13 Expert Tips – Esophageal Pressure Measurement

HAMILTON MEDICAL

Content overview

The ventilation experts

Dr. Jean-Michel Arnal
Senior Intensivist

Affiliation
Réanimation polyvalente, Hôpital Sainte Musse, Toulon, France

Dr. Aude Garnero
Senior Intensivist

Affiliation
Réanimation polyvalente, Hôpital Sainte Musse, Toulon, France

Munir Karjaghli
Respiratory Therapist

Affiliation
Hamilton Medical AG
Clinical Applications Specialist

Esophageal pressure in ARDS patients

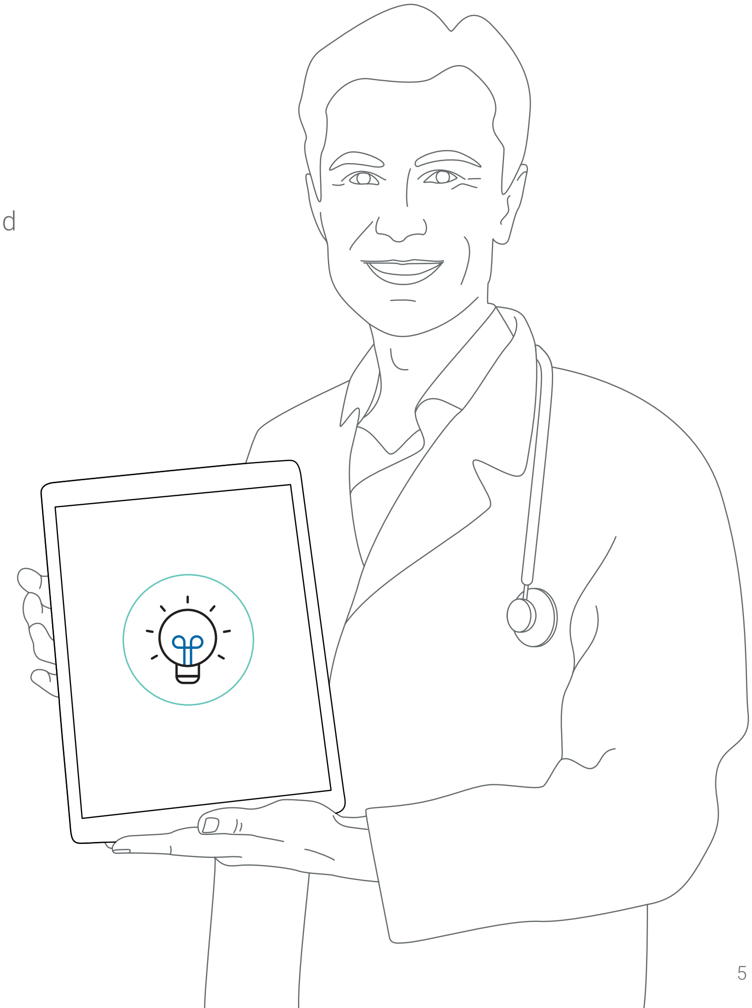
Acute respiratory distress syndrome (ARDS) is characterized by a decrease in respiratory system compliance due to a collapsed lung and/or a decrease in chest wall compliance. When mechanical ventilation is used, the pressure shown on the ventilator display is the airway pressure and does not distinguish between the lung and chest wall components.

The measurement of esophageal pressure, used as a surrogate for pleural pressure, allows calculation of the pressure required to distend the lung and the chest wall. The distending force applied to the lung, called the transpulmonary pressure, is the pressure difference between the alveoli and the esophagus, measured during a 5-second end-inspiratory or end-expiratory occlusion.

For a given alveolar pressure, transpulmonary pressure decreases when esophageal pressure increases; that is, as the chest wall becomes stiffer, the proportion of airway pressure that distends the lung decreases.

