The forgotten tale of spontaneous plateau pressure

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Abstract

This article highlights the significance of measuring plateau pressure in spontaneously breathing patients as it provides valuable information about PMI (Pmusc Index), which serves as a surrogate for the patient's efforts during mechanical ventilation.
The PMI value obtained from the difference between the end-inspiratory occlusion plateau pressure and the airway pressure before the occlusion (PEEP + PS) enables clinicians to estimate the patient's inspiratory effort accurately.

The accurate measurement of patient efforts is crucial in optimizing pressure support during lung protective weaning strategies. By titrating pressure support based on PMI values, clinicians can provide personalized care to patients, reducing the risk of ventilator-induced lung injury and enhancing the likelihood of successful weaning.

Keywords: PMI, Pmus, Plateau pressure

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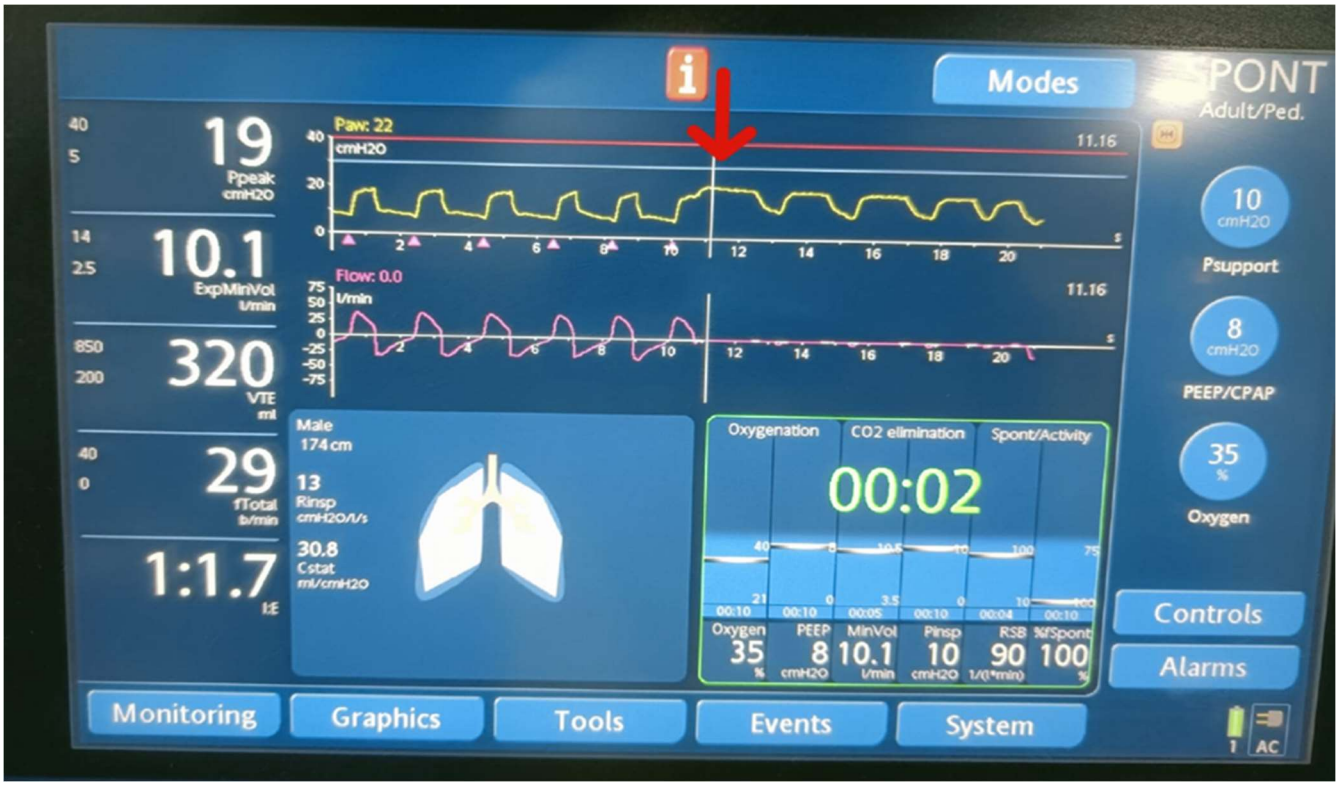

Figure 1: The Red arrow marks the plateau pressure (Pplat) more than peak pressure (Ppeak). The PMI in this figure is equal to Pplat - (PEEP + PS) i.e.22 – 18 = 4

Background

In the realm of mechanical ventilation, a traditional method of measuring plateau pressure involved a passive patient state and an inspiratory hold maneuver to eliminate airway resistance. However, the accuracy of measuring plateau pressure in spontaneous mode was compromised by the patient's efforts on airflow. Another perplexing phenomenon was observed when transitioning patients from controlled mode to pressure support mode, as lung compliance unexpectedly improved. This was attributed to the conventional ventilator's failure to account for the patient's negative inspiratory effort, leading to a decrease in peak inspiratory pressure and an apparent increase in lung compliance.

Unfortunately, these hidden inspiratory efforts posed a risk to patients, generating high transpulmonary pressure and potentially causing lung injury. [1] The conventional ventilator could not detect or measure these efforts, resulting in elevated plateau pressures and higher mortality rates. Recognizing the need for a solution, researchers sought to estimate patients' effort and adjust pressure support accordingly. By doing so, they aimed to provide more comfortable and synchronized spontaneous ventilation while identifying candidates for early extubation.

