# Lung recruitment maneuvers

## Assessment of lung recruitability and performance of recruitment maneuvers using the P/V Tool Pro

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## Introduction

In acute respiratory distress syndrome (ARDS) patients, a recruitment strategy combines recruitment maneuvers (RMs) and positive end-expiratory pressure (PEEP) to prevent atelectrauma. Recruitment maneuvers are a voluntary strategy for effecting a temporary increase in transpulmonary pressure (PL), which in turn should reopen those alveolar units that are either poorly aerated or not aerated at all. PEEP may decrease ventilator-induced lung injury (VILI) by keeping those lung regions open that may otherwise collapse.[1]

The percentage of potentially recruitable lung varies widely among ARDS patients, and zones of collapsed and consolidated alveoli in the most dependent lung frequently require airway opening pressures of more than 35 – 40 cmH2O to recruit.[1] Knowledge of the percentage of potentially recruitable lung may be important for establishing the therapeutic efficacy of PEEP. Setting levels of PEEP independently of that knowledge may reduce the possible benefits of PEEP, while use of high PEEP levels in patients with a low percentage of potentially recruitable lung provides little benefit and may actually be harmful.[2]

The P/V Tool Pro represents a simple bedside method for assessing lung recruitability and carrying out recruitment maneuvers.[3, 4, 5] The procedure for performing the assessment and RMs using the P/V Tool Pro will be described in this white paper.

## Indication

Early in the management of ARDS, when the hemodynamic condition is controlled.

## Contraindication

1. Chronic obstructive pulmonary disease (COPD) and lung emphysema
2. Hemodynamic instability
3. High intercranial pressure
4. Leaks in the system (patient and/or breathing circuit)
5. Right heart failure

## Procedure

Make sure the following conditions are met before attempting a recruitment maneuver with the P/V Tool Pro.

- The patient must be intubated and ventilated but not breathing spontaneously. Most patients require deep sedation or neuromuscular blockade to prevent spontaneous breathing efforts.
- Ensure the ETT cuff is inflated to a pressure higher than the maximum pressure set in the P/V Tool settings. If using the IntelliCuff pressure controller, cuff pressure will automatically increase to 5 cmH2O above the Ptop set-

ting. There must be no gas leak throughout the entire system composed of the ventilator, breathing circuit, and the ventilated patient.

– Nebulization must be deactivated.

– The flow sensor must be correctly calibrated.

## Performing a low flow P/V curve

1. Pstart = 0-5 cmH2O
2. Ptop = 40 cmH2O
3. End PEEP = 0-5 cmH2O
4. Ramp Speed = 2 cmH2O/s
5. Tpause = 0

   When the End PEEP setting is changed, a message will appear showing the current PEEP, new PEEP, and the question "Do you want to change the PEEP setting after the maneuver?". Select No.


*Figure 1:* Setting of the pressure-volume curve using P/V Tool Pro

The validity of the P/V curve is checked by displaying the Paw/Flow plot type (Fig. 2). If the flow is outside the range of ±10 l/min at any point, verify that the Ramp Speed is set to 2 cmH2O/s. The flow rate must be less than 10 l/min to largely eliminate the pressure change from resistive elements of the respiratory system.[6]

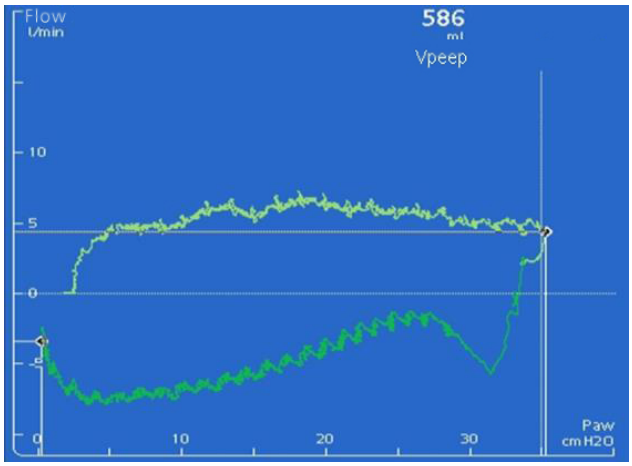


*Figure 2:* Paw/Flow plot

## Assessing recruitability of the lungs

### Shape of the inflation limb

In a non-recruitable lung, the inflation limb of the P/V curve shows upward convexity (Fig. 3); in a recruitable lung, the inflation limb of the P/V curve shows upward concavity (Fig. 4).[4, 7]

