It's Time to Reappraise the Impact of Auto-PEEP

Since Pepe and Marini[1] first used the term auto-PEEP in 1982, many studies have been conducted in this field.[2-5] For patients receiving mechanical ventilation, auto-PEEP is a common problem during the weaning process.[2-4] Even in the acute stage of acute respiratory failure, patients may suffer from the detrimental effects of auto-PEEP.[4,5]

By definition, auto-PEEP occurs when air flow does not return to zero at end-exhalation. It can occur in patients with COPD during spontaneous breathing.[6,7] Dynamic lung hyperinflation caused by auto-PEEP worsens their inspiratory capacity because inhalation cannot be initiated from relaxation volume.[6-8] Consequently, inspiratory muscles must overcome the imposed load to generate inspiratory flow.[4,8] Patients with COPD are usually instructed to practice pursed lips breathing, since this is a kind of external PEEP to ameliorate the load of the inspiratory muscles.[8]

Auto-PEEP occurs in patients receiving mechanical ventilation in the acute stage of acute respiratory failure when they have excessive minute ventilation, resulting in a relatively short expiratory time.[3,4] This can be explained by the common phenomenon of a time constant in the exhalation phase.[4,9] In this situation, patients may excessively use their expiratory muscles and persist with inspiratory muscle activity during the exhalation period to shorten the expiratory time.[2,4] This partly originates from discordance between neuroventilatory drive and peripheral muscle response and also high airway resistance.[3-5,9] Auto-PEEP will compromise the patient's hemodynamics, increase patient-ventilator asynchrony, and increase end-expiratory lung volume.[3-5] During weaning, this will hinder the effectiveness of the ventilator trigger, increase the work load of respiratory muscles, and increase the patient's anxiety.[3,5] Therefore, the best way to measure and manage auto-PEEP in patients receiving mechanical ventilation is a crucial topic in the field of respiratory care.

In this issue of RESPIRATORY CARE, Natalini et al[10] conducted a study to address and assess the factors contributing to the development of auto-PEEP in subjects receiving mechanical ventilation without an active ventilator trigger. The authors try to quantify each factor using statistical analysis. The results demonstrated that flow limitation, expiratory time/time constant, resistance of the respiratory system, and being overweight were the most important variables affecting auto-PEEP. Of note, the authors enrolled subjects receiving mechanical ventilation without active respiratory muscle activity, thereby avoiding confounders from the interplay between static factors due to underlying diseases and host status, and dynamic factors due to physiological stress. However, this methodological strategy is inherently a limitation of their study.

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The measurement of expiratory flow limitation in this study should also be mentioned. Several methods have been validated to assess expiratory flow limitation in patients with spontaneous tidal breathing.[6] A simple noninvasive way is by the manual compression of the abdomen throughout the exhalation period.[6,11,12] This maneuver creates increased pleural pressure but will not further change the expiratory flow due to the closure or fixed obstruction of downstream small airways, as found in patients with COPD and obesity.[6,7,13,14]

The use of manual compression of the abdomen to detect expiratory flow limitation in patients receiving mechanical ventilation is more complicated, and one study has been conducted to validate its use.[15] Critically ill patients suffer from pathophysiological conditions that may cause abdominal distention, rapid changes of body fluid in the abdomen, and intra-abdominal infections. Therefore, whether increased intra-abdominal pressure transmits accordingly into the pleural space is questionable. In general, performing manual compression of the abdomen in patients during the convalescent stage of disease may be appropriate in terms of patient safety and validity of the test.

Natalini et al[10] used multiple logistic regression analysis to quantify the weight of determinants of auto-PEEP. This statistical method assumes that each element is added steadily in a linear relationship. However, due to the complicated interplay of these factors, we are not sure whether their relationship can be best described statistically by lin-

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ear relationships. Due to the design of this study, the enrolled subjects were all placed in a quiet state; therefore, it is not surprising that the static characteristics of the subjects, including flow limitation, time constant, and resistance of the respiratory system, played a significant role. Natalini et al[10] conducted this study at a consortium of hospitals, enrolled a large number of subjects receiving mechanical ventilation, and recorded data regarding physiological parameters of lung mechanics in subjects with acute respiratory failure. Unfortunately, the ventilator settings were managed at the discretion of the treating physicians rather than in a standardized manner.

