P/V Tool® Pro

User Guide

Assessing lung recruitability and performing recruitment maneuvers in adult patients

HAMILTON MEDICAL

This User Guide describes how to assess recruitability and perform recruitment maneuvers in adult patients.

While the information contained herein is believed to be accurate, it does not represent an official recommendation from Hamilton Medical, nor may it substitute an opinion, assessment, or instructions provided by a trained healthcare professional.

This User Guide does *not* replace the clinical judgment of a physician, nor the content of the ventilator *Operator's Manual*, which should always be available when using the ventilator.

P/V Tool Pro is available as an option on the HAMILTON-C3/C6/G5 ventilators; it is a standard feature on the HAMILTON-S1 ventilator.

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1. Overview

1.1 Recruitment strategy and P/V Tool Pro

In ARDS patients, a recruitment strategy combines recruitment maneuvers and positive end-expiratory pressure (PEEP) to prevent atelectrauma. *Recruitment maneuver* stands for a process of intentional transient increase of transpulmonary pressure (Ptranspulm) above values used during regular mechanical ventilation, where the main objective is to open unstable distal airways and/or airless alveoli. The maneuver is also often called an *alveolar recruitment maneuver*, as the opening of collapsed alveolar units is believed to represent the major effect of a recruitment maneuver.[1] PEEP may decrease ventilator-induced lung injury by keeping those lung regions open that may otherwise collapse.[2]

The percentage of potentially recruitable lung varies widely among ARDS patients. Zones of collapsed and consolidated alveoli in the most dependent lung frequently require airway-opening pressures of more than 35–40 cmH2O to recruit.[2]

Knowledge of the percentage of potentially recruitable lung is important for establishing the therapeutic efficacy of PEEP. Setting PEEP levels too low 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.[3]

P/V Tool Pro

P/V Tool Pro provides a bedside method for assessing lung recruitability and carrying out recruitment maneuvers.[4, 5, 6]

1. Overview

1.2 Quasi-static low-flow pressure/volume curve

Flow of less than or equal to 10 l/min has been shown to be quick, safe, and reliable for determining the lung mechanics by means of a pressure-volume (P/V) loop at the bedside.[7]

We suggest using the minimum ramp speed of 2 cmH2O/s to eliminate the pressure change from resistive elements of the respiratory system.

To access this graph in P/V Tool Pro

▶ Touch the P/V Tool graphics panel and select the Paw/Flow option.
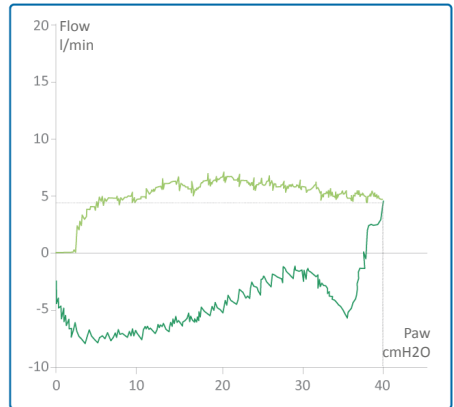
2. Conditions for use ⚠️

2.1 Important notes about recruitment and P/V Tool Pro

- Most patients require deep sedation, with some patients requiring an additional neuromuscular blockade to prevent spontaneous breathing efforts.

- Monitoring the patient's hemodynamics during maneuvers (diagnostic and recruitment) is *crucial.*
  In the event of any hemodynamic impairment, **STOP** the maneuver immediately.

- Ensure the ETT cuff is inflated to a pressure higher than the maximum pressure specified in the P/V Tool settings.*

- The patient must receive at least five (5) breaths between P/V Tool recruitment maneuvers.

- Before use, carefully review the indications and contraindications for performing a recruitment maneuver, described next on pages 7 and 8.

- P/V Tool Pro is disabled in several ventilation modes. Refer to your ventilator *Operator's Manual* for details.

* If using IntelliCuff, cuff pressure is monitored and maintained automatically.

2. Conditions for use ⚠️

2.2 Indications for performing a recruitment maneuver

Indications for use

- Early in the management of moderate to severe ARDS.

- As part of an open-lung approach.