13 Expert Tips

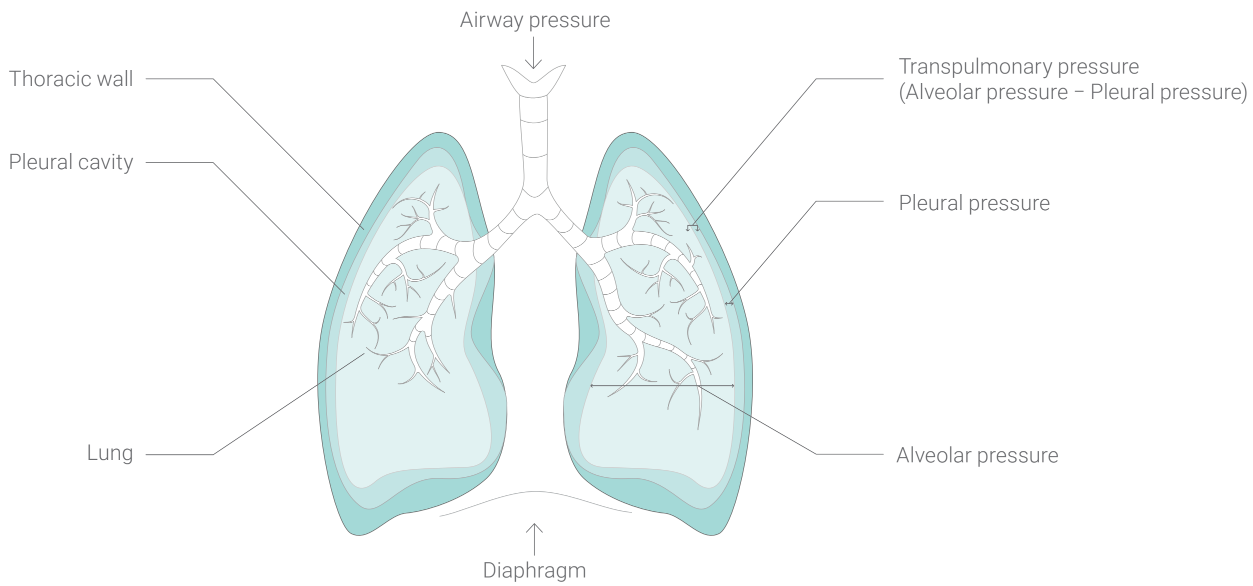
On the following pages, you will find clinically proven recommendations about what to do and what to avoid when using esophageal pressure in ARDS patients.



Use an esophageal catheter in severely hypoxemic ARDS patients

Tip 1

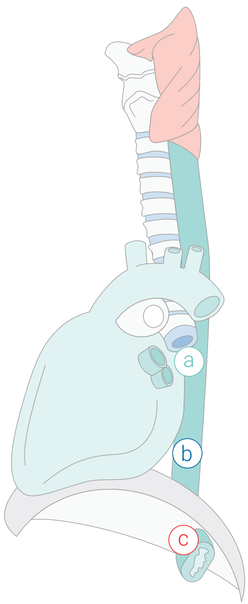
Chest wall mechanics can be severely abnormal. Partitioning the respiratory system between the lungs and the chest wall at the bedside is useful for optimizing ventilator settings. It may also help to improve oxygenation.

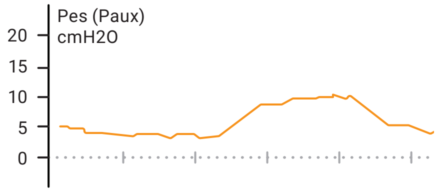


Position the balloon correctly

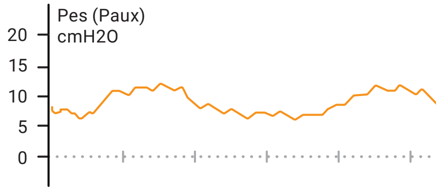
Tip 2

Position the balloon in the lower third of the esophagus. You can use the esophageal pressure waveforms as a guide for correct placement[1].

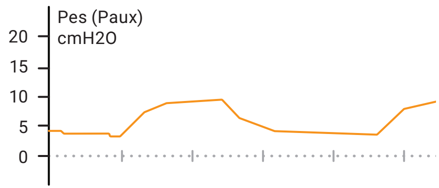




(a) A balloon catheter that is placed too high in the esophagus will result in falsely low pressures without good cardiac oscillations



