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LETTER TO THE EDITOR

Calculation of transpulmonary pressure: it's all about changes from baseline at FRC

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Dear editor,

With interest I read the article by De Jong et al. published in the Netherlands Journal of Critical Care in May of last year.[1] In their elegant study in a patient with acute respiratory distress syndrome (ARDS) they measured lung mechanics in the prone and supine position using an oesophageal balloon catheter. Using this catheter, oesophageal pressures can be measured as estimates of pleural pressure at end-expiration and end-inspiration. With this method transpulmonary pressures at end-inspiration and end-expiration can be calculated. Knowing these pressures is of great importance in patients with severe ARDS in order to set the ventilator appropriately. Limiting the transpulmonary driving pressure is needed to prevent dangerous levels of strain which may lead to biotrauma or volutrauma. The transpulmonary pressure at end-expiration can be used to set the PEEP level in order to minimise atelectasis. Although this method to set PEEP is under debate, setting PEEP correctly in severe ARDS seems of utmost importance to reduce atelectrauma while minimising PEEP-associated overdistention. Most of the research has focused on PEEP settings in the supine position. Higher levels of PEEP and prone position may have a similar effect on minimising atelectrauma but a different effect on haemodynamics. Increased intrathoracic pressure decreases cardiac output which may offset the possible benefit of less ventilator-induced lung injury. So knowledge on intrathoracic and transpulmonary pressures is very important for the management of severe ARDS.

In their study, the authors measured airway pressure and oesophageal pressure to calculate the end-expiratory and end-inspiratory transpulmonary pressure(P_L):

Absolute P_L = Paw – Pes

Using the differences between transpulmonary and oesophageal pressures measured during inspiratory and expiratory occlusion, it is possible to calculate the elastance of the lung and chest wall. The total elastance of the respiratory system is calculated by adding the elastance of the lung and chest wall together or can be calculated using the difference between Paw measured during inspiratory and expiratory occlusion. The authors state that the transpulmonary pressure (PL) can also be calculated by the relative method using the elastance of the lung and respiratory system:

Relative $P_L = P_{plateau} \times E_L / E_{RS}$

They compared the relative P_L with the measured P_L. Not surprisingly, the absolute and relative P_L differed significantly. One must remember that elastance is defined as the pressure that is needed to inflate the lung or chest wall with a volume of 1 litre assuming a linear correlation between pressure and tidal volume. The relative P_L therefore represents a pressure difference from functional residual capacity (FRC).[2] The correct formula should therefore be:

$$\Delta P_L = \Delta P \times E_L / E_{RS}$$

The formula for relative P_L as presented by the authors, assumes that the airway pressure, pleural pressure and transpulmonary pressure are zero at end-expiration. This is only true at FRC (no end-expiratory pressure) *without any additional factors influencing pleural pressure.* In this case the pleural pressure can be calculated as:

$$P_{pleural} = \Delta P \times E_{CW} / E_{RS}$$

However, measured pleural pressures are often higher in ARDS, especially in the dependent lung zones. The pleural pressure is determined by many factors that are often present in ARDS such as increased abdominal pressure, pleural fluid, etc. Indeed, the end-expiratory transpulmonary pressure is often negative in patients with ARDS resulting in atelectasis. In the present case, the difference between measured and calculated pleural pressure at end-inspiration and end-expiration is the pressure attributed to external force from the abdomen, chest wall or pleural fluid. This pressure difference represents the transpulmonary pressure at FRC and fully explains the difference between absolute and relative transpulmonary pressure.

Table 1.

Calculations for day 2		
ΔP, measured	P_{plat} – PEEP	30.6 – 16 = 14.6 cm H_2O
P_L, end-expiratory absolute	P_L = PEEP – Pes	16 – 13.5 = 2.5 cm H_2O
P_L, end-inspiratory absolute	P_L = Pplat – Pes	30.6 – 17.3 = 13.3 cm H_2O
ΔP_L, measured	ΔP_L = P_L, end-insp – P_L, end-exp	13.3 – 2.5 = 10.8 cm H_2O
E_L	E_L = ΔP_L / Tidal volume	10.8 / 0.34 = 31.76 cm H_2O/l
E_{RS}	E_{RS} = ΔP / Tidal volume	14.6 / 0.34 = 42.94 cm H_2O/l
E_{CW}	E_{CW} = E_{RS} – E_L	11.18 cm H2O/l
P_L, end-expiratory relative	P_L = PEEP x E_L / E_{RS}	16 * 31.76 / 42.94 = 11.83 cm H_2O
P_L, end-inspiratory relative	P_L = P_{plat} x E_L / E_{RS}	30.6 * 31.76 / 42.94 = 22.63 cm H_2O
ΔP_L, calculated	ΔP_L = ΔP_L, end-insp – ΔP_L, end-exp	22.63 – 11.83 = 10.8 cm H_2O
$P_{pleural}$, end-expiratory relative	P_{pl} = PEEP * E_{CW} / E_{RS}	16 * 11.18 / 42.94 = 4.16 cm H_2O
$P_{pleural}$, end-inspiratory relative	P_{pl} = P_{plat} * E_{CW} / E_{RS}	30.6 * 11.18 / 42.94 = 7.96 cm H_2O
$\Delta P_{pleural}$ absolute - relative, end-exp	Ppl, end-exp – Pes, end-exp	4.16 – 13.5 = -9.3
$\Delta P_{pleural}$ absolute - relative, end-insp	Ppl, end-insp – Pes, end-insp	7.96 – 17.3 = -9.3
P_L, abs – P_L, rel	P_L, abs – P_L, rel	13.3 – 22.63 = -9.3

Of note, with both methods the transpulmonary driving pressure can be calculated. Using the relative method, both the P_L at end-expiration and at end-inspiration may be inappropriately increased by a similar amount of pressure, and therefore the driving pressure is not influenced. Indeed, if calculated by the presented values of tidal volume, plateau pressure, PEEP, and oesophageal pressure, both methods yield the same transpulmonary driving pressure of 10.8 cm H2O (day 2 prone).
The relative and absolute methods for calculating transpulmonary pressure yield similar results if pleural pressure is only determined by transmission of airway pressure across the lung. The authors properly conclude that the formula for relative P_L may only be representative for the non-dependent lung part in the supine position as these parts have the lowest pleural pressures.

Disclosures

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References

[1] De Jong PJ, Roesthuis LH, van der Hoeven JG. The effects of prone and supine position on respiratory mechanics in a patient with ARDS. Neth J Crit Care. 2019;27:124-6.
[2] Gattinoni L, Tonetti T, Quintel M. Regional physiology of ARDS. Crit Care 2017;21(Suppl 3):312.