- In the case of impairment with oxygenation after an intervention such as surgery, resuscitation, or similar.

Conditions for use

- The patient is intubated and passive, that is, *not* breathing spontaneously.

- The breathing circuit is gas tight. There must be *no* gas leak throughout the entire system of the ventilator, the breathing circuit, or at the ventilated patient.

- Nebulization is deactivated. P/V Tool Pro is disabled during nebulization and for five (5) breaths following nebulization.

- The flow sensor must perform optimally. The accuracy of the information provided depends on the quality of the flow sensor connection. P/V Tool Pro is disabled when the Flow sensor calibration needed alarm is active.

2. Conditions for use ⚠️

2.3 Contraindications for performing a recruitment maneuver

Use of the P/V Tool is contraindicated if *any* of the following conditions apply:

- Air leaks

- Pregnancy

- Lung emphysema

- Hemodynamic instability

- Confirmed or suspected intracranial hypertension

- Patients who cannot tolerate high intrapulmonary pressure (for example, right heart failure)

3. Recruitment protocols: BASIC and ADVANCED

BASIC PROTOCOL

The BASIC protocol comprises two steps that must be performed in the order shown.
Do *not* skip a step!

Step 1.   Assess lung recruitability

Step 2a.   First lung recruitment maneuver

ADVANCED PROTOCOL

In the event that the BASIC protocol does not result in effective recruitment, proceed to the
ADVANCED protocol.

Step 2b.   Second lung recruitment maneuver
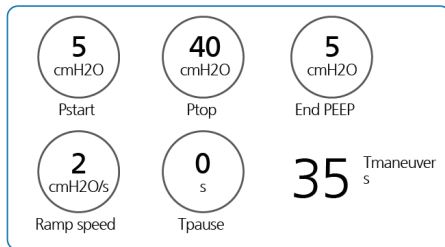
4. Step 1. Assess lung recruitability
4.1 Generate a low-flow P/V curve

In the P/V Tool Settings window, specify the following settings to generate a low-flow P/V curve:

Pstart: 5 cmH2O

Ptop: 40 cmH2O

End PEEP: 5 cmH2O

 NOTE. When prompted whether to change the PEEP setting after the maneuver, touch **No**.

Ramp speed: 2 cmH2O/s

Tpause: 0 s

To start the maneuver

▶ Touch **Start/Stop maneuver**.

4. Assess lung recruitability
4.2 Assess potential for recruitment

To assess the patient's potential for lung recruitment, calculate the normalized maximum distance (NMD) using the low-flow P/V waveform (see page 10, example on page 12).[8]

✔ **High potential for recruitment**

NMD% **≥ 41%**

$$NMD\% = \frac{\text{Max. delta volume (dV) between inflation and deflation}}{\text{Maximum volume}}$$

See page 12 for examples.

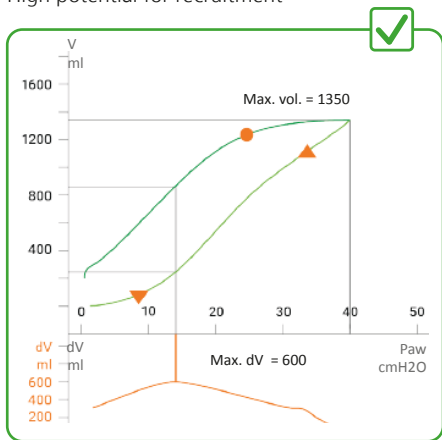✖ **Low potential for recruitment**

NMD% **< 41**%

Consider:

- Keeping PEEP < 10 cmH2O
- Prone positioning
- Persistent hypoxemia → Consider ECMO