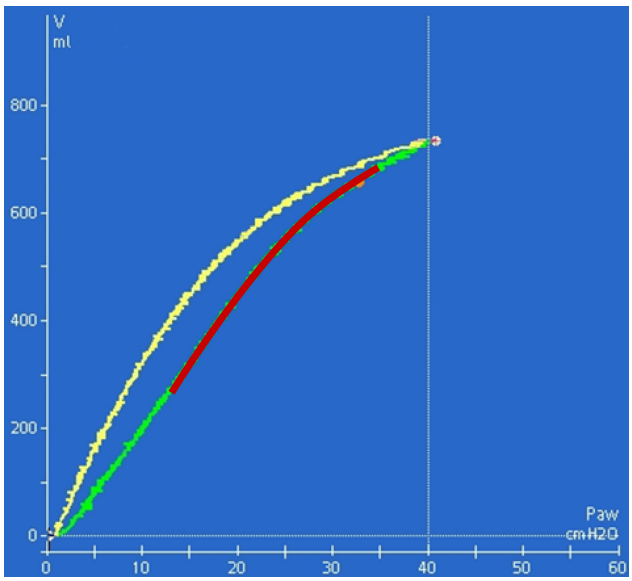


*Figure 3:* Inflation limb showing upward convexity, indicating low potential for lung recruitment

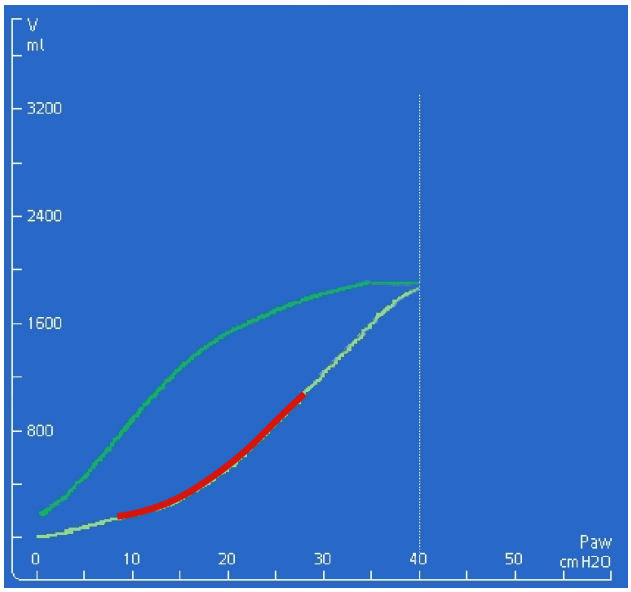


*Figure 4:* Inflation limb showing upward concavity, indicating high potential for lung recruitment

## Linear compliance ($C_{LIN}$)

Compliance refers to the steepness of the inflation pressure-volume curve; compliance is linear where the incline is constant within a range of applied pressures. Linear compliance provides an assessment of how many alveoli open during the pressure increase. High $C_{LIN}$ (> 50-60 ml/cmH2O) indicates a high percentage of potentially recruitable lung (Fig. 5).[3, 7] To measure $C_{LIN}$, Cursor 1 should be positioned above the lower inflection point and Cursor 2 below the upper inflection point, bordering the most linear part of the curve.


*Figure 5:* $C_{LIN}$ greater than 50 ml/cmH2O

## Hysteresis

An estimate of recruitability can be made based on the hysteresis of the pressure-volume curve (the area enclosed between inflation and deflation limb) or the volume difference at 20 cmH2O of pressure. In practice, the potential for lung recruitment can be considered high where the volume difference is greater than 400 ml (Fig. 6).[5]