(b) Correct position

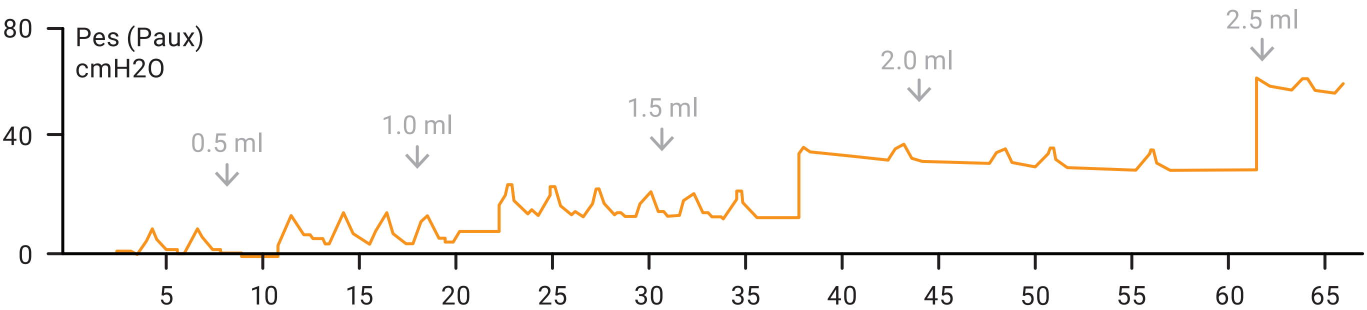


(c) A balloon catheter that is placed too low in the esophagus will result in falsely low pressures without cardiac oscillations

Optimize balloon filling volume

Tip 3

Optimize the esophageal balloon volume by progressively filling the catheter every 5 to 10 seconds in steps of 0.5 to 1.0 ml (NutriVent: 1 ml steps from 1.0 to 8.0 ml; Cooper: 0.5 ml steps from 0.5 to 2.0 ml). Measure the cyclic tidal swing of Pes after each step. The optimal filling volume is the lowest volume inside the balloon associated with the largest tidal swing of Pes during mechanical ventilation with constant tidal volumes[2, 3].

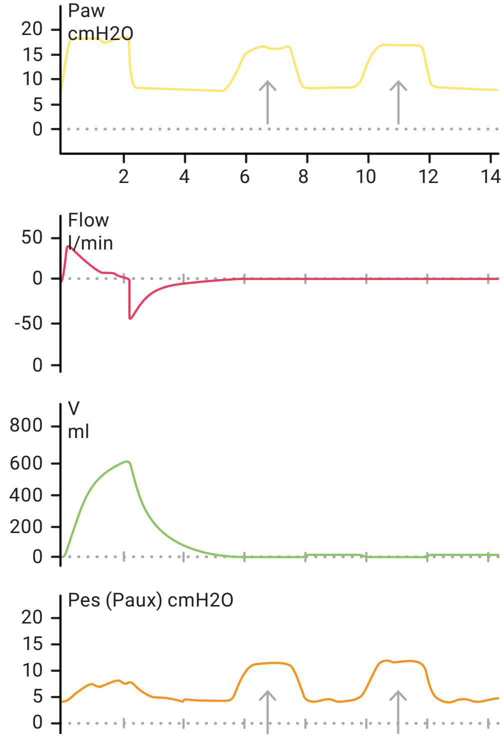


Perform an occlusion test

Tip 4

Once the esophageal balloon is placed in the mid-lower third of the esophagus and filled, perform an occlusion test to check the balloon is correctly positioned and filled to the optimal volume. During the end-expiratory occlusion, gently press or squeeze the chest.

The correct position is confirmed if the positive swings in esophageal and airway pressure are the same; that is, transpulmonary pressure does not change during the occlusion test. The acceptable deviation from a Pes to Paw ratio of 1:1 during the test is 20%. This equals a range of 0.8–1.2[3].

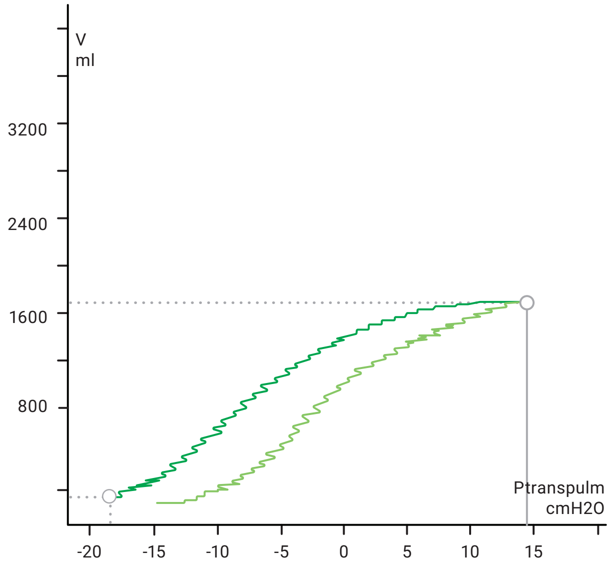


Assess lung recruitability using a transpulmonary low-flow pressure/volume curve (P/V curve)

Tip 5

Here you can see a transpulmonary low-flow pressure/volume curve (P/V curve). A large hysteresis indicates high potential for recruitment[4].

