Clinical image

The Pressure-Volume curve, how to set PEEP

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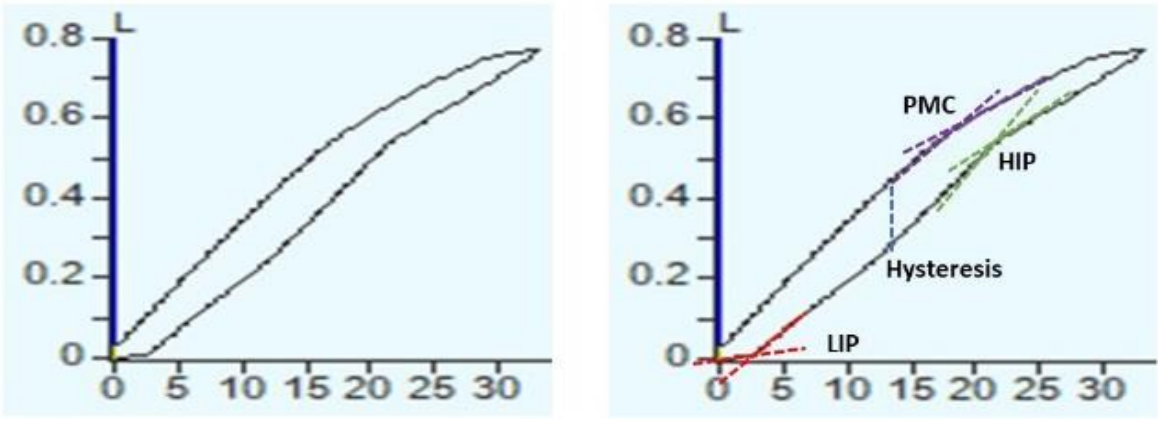

Figure 1: Pressure-Volume curve. Horizontal axis is airway pressure in cmH2O, vertical axis is resultant tidal volume in ml. LIP: Lower inflection point, HIP: high or upper inflection point, PMC: point of maximum curvature or expiratory inflection point.

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The use of positive end-expiratory pressure (PEEP) during mechanical ventilation is a well-established practice. However, because of the heterogeneous nature of the healthy and injured lungs, ventilator-induced lung injury (VILI) can result due to increased mechanical stress on alveoli due to fluctuations in pressure during improper mechanical ventilation. [1]

The P-V curve is a graphic representation of the airway pressure on the horizontal axis vs. the tidal volume on the vertical axis during both inspiration and expiration. The curve represents the compliance of the respiratory system.

If an esophageal balloon manometry inserted, the curve can also be plotted using the pleural pressure vs. the tidal volume to calculate the chest wall compliance. Similarly, estimating the elastic lung compliance can be accomplished by plotting the trans-pulmonary curve (airway pressure-pleural pressure) vs. the tidal volume. [2]

Initially this maneuver was constructed with a super syringe or the inspiratory occlusion technique, but those maneuvers require disconnection from the ventilator and long time that are usually intolerable for the hypoxic patient and may require modification of the lung volumes. [3]

The quasi-static technique (with a very low flow 5-10 L/min or slow pressure ramp 2-3 cmH_2O to reduce the effect of airway resistance) to construct the pressure-volume (P-V) curve have been studied extensively.

The advantage of this technique is that it is available on most new generation ventilators, takes reasonably short time (10-30 seconds depending on the flow rate, tidal volume or if end-inspiratory pause maneuver applied). It can aid in setting the PEEP as below, measuring respiratory system compliance and assess the lung recruitability, and can be used as a recruitment maneuver by itself. [4,5]

The disadvantage of this technique is the need of a passive patient (static P-V curve), must be obtained using the volume-controlled ventilation mode (VCV) with constant low flow, and sometimes it is hard to find the inflection points discussed below.

The dynamic P-V curve can be done with the high flow in the VCV mode and can be assessed breath to breath. However, that curve is less useful as the high flow does not give an accurate low inflection point because the element of resistance, it might help showing the upper inflection point. It is much less useful in the pressure-controlled modes. [5]

PEEP should be selected as a balance between alveolar recruitment and overdistention. Evidence is not currently available to suggest that one approach to setting PEEP leads to better outcomes than other approaches. [6]

What to look for in the curve?

Low inflection point (LIP)

It was long thought to be the site of dramatic recruitment; therefore, it indicated a pressure at which to set PEEP to prevent alveolar collapse, however this is probably inaccurate. [7] LIP is the point of a significant compliance change or the beginning of recruitment. Although LIP may be difficult to identify accurately, once determined, the consensus is to set PEEP at LIP + 2 cmH_2O in conjunction with low tidal volume to ensure recruitment while minimizing the negative impact on hemodynamic effects of PEEP. [8]

Upper or High inflection point (HIP)

It is generally agreed that if the applied pressure or tidal volume is higher than this point, alveolar distention, and possibility of volutrauma can happen. [4]

Point of maximum curvature (PMC)

The PMC or the deflection point on the expiratory limb of the P-V curve is the point where lung de-recruitment happens and now argued to be the correct physiological point at which to set PEEP. [9]

Hysteresis

Hysteresis is the volume differences between the inspiratory and expiratory limbs at a given pressure. and may be key in the interpretation of lung recruitability and setting PEEP on the P-V curve. (Figure 2)

Setting PEEP at the area of the highest hysteresis or where volume change more than 500 ml has shown to be indicative of lung recruitment. [10]

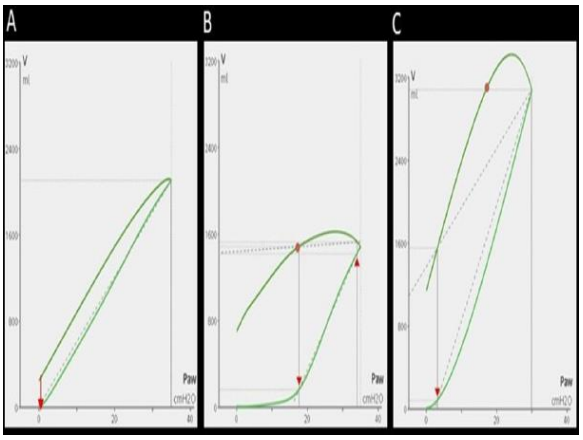

Figure 2: Pressure-Volume curves, Airway pressure on x-axis and Volume on the y-axis. A: normal lung, note the narrow hysteresis (the area between the inspiratory and expiratory limbs) between inspiration and expiration, and the semi-linear inspiratory and expiratory limbs, B: ARDS lung, notice the wide hysteresis and the high pressure required to open the lung, C: COPD lung, notice the wide hysteresis but the low pressure required to open the lung and the very high tidal volume at the end of the pressure maneuver. Red arrow indicates the beginning of the linear portion or the beginning of the best compliance of the inspiratory limb (LIP). The red circle indicates the de-recruitment of the lung during exhalation PMC.

Conclusion

The P-V curve can supply the clinician with a wealth of information about the respiratory system mechanics. However, it is not used routinely in practice and there has been no consensus on setting the PEEP according to the curve. The most important learning points a

- Avoid tidal volumes and airway pressures above the UIP
- Keep the airway pressure on the linear part of the inspiratory limb of the curve
- Trying to assess the point of maximum hysteresis and the PMC are probably more important than the LIP.
- Setting the PEEP for best recruitment and least de-recruitment should e the goal

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