$ correlated with improving serial static compliance measurements warrants a consideration of decreasing the PEEP level. Obviously, a drop in PaO$_2$ correlated with deteriorating static compliance measurements warrants the opposite.

STATIC COMPLIANCE PROCEDURE

The following procedure is a general guideline only. Each hospital will have its own specific procedure. The procedure manual for your institution should be followed. The procedure is not without complications and should only be undertaken by qualified personnel. Vital signs, particularly blood pressure, need to be closely monitored. Any indications of non-tolerance to the procedure should result in its immediate termination.

1. Set pressure limit 10-15 cm H$_2$O above ventilating pressure (or per institutional policy).

2. Turn ventilator sighs off for the procedure if being used.

3. Explain the procedure to the patient and to be as relaxed as possible. It may be advantageous to sedate the patient. It is extremely important that all measurements be obtained under the same conditions to provide accurate results.

4. The patient should be as upright as possible. Each measurement should be taken with the patient in the same position.

5. Determine the static compliance at 0 cm PEEP. The tidal volume, peak and plateau pressures should be noted. Tidal volume should be corrected to account for
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compressed volume. This is done by multiplying peak inspiratory pressure times the ventilator tubing compliance factor (usually 2-4 cc/cm H₂O). Note that when calculating corrected VT using PEEP, the PEEP must be subtracted from the peak pressure prior to dividing by the tubing compliance factor. This number is subtracted from the observed VT. The corrected VT is then divided by the plateau pressure for the static compliance. If the ventilator you are using compensates for lost volume prior to displaying the exhaled VT, it will be unnecessary to account for compressed volume.

6. Determine the static compliance at 3 cm H₂O PEEP using the same procedure as above, with one exception. The 3 cm H₂O PEEP pressure should be subtracted from the peak and plateau pressures. (Compliance is calculated by the change in pressure. PEEP raises the baseline pressure and so the change in pressure is the pressure above the PEEP.) Always subtract PEEP from peak and plateau pressures before calculations.

7. Determine static compliance at 6, 9, and 12 cm H₂O PEEP, or at increments determined by your institution. (Two cm H₂O increments are also common. It may be necessary to determine static compliance with PEEP levels up to 15 cm H₂O, and rarely higher than 15 cm H₂O).

8. Should the pressure limit be reached on any level of PEEP, the study is terminated at that point. One risks alveolar stretch injury in normal alveoli at plateau pressures in the above 30 cm H₂O range. Alveolar rupture is possible at plateau pressures > 50 cm H₂O. The duration and frequency of the pressure also contribute to injury. One should consider these as PEEP is increased. Some may wish to terminate the study at plateau pressures ≥ 30 cm H₂O.

9. Blood pressure and other vital signs must be closely monitored. Significant changes warrant termination of the procedure.

10. The patient should be placed on the lowest PEEP level providing the greatest static compliance.

11. Optimal PEEP should be re-evaluated PRN and adjusted accordingly.

1. Once the optimal PEEP level has been determined and stabilization has taken place, an ABG should be drawn to verify arterial oxygenation.

2. When weaning from PEEP, an ABG may be needed for each decrease. Correlation of pulse oximetry with ABG results makes it possible to minimize arterial punctures and use oximetry for monitoring. Atelectasis may be slow to develop so continuous oximetry or an ABG should be obtained approximately one hour after each decrease.
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CALCULATIONS

The basic equation\(^4\) for computing static compliance is:

\[
\text{Static compliance} = \frac{(\text{Tidal volume} - \text{Tubing expansion volume})}{(\text{Plateau pressure} - \text{PEEP})}
\]

To estimate tubing expansion volume, use the following calculation:

\[
\text{Tubing expansion volume} = \text{Peak Inspiratory Pressure (PIP)} \times 3\text{ml}
\]

The value of 3ml is generally accepted as the compliance factor for most disposable tubing use on ventilator circuit.