Hysteresis is the surface enclosed between the inflation and deflation limbs of the P/V curve. Hysteresis is large in ARDS because the pressures to recruit during inflation are higher than the pressures to derecruit[5].



The P/V Tool available on the HAMILTON-C3/C6 and HAMILTON-G5/S1 ventilators, performs a respiratory mechanics maneuver that records a quasi-static pressure/volume curve showing both the inflation and deflation curves. This data can then be analyzed to determine the lung recruitability and recruitment strategy to apply.

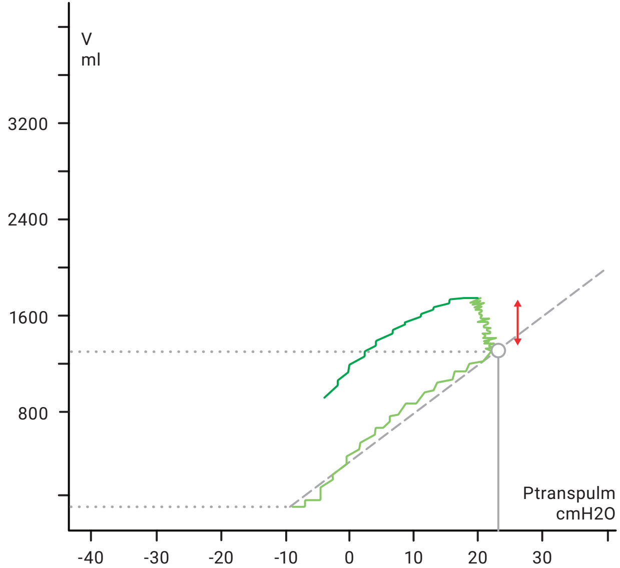
Use a recruitment maneuver to reach the upper limit of transpulmonary pressure

Tip 6

The P/V Tool can be used to perform a sustained-inflation recruitment maneuver. The transpulmonary pressure achieved during the recruitment maneuver can be measured and titrated.

Perform a recruitment maneuver targeting 20 cmH2O of transpulmonary pressure to reach the upper physiologic limit of transpulmonary pressure.

In addition, the decrease in transpulmonary pressure during the recruitment maneuver is an assessment of the lung recruitment[6].



The P/V Tool can also be used to apply a sustained-inflation lung-recruitment maneuver. Once completed, the effective increase in lung volume is displayed. This is particularly helpful in ARDS patients, as appropriate lung recruitment is critical[7].

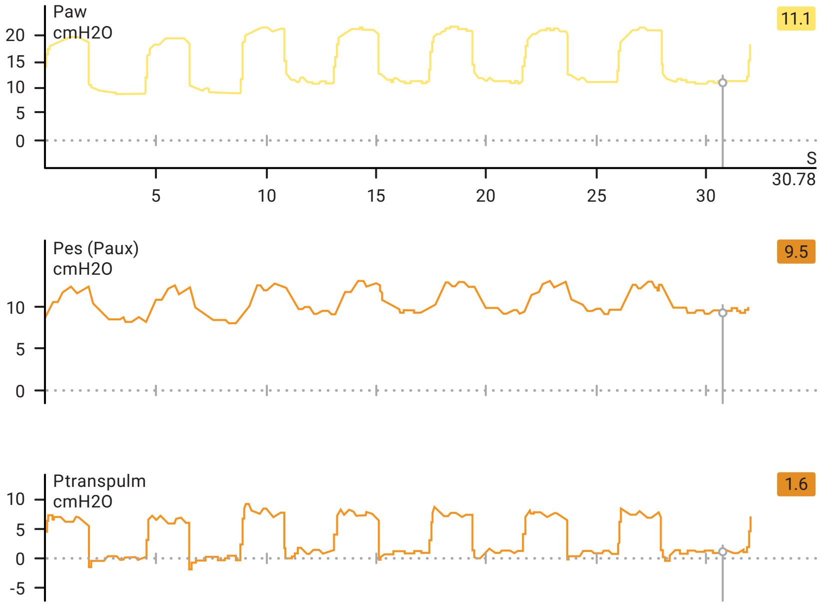
Set PEEP to result in positive end-expiratory transpulmonary pressure

Tip 7

This ventilator display shows airway pressure (Paw), esophageal pressure (Pes), and transpulmonary pressure (Ptranspulm).