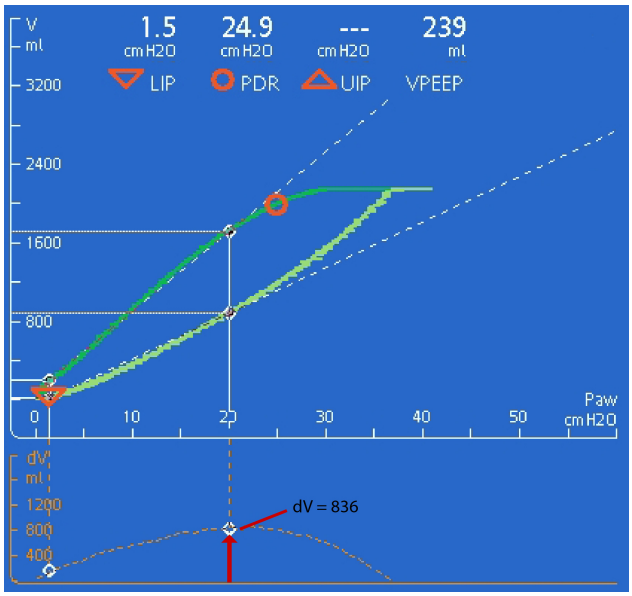


*Figure 6:* Large volume difference at 20 cmH2O of pressure, indicating high potential for lung recruitment

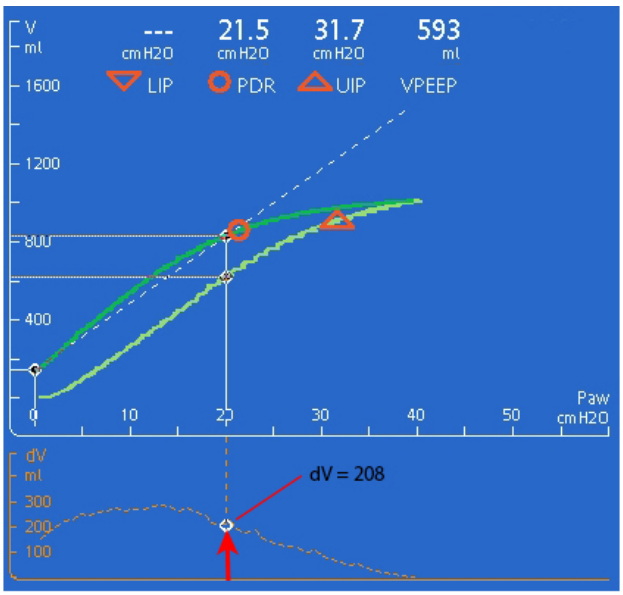


*Figure 7:* Small volume difference at 20 cmH2O, indicating low potential for lung recruitment

If two of the three criteria above are met, namely an inflation limb showing upward concavity, high $C_{LIN}$ above the low inflection point or a large hysteresis, then a recruitment maneuver can be attempted.


*Figure 8:* Decision regarding recruitment strategy

## Titrating recruitment maneuver

### Step 1

- Decrease FiO2 before the first RM to reach an SpO2 value of approx. 92%
- Pstart: Actual PEEP
- End PEEP: 20-25 cmH2O (if performing a decremental PEEP trial*)

  When the End PEEP setting is changed, a message will appear showing the current PEEP, new PEEP, and the question "Do you want to change the PEEP setting after the maneuver?". Select Yes.
- Ramp Speed: 5 cmH2O/s
- Tpause: 10 s
- Ptop: 40 cmH2O

### Step 2

Measure the volume recruited at Ptop (the end of the curve). If the volume recruited is greater than 2 ml/kg PBW or greater than 200 ml (Fig. 9), and SpO2 increases to 99% - 100% immediately after the first RM, consider the maneuver to have been effective and start PEEP titration.

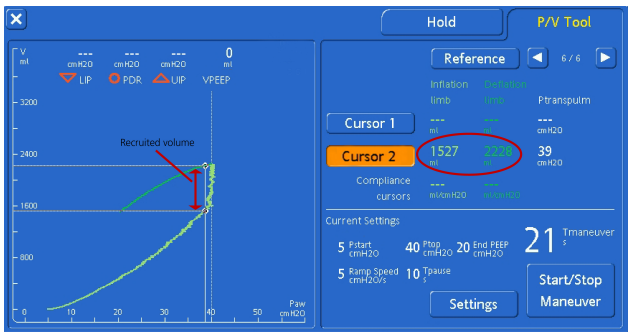


*Figure 9:* Recruited volume greater than 200 ml

### Step 3

If the recruited volume is less than 2 ml/kg PBW or 200 ml, the RM at 40 cmH2O was well-tolerated hemodynamically, and SpO2 only increases to 96% - 97%, try another RM at higher pressure by repeating step 1, and increase Ptop to 50 cmH2O.

