Clinical image

Calculating the work of breathing during mechanical ventilation

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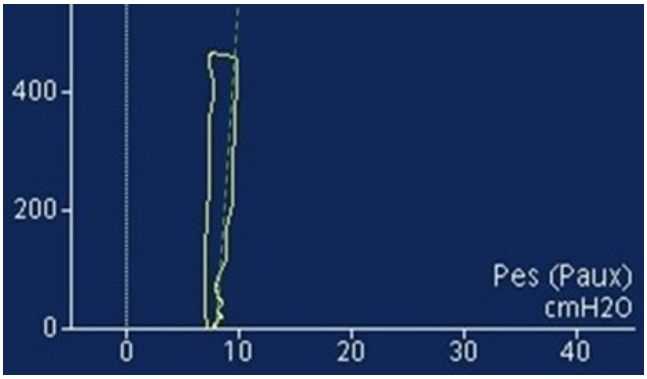
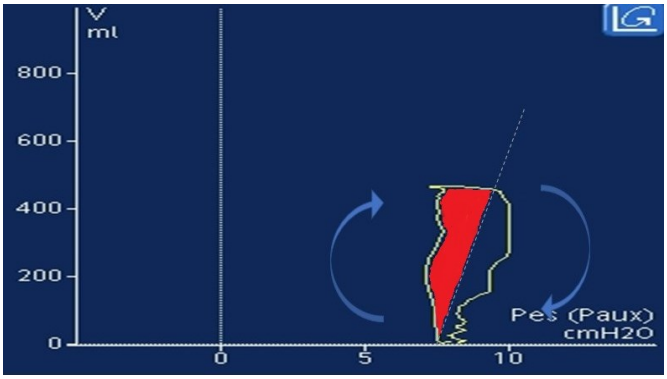
2(2):71-72.





Left figure: Passive patient esophageal pressure (Pes) in cmH_2O on x-axis versus tidal volume in ml on y-axis. Green dashed line represents the chest wall compliance

Right figure: same patient actively breathing on pressure support ventilation. (Pes) in cmH_2O on x-axis versus tidal volume in ml on y-axis. Green dashed line represents the chest wall compliance. Red shaded area is the Campbell diagram representing the inspiratory work of breathing

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Knowledge of the patients' effort during mechanical ventilation has many applications, in initial settings, but especially during asynchronies and during weaning from mechanical ventilation. Many methods could be used for estimation of patients' efforts. Among them is the work of breathing (WOB), the pressure-time product (PTP), direct measurement of the muscle pressure (Pmus), and airway occlusion pressure at 100 msec (P0.1).

The term WOB is erroneously used in clinical practice to describe a patient who might be in respiratory distress, so caution is advised before using this term empirically.

The work is the amount of pressure required to move a volume and is calculated by the integral of the tidal volume and esophageal pressure (as surrogate of pleural pressure) during inspiration and is expressed in units of Joules.

To obtain such calculation, an esophageal balloon manometry is required to construct the Campbell diagram above. [1,2] The esophageal balloon is necessary:

- To calculate the chest wall compliance (Relaxed chest wall) calculated from the volume-esophageal pressure curve
- To mark the beginning and the ending of the respiratory muscles (negative deflection in esophageal pressure during inspiration), and the duration of respiratory contraction.

Formula to calculate WOB

$\int$ (Pcw – Pes) x Δ V

Pcw: relaxed chest wall compliance

Pes: esophageal pressure

Δ V: change in tidal volume

In our example above:

$$\int_{7.5}^{9} \left(\frac{tidal\ volume}{esophageal\ pressure} - esophageal\ pressure \right) \Delta V$$

$$= 0.69 - 0.375$$

= 0.315 J

As seen, the calculation is somewhat cumbersome and require an additional esophageal balloon.

Most of modern generation ventilators offer measurements of WOB but caution is that is the total work of breathing that could be done with the ventilator alone, in combination with the patient depending on if the patient is active or passive. Ventilators which are equipped with an esophageal balloon can directly measure the patients work of breathing automatically. A specific mode that uses the WOB in its operation is Proportional Adaptive Ventilation (PAV+) that allows the clinician to adjust the percent support according to estimation of patient and total WOB.

References:

[1] Iotti GA, Braschi A. Measurements of respiratory mechanics during mechanical ventilation. Hamilton Medical Scientific Library, Rhäzüns, Switzerland. 1999: 116-124.

[2] Akoumianaki E, Maggiore SM, Valenza F, et al. The application of esophageal pressure measurement in patients with respiratory failure. Am J Respir Crit Care Med 2014; 189(5):520-531.