**Example # 1**
Calculation of static compliance **without** PEEP

Step A: 
\[
\text{PIP} \times \text{tubing compliance factor} = \text{lost volume}
\]

Step B: 
\[
\text{Measured } V_T - \text{lost volume} = \text{corrected tidal volume}
\]

Step C: 
\[
\text{Plateau Pressure} - (\text{PEEP of 0}) = \text{corrected change in pressure}
\]

Step D: 
\[
\frac{\text{Corrected tidal volume}}{\text{Plateau Pressure}} = \text{Static compliance}
\]

**Actual Calculation**

Step A: 
\[
45 \times 3 = 135
\]

Step B: 
\[
700 - 135 = 565
\]

Step C: 
\[
39 - 0 = 39
\]

Step D: 
\[
565 \div 39 = 14.49
\]

**Example # 2**
Calculation of static compliance **with** PEEP

Step A: 
\[
(\text{PIP} - \text{PEEP}) \times \text{tubing compliance factor} = \text{lost volume}
\]

Step B: 
\[
\text{Measured } V_T - \text{lost volume} = \text{corrected tidal volume}
\]

Step C: 
\[
(\text{Plateau Pressure} - \text{PEEP}) = \text{corrected Plateau Pressure}
\]
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Step D:
Corrected tidal volume ÷ corrected Plateau Pressure = Static compliance

Actual Calculation with a **PEEP of 5**

Step A:
\[(45 - 5) \times 3 = 120\]
Step B:
\[700 - 120 = 580\]
Step C:
\[45 - 5 = 40\]
Step D:
\[580 \div 40 = 14.5\]

PEEP can be applied in many mechanical ventilation modes including but not limited to: CMV, Assist/Control (also known as Volume Control), Pressure Control, SIMV, or in conjunction with Pressure support. (PEEP is technically called CPAP when there is no mechanical ventilation rate. In the clinical setting, with a patient on pressure support, PEEP and CPAP are often used interchangeably). It is important to note the sensitivity setting with any patient-triggered mode. Most modern ventilators have PEEP-compensated sensitivity mechanisms. Example: If the sensitivity is set at -2 cm H₂O while the patient is on 10 cm H₂O PEEP, the ventilator would trigger at 8 cm H₂O. However, if the ventilator does not have a PEEP-compensated sensitivity mechanism, the patient would have to draw negative pressure to 2 cm H₂O below atmospheric to trigger the ventilator. If this is the case, then care should be taken to adjust the sensitivity accordingly, and make necessary changes whenever the PEEP level is changed.
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CLINICAL PRACTICE EXERCISE

The following practice exercise is discussed at the end of the course.

The patient is a 68-year old male, 12 hours post cardiac bypass surgery. There was massive hemorrhage during surgery and the patient remains hypotensive. He is being mechanically ventilated. Ventilating pressures have shown a steady rise since admission to the unit. Heart rate is 120, blood pressure is 85/60, respiratory rate is 35, SpO₂ is 85%, PaO₂ is 53 mm Hg on 80 FIO₂. You are asked to evaluate the patient for use of PEEP. The following numbers are obtained on various levels of PEEP. Calculate the corrected tidal volume (tubing compliance 3 cc/cm H₂O) and the static compliance. Determine the optimal PEEP level from your calculations.

<table>
<thead>
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<th>PIP</th>
<th>PEEP</th>
<th>CORRECTED Vₜ</th>
<th>PLATEAU PRESSURE</th>
<th>STATIC COMPLIANCE</th>
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PRACTICE EXERCISE DISCUSSION

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<th>CORRECTED Vₜ</th>
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The most common mistake in calculating static compliance for a PEEP study is to forget to subtract the PEEP from the peak and plateau pressures before calculation. If you came up with different numbers than the above, this may have occurred.

On this patient compliance increases as PEEP is increased to 9 cm H₂O. Compliance decreases beyond 9 cm H₂O. This indicates that alveoli are being recruited up to 9 cm H₂O and overdistended beyond this point. Optimal PEEP at this time is therefore 9 cm H₂O. This optimal PEEP level must be re-evaluated as the patient deteriorates or improves.
OPTIMAL PEEP DETERMINATION

SUMMARY

PEEP is used to treat oxygenation failure as a result of increased elastic resistance and reduced FRC. It results in “trapping” air in the lungs. Hopefully, this results in a return to a normal FRC. A determination should be made of the optimal PEEP level. Optimal PEEP levels are those that maximize oxygenation of the tissues. Optimal PEEP determination can be done by ABG’s, cardiac output measurements, A-V O₂ content differences, mixed venous PO₂, or static compliance measurements. The greatest static compliance is associated with an adequate cardiac output and mixed-venous PO₂. The PEEP level that provides the greatest static compliance is considered optimal.