4. Assess lung recruitability

4.3 About the normalized maximum distance (NMD)
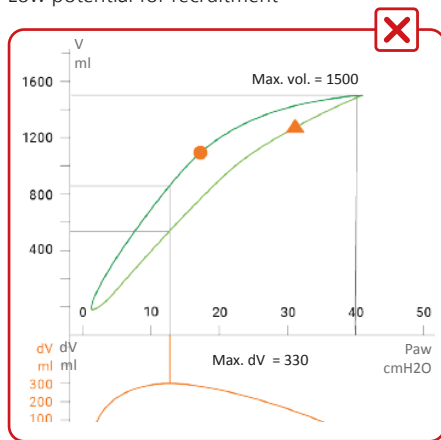
NMD% ≥ 41%

High potential for recruitment

Max. dV / Max. volume = 600/1350

NMD% = 44%

NMD% < 41%

Low potential for recruitment

Max. dV / Max. volume = 330/1500

NMD% = 22%

5. Step 2a. Performing a recruitment maneuver

5.1 Before you start

- Before performing a recruitment maneuver, consider decreasing the Oxygen setting to reach an SpO2 value of 92%.[16]

  When the SpO2 saturation is above 92%, it can be difficult to evaluate the improvement in oxygenation after the recruitment maneuver.

- If **NMD% ≥ 41%** (pages 11 and 12), a recruitment maneuver is warranted.[8]
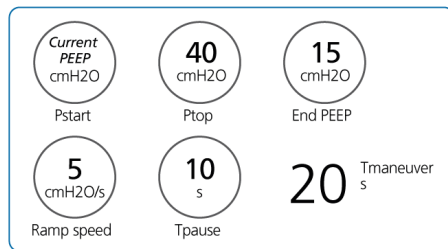
5. Performing a recruitment maneuver
5.2 Specify settings for a recruitment maneuver

In the P/V Tool Settings window, specify the following settings to perform an initial recruitment maneuver:

Pstart: Current PEEP

Ptop: 40 cmH2O [9]

End PEEP: 15 cmH2O
(or current PEEP *if* current PEEP *is above 15 cmH2O)* [10, 11]

NOTE. When prompted whether to change the PEEP setting after the maneuver, touch **Yes**.

Ramp speed: 5 cmH2O/s

Tpause: 10 s [13]

To start the maneuver

▶ Touch **Start/Stop maneuver**.

5. Performing a recruitment maneuver
5.3 Assess the effectiveness of the maneuver

The following criteria help you assess whether the recruitment maneuver was effective.

✔ Effective recruitment

When both of the following criteria are met, recruitment was effective:

- Volume increase at Ptop was greater than 2.0 ml/kg IBW [6] (page 16)
- SpO2 was above 97% within 5 minutes [17]

✘ Ineffective recruitment

If either of the above criteria was *not* met, proceed to the ADVANCED protocol (page 17).
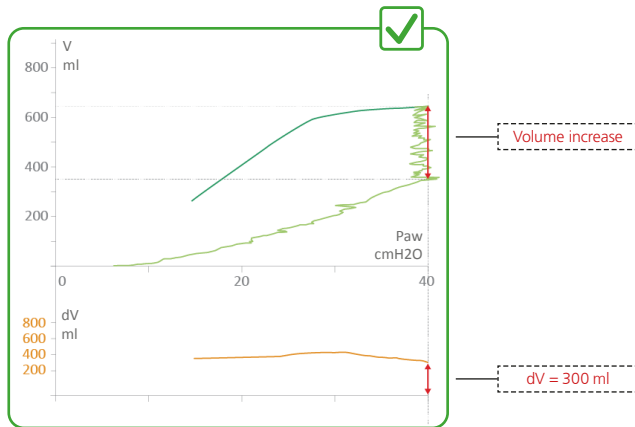
NOTE. Effective recruitment increases respiratory system compliance, and results in either an increase in tidal volume or a reduction in driving pressure.

5. Performing a recruitment maneuver
5.4   Was the volume increase at Ptop sufficient?

Increase at Ptop is greater than 2.0 ml/kg IBW*

Effective recruitment

Example

For effective recruitment with
IBW = 70 kg
dV must be > 140 ml

* To view the volume difference, touch the P/V Tool graphics panel and select the Paw/V + Paw/dV graph option.

6. Step 2b. Performing a second recruitment maneuver

6.1 Before you start

⚠️ **ONLY use the ADVANCED protocol if the first recruitment maneuver (using the BASIC protocol) was well tolerated hemodynamically.**

- Try to limit the patient's respiratory system driving pressure* to a maximum of 15 cmH2O after the recruitment maneuver.

- If the patient shows indications of increased chest wall elastance, for example, morbid obesity or intra-abdominal hypertension, consider esophageal pressure measurement to guide your recruitment strategy (page 22).