Ptranspulm ≈ Paw - Pes

Ensure you set PEEP so that Ptranspulm is 2–5 cmH2O at the end of expiration[8].

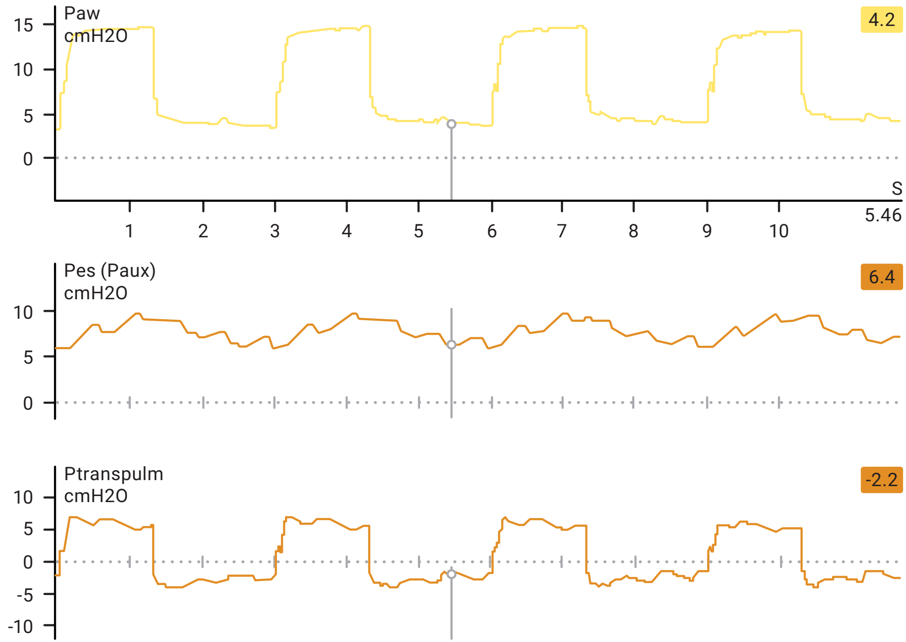


Combining the P/V Tool and esophageal pressure measurement is useful for fine-tuning the recruitment maneuver. Doing so allows for the appropriate setting of PEEP and tidal volume to adequately ventilate the patient without injuring the lungs[9].

Avoid negative end-expiratory transpulmonary pressure

Tip 8

Negative end-expiratory transpulmonary pressure can cause ventilator-induced lung injury due to atelectrauma[10].



When NOT to use esophageal pressure measurement and when to use with caution

Tip 9

When not to use

Do not use an esophageal catheter in the presence of contraindications to nasogastric tube insertion, such as pharyngeal or esophageal lesions, risk of bleeding (e.g., esophageal varices, severe thrombopenia), and risk of local injury in some specific patients (e.g., skull or maxilla-facial fractures).

When to use with caution

The interpretation of transpulmonary pressure in the case of a large pleural effusion has not yet been studied. Therefore, esophageal pressure measurement should be used here with caution.

Tip 10

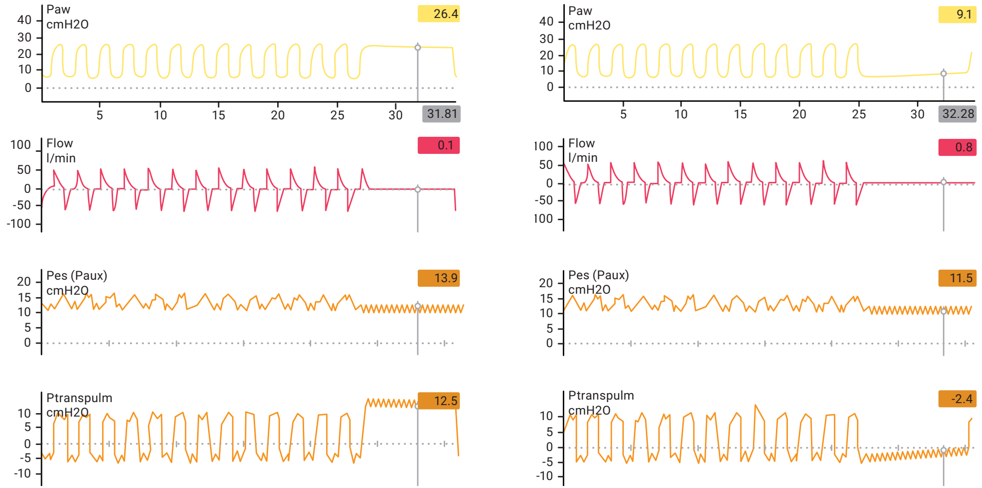
Measuring transpulmonary driving pressure with end-inspiratory and end-expiratory occlusions

