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Understanding the setting of PEEP from esophageal pressure in patients with ARDS

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The act of breathing during mechanical ventilation requires a driving force, which is generated, totally or in part, by contraction of the respiratory muscles and by the ventilator (controlled or assisted ventilation). This driving force must overcome the elastic and resistive properties of the respiratory system. Because the respiratory system is composed of lung and chest wall, in series, in order to know what pressure is distending the lung, it is necessary to measure the transpulmonary pressure [1]. The transpulmonary pressure is computed as the difference between airway and pleural pressures, where the distending force of the chest wall is the pleural pressure. Unfortunately, in clinical practice, the airway pressure is widely erroneously assumed to reflect the transpulmonary pressure, despite the fact that several studies have shown that the contribution of pleural pressure is often important and unpredictable [1].

Since it is impossible to measure the pleural pressure directly, the only bedside method to assess the transpulmonary pressure in critically ill patients is the

measurement of esophageal pressure (Fig. 1) [1]. This is recorded by a dedicated esophageal balloon-tipped catheter positioned in the lower part of the esophagus [2, 3]. The limitations of esophageal pressure for estimating pleural pressure are well known and, even when strong, are beyond the scope of this paper [4]. As the topic is broad enough and has been recently reviewed in detail [1], we will focus here on setting positive end expiratory pressure (PEEP) in patients with acute respiratory distress syndrome (ARDS).

The role of PEEP in ARDS has been investigated in many animal and human studies [5]. Whereas PEEP has long been used with the primary goal of improving oxygenation, the current paradigm regarding its selection is based on preventing ventilator-induced lung injury [5]. Specifically, PEEP is applied to maintain the lung as recruited and to limit intratidal opening and closing [6]. Thus, it would be important to optimize PEEP in each patient based on the respiratory characteristics. In ARDS, we have to deal with the transpulmonary pressure at both end inspiration and end expiration. Considering end inspiration, due to the high variability of chest wall to lung elastance ratio across the patients, similar pressure applied to the airway opening can generate different changes in transpulmonary pressure (i.e., different lung stress) [7]. Consequently, the application of similar tidal volume and PEEP may have harmful or not harmful effects on the lung stress/strain depending on the patient's respiratory characteristics. In addition, for the same tidal volume, different PEEP levels may result in different degrees of ventilator-associated lung injury. In clinical practice, the lung stress generated at end inspiration can be obtained similarly by estimating the difference in transpulmonary pressure between end inspiration and a release maneuver (release-derived end inspiratory transpulmonary pressure) or as the product of airway plateau pressure at end inspiration to lung elastance to respiratory system elastance ratio (elastance-derived end

Fig. 1 From top to bottom, recordings of flow, airway pressure (P_{aw}), esophageal pressure (P_{es}), and transpulmonary pressure (P_{tp}) in an ARDS patient sedated and paralyzed under volume-

controlled ventilation at constant flow inflation. After three baseline breaths, the airways are occluded at the end of expiration then at the end of inspiration

inspiratory transpulmonary pressure) [8, 9] (Fig. 1). The elastance-derived method does not require any disconnection from the ventilator or release maneuver to atmospheric pressure and, hence, avoids any possible risk of alveolar derecruitment and hypoxemia. In a series of ARDS patients with H1N1, the measurement of elastance-derived end inspiratory transpulmonary pressure allowed the use of higher PEEP levels in more than 50 % of the patients [10]. This was associated to a better oxygenation, and avoided the use of extra-corporeal membrane oxygenation without overcoming the upper limit of lung stress [10].

For the lung to remain open at end expiration, the transpulmonary pressure must be positive. Despite controversy about the interpretation of the directly measured esophageal pressure, the end expiratory transpulmonary pressure was computed as the difference between set PEEP and esophageal pressure. If the directly measured esophageal pressure is equal to the pleural pressure [4], a negative end expiratory transpulmonary pressure should indicate massive collapse of the lung sampled close to the esophageal balloon [1]. In the supine position, however, esophageal pressure is very often positive and, hence, end expiratory transpulmonary pressure is negative for other reasons than lung collapse. Therefore, negative transpulmonary pressure recorded at end expiration may be an artefactual [4]. However, with this criticism in mind, Talmor et al. [11], in a small single-center randomized controlled trial, individualized PEEP in order to achieve end expiratory transpulmonary pressure between 0 and 10 cm H₂O in ARDS patients for 3 days (EPVent1). They found higher PEEP levels, better oxygenation and greater compliance of the respiratory system in the esophageal pressure PEEP-guided group as compared to the control

group (gas exchange-based PEEP). End inspiratory transpulmonary pressure and mortality rate at 28 days were similar in the two groups. In order to clarify this strategy in a large number of ARDS patients, an ongoing multicenter trial is currently testing ventilation strategy in which PEEP is adjusted to achieve end expiratory transpulmonary pressure between 0 and 6 cm H₂O (EPVent2), compared to a gas exchange-based strategy (PEEP/FIO₂ table) [12]. The duration of intervention has been prolonged from 3 to 28 days and the primary end point is a combination of ventilator-free days and mortality at 28 days.

However, setting PEEP from directly measured esophageal pressure may be questionable for various reasons. The directly measured esophageal pressure did not correlate with the lung weight measured by CT scan and the severity of ARDS [8], and when the direct values of esophageal pressure were used to select PEEP, the resulting PEEP levels were not different among mild, moderate, and severe ARDS [13], and more importantly were not related to lung recruitability [8]. It has been found that the directly measured and the release-derived end expiratory transpulmonary pressure were not related to lower values for the former [8]. Setting PEEP on the basis of directly measured and elastance-derived transpulmonary pressure were not directly related, and in up of 33 % of the patients gave opposite recommendations [14].

Attempts were made to correct for the directly values of end expiratory esophageal pressure were made by subtracting a single value of 5 cm H₂O or by referring to its value at the relaxation volume of the respiratory system (V_r) [15]. Neither corrections were found to be equivalent and directly measured esophageal pressure at

the end of expiration did not correlate with the esophageal pressure corrected for its value at Vr.

Based on the present data, the appropriate use of esophageal pressure requires further investigation.

Conflicts of interest The authors declare that they have no conflict of interest.

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