

Using esophageal balloon monitoring to optimize PEEP

David Brouwer

Department of Respiratory Care

Ashraf Elshami

Pulmonary and Critical Care Medicine

Bill Roberts

Department of Respiratory Care, Sanford USD Medical Center, Sioux Falls, SD

Introduction

Total respiratory system compliance is composed of two different values: lung (*airway*) compliance and chest wall (*pleural*) compliance. When monitoring the respiratory system compliance of a patient on mechanical ventilation, we cannot separate the two. Since the Acute Respiratory Distress Syndrome Network (ARDSnet) trial on using lower tidal volumes (V_t) vs. traditional tidal volumes, professionals have widely believed that they must maintain plateau pressures at $< 30\text{cmH}_2\text{O}$ to prevent ventilator-induced lung injury (VILI).¹ This compliance measurement is taken by the ventilator during an inspiratory hold and measures the total respiratory system compliance. With this measurement, we may decrease volume or positive end-expiratory pressure (PEEP) delivery if the plateau pressure is $> 30\text{cmH}_2\text{O}$, without considering the amount of chest wall (*pleural pressure*) compliance that may play a role in expanding or not expanding the lung (*airway*).

We may actually be doing a disservice to patients by adjusting the ventilator based on high plateau pressure and increasing the chances of lung damage by continually opening and collapsing the alveoli. Using an esophageal balloon, we can separate the two components of respiratory system compliance and adjust the ventilator based on the estimated transpulmonary pressure. With an inspiratory hold, we can measure lung strain by comparing the esophageal pressure to the airway pressure and calculating transpulmonary plateau pressure (PtpPlat). With an expiratory hold, we can compare the esophageal pressure and airway pressure to calculate the transpulmonary positive end-expiratory pressure (PtpPEEP). Using this measurement, we can determine how much pleural pressure must be overcome to prevent alveolar collapse. If we adjust the V_t and PEEP to maintain a PtpPlat $< 25\text{cmH}_2\text{O}$, we can prevent lung overdistention while adjusting our PEEP setting to maintain a PtpPEEP = $0\text{--}10\text{ cmH}_2\text{O}$ to prevent lung collapse at the critical closing pressure of the alveoli.²

Case summary

A 39-year-old morbidly obese male with asthma, sleep apnea and hypoventilation syndrome was brought to a referring facility emergency department (ED) due to increased sleepiness and confusion over the previous few days. Upon his arrival, his color was increasingly gray-blue with severe hypoxia and hypercapnia. He was intubated for respiratory failure, placed on mechanical ventilation and sent to our facility. Upon admission, he was placed on 14 cmH₂O of PEEP and an FiO₂ of 1 with arterial blood gas (ABG) test findings of pH 7.40, PaCO₂ 54 and PaO₂ 61, and a P/F ratio of 61. On the day of admission, a cardiac echogram was performed to look at heart function and check for shunting, but its quality was poor due to his body size. A transesophageal echogram (TEE) was performed on day 2, which showed mild-moderate pulmonary hypertension with no evidence of an intracardiac shunt. Based on these findings and no change in the patient's oxygenation status, we decided to prone the patient.

By placing the patient in the prone position, we thought we could recruit a substantial part of the dorsal lung, making it a nondependent lung region, and gain more effective gas exchange. This recruitment would improve our overall ventilation/perfusion matching and decrease the hypoxia. Within the two hours he was in the prone position, we were able to wean the oxygen down to an FiO₂ of 0.4 with ABGs of pH 7.47, PaCO₂ 46 and PaO₂ 91, and a P/F ratio of 228. We continued with prone positioning for a few days to maintain our current oxygen needs and wean the PEEP to 8 cmH₂O. At this time, we decided to discontinue prone positioning.

With the patient awake, we wanted to get him in a chair and increase his activity as tolerated with the goal to liberate him from the ventilator within a couple of days. Within a few days, our oxygen needs increased to an FiO₂ of 0.7 on 14 cmH₂O of PEEP with a P/F ratio of 65. Prior to this,

we had discussed that the patient may need a tracheotomy to facilitate ventilator liberation due to his severe sleep apnea and hypoventilation syndrome. Due to his increased hypoxia over the next few days, we placed a tracheotomy. On day 15, we decided to place an esophageal balloon to determine how much the patient's obesity was affecting lung compliance. We placed an esophageal balloon attached to an orogastric tube (OG) to measure his estimated transpulmonary pressure at end expiration and optimize the PEEP. The esophageal balloon was easily placed into the stomach at a depth of approximately 55 cm, which was confirmed by a pressure increase on our esophageal balloon pressure waveform with gentle compression on the lower abdomen. Then, the balloon was withdrawn to approximately 35 cm from the front teeth, and a cardiac artifact was seen on the esophageal balloon waveform.