Driving transpulmonary pressure = Transpulmonary pressure (end-insp.) - Transpulmonary pressure (end-exp.)

$$\Delta P_L = P_{L;EI} - P_{L;EE}$$

e.g., Transpulmonary pressure (end-insp.) = 12.5
Transpulmonary pressure (end-exp.) = -2.4

$\Delta P_L = P_{L;EI} - P_{L;EE}$
$= 12.5 + 2.4$
$= 14.9$ cmH2O



Keep tidal transpulmonary pressure variations under 10 cmH2O

Tip 11

Avoid tidal transpulmonary pressure variations above 10 cmH2O to limit global lung stress.

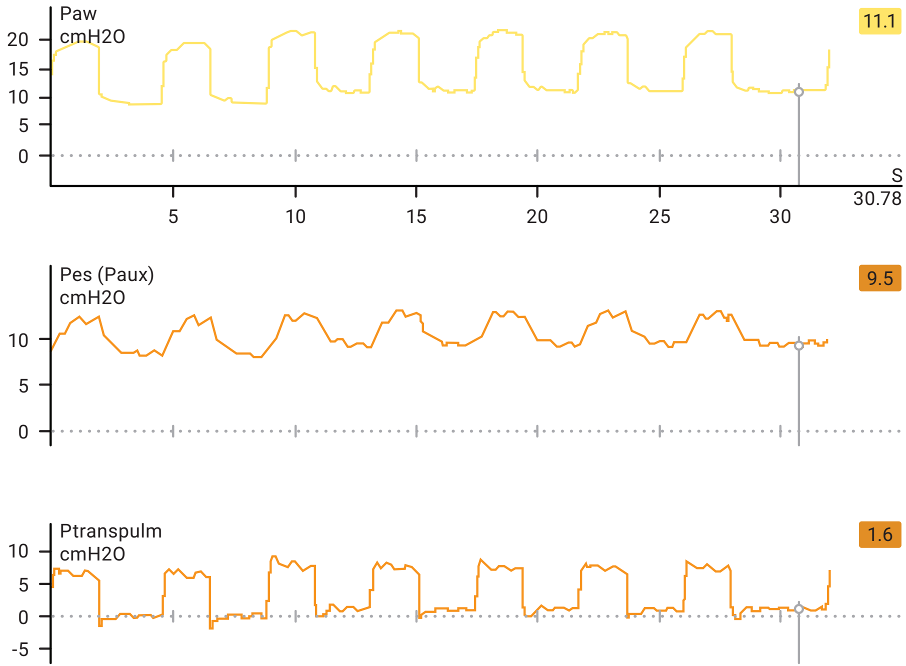
Cyclic opening and closing of parts of the lung may directly induce the release of inflammatory mediators and noxious proteinases[11].

Use the same device for airway and esophageal pressure monitoring

Tip 12

To calculate transpulmonary pressure, airway pressure and esophageal pressure have to be synchronized on the same screen.

When two different devices are used, the calculation is more complicated due to different units and time scales used on each device. The calculations have to be made manually and synchronization is difficult to achieve.



Minimize ventilator-induced lung injury with venovenous ECMO

Tip 13

Venovenous ECMO allows mechanical ventilation with very low tidal volumes, and a lower plateau pressure (Pplateau) and respiratory rate (fTotal), potentially minimizing ventilator-induced lung injury (VILI)[12]. However, the optimal mechanical ventilation strategy for patients with severe ARDS receiving venovenous ECMO is unclear. A recent randomized controlled trial reported that a ventilation strategy guided by transpulmonary pressure could increase the proportion of patients with severe ARDS successfully weaned from venovenous ECMO[13].

Protective Ventilation Tool (P/V Tool) 1/3

The P/V Tool performs a respiratory mechanics maneuver that records a quasi-static pressure/volume curve showing both the inflation and the deflation curves. This data can then be analyzed to determine the lung recruitability and recruitment strategy to apply. The P/V Tool can also be used to display the decrease in transpulmonary pressure during recruitment maneuvers. This is particularly useful in ARDS patients, as appropriate lung recruitment and correct setting of PEEP are critical.