There are several implications of this study. First, we can clarify and measure expiratory flow limitation for patients receiving mechanical ventilation at bedside using a simple, noninvasive maneuver by manual compression of the abdomen. According to the waterfall theory,[16] applying external PEEP in these patients will unload the burden of the inspiratory muscles and facilitate weaning.[4,15] However, the misuse of external PEEP without the existence of expiratory flow limitation may result in increased alveolar pressure at end inspiration, thereby inducing acute lung injury. Second, the impact of weighted factors regarding the development of auto-PEEP in patients receiving mechanical ventilation needs to be taken into account. With an individualized approach, we can target more severe factors to overcome the obstacles of auto-PEEP. Finally, enrolling subjects from multiple centers can result in a larger sample size; however, ventilator management should be performed in a standardized manner, which will allow for more information to be obtained from a large heterogeneous group.

In conclusion, factors involved in the development of auto-PEEP do not occur equally. It is time to prioritize and manage the burden of auto-PEEP on patients receiving mechanical ventilation.

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REFERENCES

1. Pepe PE, Marini JJ. Occult positive end-expiratory pressure in mechanically ventilated patients with airflow obstruction: the auto-PEEP effect. Am Rev Respir Dis 1982;126(1):166-170.
2. Zakynthinos SG, Vassilakopoulos T, Zakynthinos E, Roussos C. Accurate measurement of intrinsic positive end-expiratory pressure: how to detect and correct for expiratory muscle activity. Eur Respir J 1997;10(3):522-529.
3. Rossi A, Polese G, Brandi G, Conti G. Intrinsic positive end-expiratory pressure (PEEPi). Intensive Care Med 1995;21(6):522-536.
4. Laghi F, Goyal A. Auto-PEEP in respiratory failure. Minerva Anestesiol 2012;78(2):201-221.
5. Marini JJ. Dynamic hyperinflation and auto-positive end-expiratory pressure: lessons learned over 30 years. Am J Respir Crit Care Med 2011;184(7):756-762.
6. Koulouris NG, Hardavella G. Physiological techniques for detecting expiratory flow limitation during tidal breathing. Eur Respir Rev 2011;20(121):147-155.
7. Loring SH, Garcia-Jacques M, Malhotra A. Pulmonary characteristics in COPD and mechanisms of increased work of breathing. J Appl Physiol 2009;107(1):309-314.
8. Alvisi V, Romanello A, Badet M, Gaillard S, Philit F, Guérin C. Time course of expiratory flow limitation in COPD patients during acute respiratory failure requiring mechanical ventilation. Chest 2003; 123(5):1625-1632.
9. Hess DR. Respiratory mechanics in mechanically ventilated patients. Respir Care 2014;59(11):1773-1794.
10. Natalini G, Tuzzo D, Rosano A, Testa M, Grazioli M, Pennestri V, et al. Assessment of factors related to auto-PEEP. Respir Care 2016; 61(2):134-141.
11. Ninane V, Leduc D, Kafi SA, Nasser M, Houa M, Sergysels R. Detection of expiratory flow limitation by manual compression of the abdominal wall. Am J Respir Crit Care Med 2001;163(6): 1326-1330.
12. Abdel Kafi S, Sersté T, Leduc D, Sergysels R, Ninane V. Expiratory flow limitation during exercise in COPD: detection by manual compression of the abdominal wall. Eur Respir J 2002;19(5):919-927.
13. Pankow W, Podszus T, Gutheil T, Penzel T, Peter J, Von Wichert P. Expiratory flow limitation and intrinsic positive end-expiratory pressure in obesity. J Appl Physiol 1998;85(4):1236-1243.
14. Salome CM, King GG, Berend N. Physiology of obesity and effects on lung function. J Appl Physiol 2010;108(1):206-211.
15. Lemyze M, Favory R, Alves I, Perez T, Mathieu D. Manual compression of the abdomen to assess expiratory flow limitation during mechanical ventilation. J Crit Care 2012;27(1):37-44.
16. Tobin MJ, Lodato RF. PEEP, auto-PEEP, and waterfalls. Chest 1989; 96(3):449-451.