After the balloon placement, with the patient sedate and in the supine position with the head of the bed at 30 degrees, we performed a series of three inspiratory hold and expiratory hold maneuvers to average our transpulmonary pressure measurements while on a PEEP of 14 cmH₂O and Vt of 8 mL/kg ideal body weight (IBW). We had a PtpPlat of 3 and a PtpPEEP of -16. We increased our PEEP to 30 cmH₂O and performed the series of inspiratory and expiratory maneuvers again to measure our transpulmonary pressure. We had a PtpPlat of 6 and a PtpPEEP of 0. Within a few hours, we were able to wean our FiO₂ down to 0.5 with a P/F ratio of 196. The next day, we changed the patient to a spontaneous breathing mode of ventilation with a pressure support (PS) of 10 cmH₂O and PEEP of 30 cmH₂O, and continued to advance his activity as tolerated to help with deconditioning. Over the next few days, we slowly decreased the PEEP and transferred him to a step-down unit on a PEEP of 20cmH₂O and a FiO₂ of 0.5 with no adverse effects noted from the high levels of PEEP.

Discussion

In this specific patient, we used esophageal pressure monitoring to optimize our use of PEEP. Considering the growing number of morbidly obese patients and how this number affects total respiratory system compliance, we know that esophageal pressure monitoring can greatly impact ventilation strategy. Without this technology, we probably would not have increased the PEEP to this level. Without this increase, the risk of VILI and time spent on mechanical ventilation would have been much higher.

Prior to using an esophageal balloon in this patient, our staff had limited experience with placing balloons and measuring esophageal pressure. After using esophageal pressure

monitoring, our staff has appreciated the ability to positively influence ventilator management for individual patients. With the ability to easily place a balloon attached to a nasogastric (NG) or OG tube, we can also easily receive relevant data to correctly adjust ventilator settings. By easily performing an inspiratory and expiratory hold maneuver, we can separate the components of respiratory system compliance and optimize Vt and PEEP management on an individual basis to improve patient care. Esophageal pressure monitoring certainly is not for every ventilator patient, but after our brief experience with esophageal pressure monitoring, we are looking forward to using it in specific patient populations to improve ventilator management.

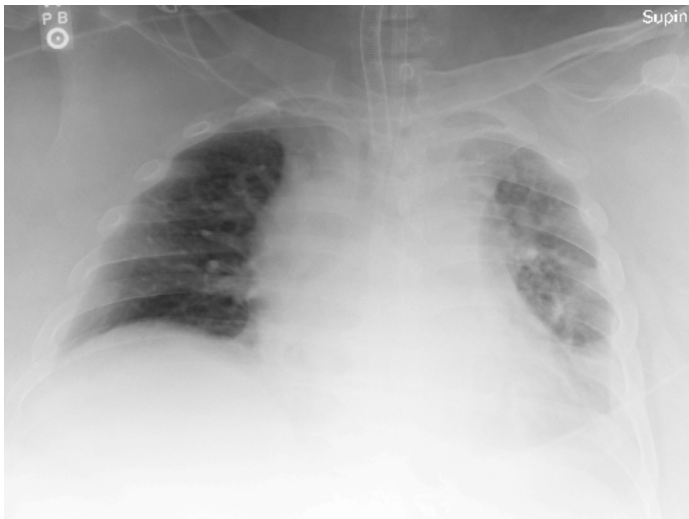


Figure 1. CXR 10/15/12 on 14 PEEP

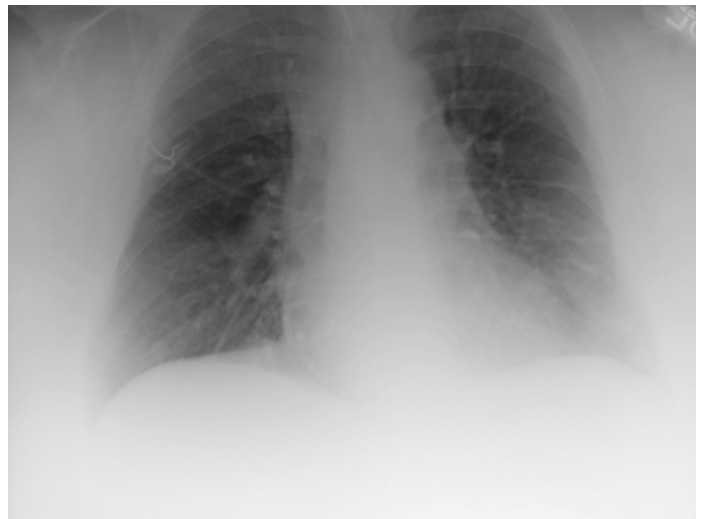


Figure 2. CXR 10/16/12 on 30 PEEP

References

- 1 The Acute Respiratory Distress Syndrome Network. Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome. *NEJM*, May 4, 2000, 342:1301–1308.
- 2 Talmor, D. et al. Mechanical ventilation guided by esophageal pressure in acute lung injury, *NEJM*, November 13, 2008, 359(20):2095–2104.

CareFusion
22745 Savi Ranch Parkway
Yorba Linda, CA 92887

800.231.2466 toll-free
714.283.2228 tel
714.283.8493 fax

carefusion.com