Benefits of the P/V Tool

- Easy for the operator and safe for the patient[14]
- No disconnection of the breathing circuit and no changes to ventilation settings
- Easily repeatable process to monitor changes in the patient‘s condition and the treatment's effectiveness over time
- Interpretation is assisted by automatic calculations and cursors to aid analysis

Protective Ventilation Tool (P/V Tool) 2/3

Quasi-static P/V curve

The P/V Tool records the pressure/volume relationship of the lungs at low-flow conditions using a patented pressure-ramping technique. This method allows the P/V Tool to be not only a diagnostic tool, but also a therapeutic lung-recruitment tool.

The resulting curves can be used to analyze:

- The lower and upper inflection points (LIP, UIP) on the inflation pressure/volume curve
- The deflection point on the deflation pressure/volume curve (PDR)
- The linear compliance of the inflation pressure/volume curve
- The hysteresis (the difference in volume between the two curves)

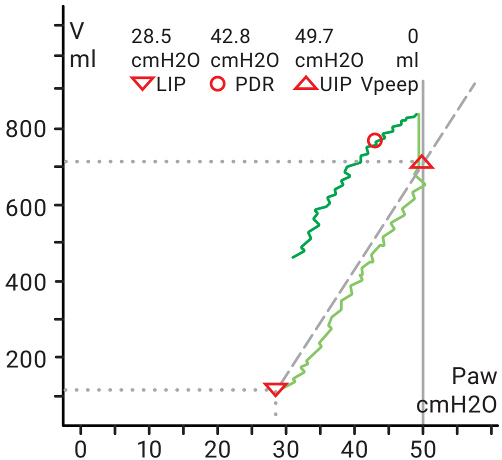
Protective Ventilation Tool (P/V Tool) 3/3

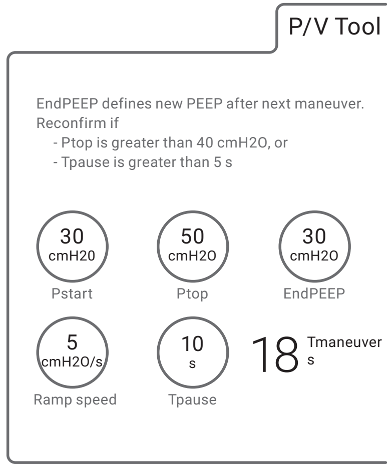
Sustained-inflation recruitment maneuver

The breathing circuit is pressurized linearly to the operator-set target pressure at the operator-set ramp speed, and the resulting volume changes are recorded.

When the pressure reaches the target, an operator-set pause is executed.

After the pause, pressure is released linearly to the operator-set end-PEEP level.





A cursor function permits graphical analysis of the curve, including identification of inflection points. The optimum pressure/volume relationship is between the lower inflection point (LIP) and the upper inflection point (UIP).

References

1 Milic-Emili J, Mead J, Turner JM. Topography of esophageal pressure as a function of posture in man. J Appl Physiol. 1964 Mar;19:212-6. doi: 10.1152/jappl.1964.19.2.212. PMID: 14155284.

2 Akoumianaki E, Maggiore SM, Valenza F, Bellani G, Jubran A, Loring SH, Pelosi P, Talmor D, Grasso S, Chiumello D, Guérin C, Patroniti N, Ranieri VM, Gattinoni L, Nava S, Terragni PP, Pesenti A, Tobin M, Mancebo J, Brochard L; PLUG Working Group (Acute Respiratory Failure Section of the European Society of Intensive Care Medicine). The application of esophageal pressure measurement in patients with respiratory failure. Am J Respir Crit Care Med. 2014 Mar 1;189(5):520-31. doi: 10.1164/rccm.201312-2193CI. PMID: 24467647.

3 Mojoli F, Torriglia F, Orlando A, Bianchi I, Arisi E, Pozzi M. Technical aspects of bedside respiratory monitoring of transpulmonary pressure. Ann Transl Med. 2018 Oct;6(19):377. doi: 10.21037/atm.2018.08.37. PMID: 30460251; PMCID: PMC6212357.

4 Chiumello D, Arnal JM, Umbrello M, Cammaroto A, Formenti P, Mistraletti G, Bolgiaghi L, Gotti M, Novotni D, Reidt S, Froio S, Coppola S. Hysteresis and Lung Recruitment in Acute Respiratory Distress Syndrome Patients: A CT Scan Study. Crit Care Med. 2020 Oct;48(10):1494-1502. doi: 10.1097/CCM.0000000000004518. Erratum in: Crit Care Med. 2022 Mar 1;50(3):e339. PMID: 32897667.