Concept of PMI (Pmusc Index)

In 1997 a group of researchers led by Giuseppe Foti embarked on a quest to evaluate the end-inspiratory occlusion maneuver in spontaneously breathing patients. Their goal was to estimate the inspiratory effort during pressure support ventilation (PSV). They introduced a concept known as PMI (Pmusc index), which measured the difference between the end-inspiratory occlusion plateau pressure and the airway pressure before the occlusion (PEEP + PS). This PMI value served as an estimate of the patient's inspiratory effort. [2,3]

To validate the usefulness of PMI, the researchers compared it with two other measures: the direct measurement of Pmusc,ei (the pressure developed by the inspiratory muscles at the end of inspiration) and the pressure-time product per breath (PTP/b), which provided a comprehensive indicator of inspiratory effort. [2]

Their study yielded fascinating results. They discovered significant correlations between PMI and both Pmusc,ei and PTP/b, indicating that PMI accurately reflected the patient's inspiratory effort. In fact, they found that a PMI threshold of 6 cm H_2O could effectively detect a PTP/min (pressure-time product per minute) of 125 cm H_2O s/min with a sensitivity and specificity of 0.89. These findings led the researchers to conclude that PMI could serve as a reliable estimation of the pressure generated by the inspiratory muscles in patients with acute lung injury (ALI), enabling effective adjustments of PS levels. [2]

They found that Airway occlusion pressure 100 msec (P0.1) was highly sensitive to changes in pressure support settings and could be utilized to determine the appropriate PSV level when the objective was to reduce the patient's work of breathing. However, they proposed using PMI as an effective alternative for selecting the appropriate PS level. Unlike P0.1, PMI directly reflected the pressure generated by the inspiratory muscles during inspiration (Pmusc,ei) and aligned with their reference target, the pressure-time product. [2]

Somehow this interesting idea of estimating plateau pressure got forgotten and people kept practicing the age-old way of estimating plateau pressure only in passive patients. Also, the secret that the Plateau pressure can be greater than Peak pressure was also forgotten. [4]

Limitations of this method:

It is important to note that the conclusions drawn from the study by Foti and colleagues cannot be universally applied to all patient populations. Specifically, the researchers found limitations when extrapolating their findings to chronically obstructed respiratory patients or those with longer inspiratory times. Previous evidence indicated that these patients exhibit expiratory activity on multiple occasions, which may affect the applicability of PMI. Therefore, further research is needed to explore the use of PMI in these specific patient groups. [2]

In the realm of measuring inspiratory effort, the act of pressing the inspiratory hold button during a spontaneous breath typically creates a plateau. However, it is crucial to exercise caution and not always consider this plateau as a reliable indicator. There are instances where the plateau may be misleading and must be disregarded. One common reason for this discrepancy is the patient's muscles not fully relaxing during the inspiratory hold, leading them to attempt exhalation while the hold is in effect. As a result, the generated plateau may not accurately reflect the true inspiratory effort. Therefore, it is essential to interpret such plateaus with caution or exclude them from analysis when assessing respiratory mechanics. [5]

Mantras for valid Plateau pressure trace [5]

1. Pplat must be flat, with no or a rapid increase or decrease from normal airway pressure trace.
2. Keep the hold for 2-3 seconds.
3. The flow must be zero during Pplat.
4. The existence of tiny incisures on pressure curves (inspiratory efforts when the valve is closed) does not invalidate plateau as long as the Pplat trace is flat before and after the incisures and can be measured in the flat part.
5. If Pplat has a curve shape; if it decreases or increases over time; if the increase from airway peak pressure to plateau pressure is not steep; if the flow does not go to zero during the inspiratory hold; and if the patient clearly contracts expiratory muscles during the hold, Pplat must be considered unreliable.

How can we use the lessons learnt from this story?

1. For estimating the patient’s effort while weaning, and if PMI > 6, which means excessive efforts by the patient, we may offer better support or a change of mode to the patient.
2. We may conduct studies for finding optimum PMI outcomes.
3. We may devise some score, once we have data, combining P0.1, Diaphragm US and PMI to guide “lung protective weaning”.
4. Estimation of compliance correctly in spontaneously breathing patients by using the driving pressure calculated by inspiratory hold in spontaneous mode and dividing tidal volume by it.
5. If the PMI is < 0, it signifies the patient in spontaneous mode is over-supported.

Conclusion

When an inspiratory hold maneuver is performed correctly during assisted ventilation, it enables the measurement of the total distending pressure (Pplat) = PEEP +PS +PMI. It facilitates the calculation of compliance and estimation of patient’s effort. These measurements can provide valuable information for implementing better protective ventilation strategies.

The total distending pressure (Pplat) obtained during the inspiratory hold reflects the static pressure in the lungs at the end of inspiration. Additionally,

calculating the pressure difference (ΔP) through the inspiratory hold maneuver provides insights into the driving pressure applied to the lungs. PMI further tells about the respiratory efforts of the patient and titrate Pressure Support to keep it at a safe limit.

These parameters offer valuable information to guide protective ventilation strategies and "Lung protective weaning".

References

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