Numerous complications are associated with PEEP. These include: pneumothorax, decreased venous return, hypotension, fluid retention, and decreased cardiac output. When determining or monitoring optimal PEEP, it is important that all variables that can be controlled by the clinician be kept constant. This is to prevent changes in technique being mistaken for changes in the patient’s condition.
OPTIMAL PEEP DETERMINATION

SUGGESTED READING AND REFERENCES:


POST TEST

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1. Which of the following are indications for PEEP?
   1. reduced FRC
   2. hypercapnia
   3. hypotension
   4. toxic levels of FIO₂
      a. 1, 3
      b. 2, 3
      c. 1, 4
      d. 1, 2, 3

2. When determining optimal PEEP via measurement of mixed venous PO₂, one looks for:
   a. the PEEP level that gives the lowest mixed venous PO₂.
   b. the PEEP level that gives the highest mixed venous PO₂.

3. What is the danger of not reducing PEEP as the patient improves?
   a. sepsis
   b. reduced PaO₂
   c. acid-base disturbances
   d. hypoventilation

4. What effect may PEEP have on cardiac output if overdistention occurs?
   a. decrease
   b. increase
   c. no effect

5. When determining optimal PEEP via static compliance measurements, one looks for:
   a. the greatest static compliance and lowest elastic resistance.
   b. the least static compliance, and highest elastic resistance.
   c. stable static compliance.
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6. Why is it important to determine optimal PEEP?

   a. Optimal PEEP will help to decrease the FRC and improve oxygenation
   b. Optimal PEEP will improve the patients’ oxygenation, and helps reduce ventilator-induced lung injury from overdistention
   c. Optimal PEEP will improve ventilation as evidenced by normalized PaCO₂ values
   d. All of the above

7. How does PEEP cause a reduction in the work of breathing?

   a. it causes a reduction in elastic resistance through improved FRC
   b. it causes a reduction in airway resistance
   c. it improves flow rates through stabilizing membranes
   d. none of the above

8. Which of the following is a complication of PEEP?

   a. increased FRC
   b. decreased FRC
   c. decreased cardiac output
   d. improved oxygenation

9. The least invasive method of determining optimal PEEP is the:

   a. Best PaO₂ method
   b. Smallest difference between arterial and venous O₂ content method
   c. Lowest resistance/greatest static compliance method
   d. Acceptable PaO₂ with no change in cardiac output method

10. What is the formula for measuring static compliance?

    b. Static compliance = (Tidal volume – 200cc) / (Peak pressure – PEEP).
    c. Static compliance = (Peak pressure – Plateau pressure) / (Tidal volume – PEEP).
    d. Static compliance = (Tidal volume) / (Peak pressure – Plateau pressure).
    e. None of the above.

11. What is the ultimate goal of PEEP therapy?

    a. enhanced tissue oxygenation
    b. decrease cardiac output
    c. increase venous return
    d. increase vital capacity
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12. Normally, there is no significant impairment of the right ventricle with PEEP levels of 15 cm H₂O or less. At a PEEP level of 20 cm H₂O, right ventricular function decreases.

   a. True
   b. False

13. A minimal PEEP level is considered:

   I. To be 2-5 cm H₂O
   II. To compensate for the loss of FRC in the patient with normal lungs
   III. For use with the COPD patient who air traps (as evidenced by auto-PEEP)
   IV. 10 cm H₂O

   a. I, III, IV
   b. III & IV only
   c. I, II, III
   d. II, III, IV

14. A patient has been on a PEEP of 10 cm H₂O for several days. Which of the following indicate PEEP can be reduced?

   a. PaO₂ is increasing
   b. Pulse oximetry saturation is increasing
   c. Patient status is improving, with normal pulmonary function values
   d. All of the above

15. Which of the following is true of PEEP effects in the lungs?

   a. There is an increase in alveolar lung volumes as PEEP is increased.
   b. This increase in volume is linear up to a point when it plateaus. Further increases in PEEP merely increase pressure, not alveolar volume.
   c. PEEP increases the FRC, and prevents alveolar collapse
   d. All of the above

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ANSWER SHEET

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1. a b c d
2. a b
3. a b c d
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8. a b c d
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10. a b c d e
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14. a b c d
15. a b c d

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# Optimal PEEP Determination

## Evaluation Form

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<th>NAME:____________________________________________</th>
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