5 Crotti S, Mascheroni D, Caironi P, Pelosi P, Ronzoni G, Mondino M, Marini JJ, Gattinoni L. Recruitment and derecruitment during acute respiratory failure: a clinical study. Am J Respir Crit Care Med. 2001 Jul 1;164(1):131-40. doi: 10.1164/ajrccm.164.1.2007011. PMID: 11435251.

6 Baedorf Kassis E, Loring SH, Talmor D. Recruitment maneuvers: using transpulmonary pressure to help Goldilocks. Intensive Care Med. 2017 Aug;43(8):1162-1163. doi: 10.1007/s00134-017-4784-2. Epub 2017 Apr 6. PMID: 28386726.

7 Demory D, Arnal JM, Wysocki M, Donati S, Granier I, Corno G, Durand-Gasselin J. Recruitability of the lung estimated by the pressure volume curve hysteresis in ARDS patients. Intensive Care Med. 2008 Nov;34(11):2019-25. doi: 10.1007/s00134-008-1167-8. Epub 2008 Jun 25. PMID: 18575846.

8 Yoshida T, Amato MBP, Grieco DL, Chen L, Lima CAS, Roldan R, Morais CCA, Gomes S, Costa ELV, Cardoso PFG, Charbonney E, Richard JM, Brochard L, Kavanagh BP. Esophageal Manometry and Regional Transpulmonary Pressure in Lung Injury. Am J Respir Crit Care Med. 2018 Apr 15;197(8):1018-1026. doi: 10.1164/rccm.201709-1806OC. PMID: 29323931.

References

9 Baedorf Kassis E, Loring SH, Talmor D. Should we titrate peep based on end-expiratory transpulmonary pressure?-yes. Ann Transl Med. 2018 Oct;6(19):390. doi: 10.21037/atm.2018.06.35. PMID: 30460264; PMCID: PMC6212356.

10 Talmor D, Sarge T, Malhotra A, O'Donnell CR, Ritz R, Lisbon A, Novack V, Loring SH. Mechanical ventilation guided by esophageal pressure in acute lung injury. N Engl J Med. 2008 Nov 13;359(20):2095-104. doi: 10.1056/NEJMoa0708638. Epub 2008 Nov 11. PMID: 19001507; PMCID: PMC3969885.

11 Curley GF, Laffey JG, Zhang H, Slutsky AS. Biotrauma and Ventilator-Induced Lung Injury: Clinical Implications. Chest. 2016 Nov;150(5):1109-1117. doi: 10.1016/j.chest.2016.07.019. Epub 2016 Jul 29. PMID: 27477213.

12 Schmidt M, Stewart C, Bailey M, Nieszkowska A, Kelly J, Murphy L, Pilcher D, Cooper DJ, Scheinkestel C, Pellegrino V, Forrest P, Combes A, Hodgson C. Mechanical ventilation management during extracorporeal membrane oxygenation for acute respiratory distress syndrome: a retrospective international multicenter study. Crit Care Med. 2015 Mar;43(3):654-64. doi: 10.1097/CCM.0000000000000753. PMID: 25565460.

13 Wang R, Sun B, Li X, Tang X, He H, Li Y, Yuan X, Li H, Chu H, Tong Z. Mechanical Ventilation Strategy Guided by Transpulmonary Pressure in Severe Acute Respiratory Distress Syndrome Treated With Venovenous Extracorporeal Membrane Oxygenation. Crit Care Med. 2020 Sep;48(9):1280-1288. doi: 10.1097/CCM.0000000000004445. PMID: 32590385.

14 Pestaña D, Hernández-Gancedo C, Royo C, Uña R, Villagrán MJ, Peña N, Criado A. Adjusting positive end-expiratory pressure and tidal volume in acute respiratory distress syndrome according to the pressure-volume curve. Acta Anaesthesiol Scand. 2003 Mar;47(3):326-34. doi: 10.1034/j.1399-6576.2003.00011.x. PMID: 12648200.

More information:
www.hamilton-medical.com/esophageal-pressure

Manufacturer:
Hamilton Medical AG
Via Crusch 8, 7402 Bonaduz, Switzerland
+41 58 610 10 20
info@hamilton-medical.com
www.hamilton-medical.com

Authors: Dr. Jean-Michel Arnal, Dr. Aude Garnero, Munir Karjaghli
Release date: July 2015
Edition: 2

ELO20150701N.01