### Step 4

Go back to step 2.

### Step 5

If the recruited volume is less than 2 ml/kg PBW or 200 ml, the RM at 50 cmH2O was well-tolerated hemodynamically, and SpO2 only increases to 96% - 97%, try another RM at higher pressure by repeating step 1, increase Ptop to 60 cmH2O (Fig. 10), and then start PEEP titration.

If a catheter is in place for measuring esophageal pressure, perform a recruitment maneuver targeting 25 cmH2O of transpulmonary pressure to reach the upper physiological limit of transpulmonary pressure, which can be determined by selecting the Ptranspulm/V plot type.

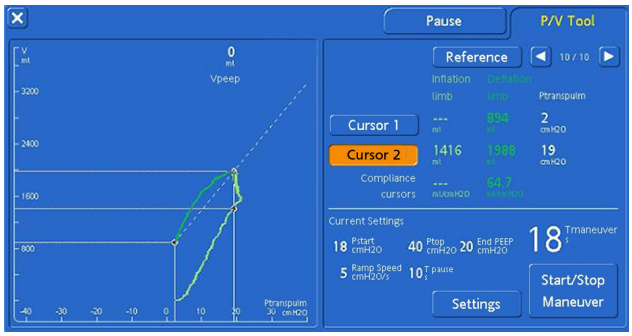


*Figure 10:* Ptop of 60 cmH2O, Ptranspulm of 21 cmH2O

*More recent evidence suggests that setting PEEP based on a decremental PEEP trial may be more physiologic than setting PEEP based on LIP, PDR or hysteresis.[8]

## Setting PEEP

Decrease FiO2 before the decremental PEEP trial to bring SpO2 to approx. 92%, then decrease PEEP by 2 cmH2O every 5 to 10 min. Monitor SpO2. As soon as oxygenation decreases with PEEP titration (SpO2 decreases by 2%), revert to the prior PEEP value. Repeat the last RM (use the same recruiting pressures used in the last step of the RM) and then set PEEP to the optimum PEEP value, as determined from the decremental PEEP trial.

## References


1. Borges, João et al. "Reversibility Of Lung Collapse And Hypoxemia In Early Acute Respiratory Distress Syndrome". Am J Respir Crit Care Med 174.3 (2006): 268-278.

2. Gattinoni, Luciano et al. "Lung Recruitment In Patients With The Acute Respiratory Distress Syndrome". New England Journal of Medicine 354.17 (2006): 1775-1786.

3. Maggiore, Salvatore et al. "Alveolar Derecruitment At Decremental Positive End-Expiratory Pressure Levels In Acute Lung Injury". Am J Respir Crit Care Med 164.5 (2001): 795-801. Web.

4. Grasso, Salvatore et al. "Effects Of High Versus Low Positive End-Expiratory Pressures In Acute Respiratory Distress Syndrome". Am J Respir Crit Care Med 171.9 (2005): 1002-1008.

5. Demory, Didier et al. "Recruitability Of The Lung Estimated By The Pressure Volume Curve Hysteresis In ARDS Patients". Intensive Care Med 34.11 (2008): 2019-2025.

6. Lu, Qin et al. "A Simple Automated Method For Measuring Pressure–Volume Curves During Mechanical Ventilation". Am J Respir Crit Care Med 159.1 (1999): 275-282. Web.

7. Gattinoni, Luciano et al. "Pressure-Volume Curve Of Total Respiratory System In Acute Respiratory Failure: Computed Tomographic Scan Study". Am Rev Respir Dis 136.3 (1987): 730-736. Web.

8. Kacmarek, Villar et al. "Open Lung Approach for the Acute Respiratory Distress Syndrome: A Pilot, Randomized Controlled Trial". Crit Care Med. 2016 Jan;44(1):32-42.




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