- Before performing the recruitment maneuver, consider decreasing the Oxygen setting to reach an SpO2 value of 92%.[16]

  When the SpO2 saturation is above 92%, it can be difficult to evaluate the improvement in oxygenation after the recruitment maneuver.

* Driving Pressure = Pplat – PEEPtotal
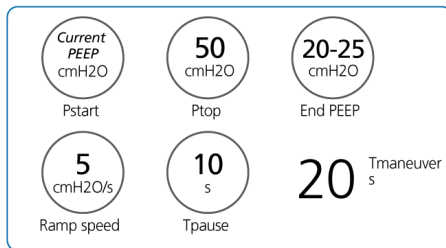
6. Performing a second recruitment maneuver
6.2 Specify settings for a recruitment maneuver

In the P/V Tool Settings window, specify the following settings to perform a second recruitment maneuver:

Pstart:	Current PEEP
Ptop:	50 cmH2O [9, 12]
End PEEP:	20 to 25 cmH2O [12]

NOTE. When prompted whether to change the PEEP setting after the maneuver, touch **Yes**.

Ramp speed:	5 cmH2O/s
Tpause:	10 s [13]

To start the maneuver

▶ Touch **Start/Stop maneuver**.

6. Performing a second recruitment maneuver
6.3 Assess the effectiveness of the maneuver

The following criteria help you assess whether the recruitment maneuver was effective.

✔ Effective recruitment

When both of the following criteria are met, recruitment was effective.

- Volume increase at Ptop was greater than 2.0 ml/kg IBW [6] (page 16)
- SpO2 was above 97% within 5 minutes [17]

If the second recruitment maneuver was effective, perform decremental PEEP titration (page 20) to determine optimal PEEP for use in a third and final recruitment maneuver (page 21).

✖ Ineffective recruitment

If either of the above criteria was *not* met, the recruitment maneuver was *not* effective. Consider using esophageal manometry in your recruitment strategy (page 22).

7. Performing decremental PEEP titration

When the second recruitment maneuver is effective ✔ (page 19), perform decremental PEEP titration to determine the optimal PEEP for a final recruitment effort.

Before you start, consider decreasing the Oxygen setting to reach an SpO2 value of 92%.[16]

When the SpO2 saturation is above 92%, it can be difficult to evaluate the improvement in oxygenation after the recruitment maneuver.

To perform decremental PEEP titration

1 Decrease PEEP by 2 cmH2O every 3 minutes.[14]

2 Monitor SpO2 to determine the optimal PEEP value:

As soon as oxygenation decreases with PEEP titration (SpO2 decreases by 2%), revert to the prior PEEP value, which is the *optimal* PEEP.
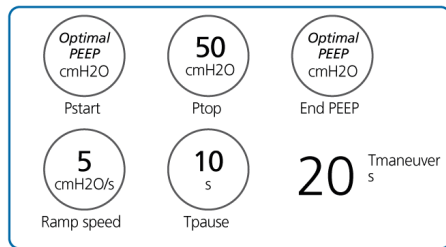
8. Performing a third recruitment maneuver
8.1 Specify settings for a recruitment maneuver

In the P/V Tool Settings window, specify the following settings to perform a third recruitment maneuver:

Pstart:	Optimal PEEP
Ptop:	50 cmH2O
End PEEP:	Optimal PEEP
Ramp speed:	5 cmH2O/s
Tpause:	10 s [13]



To start the maneuver

▶ Touch **Start/Stop maneuver**.

9. Esophageal pressure measurement

When the second recruitment maneuver is ineffective ✖ (page 19), consider using esophageal pressure measurement* as part of your recruitment strategy. The transpulmonary pressure achieved during the recruitment maneuver can be measured and titrated.

To measure the transpulmonary pressure achieved during a recruitment maneuver

1 Touch the P/V Tool graphics panel and select the Ptranspulm/V graph option.

2 Perform a recruitment maneuver, paying particular attention to the following settings:

   • To reach the upper physiological limit of transpulmonary pressure, perform a recruitment maneuver using a Ptop value that results in a transpulmonary pressure of 20 cmH2O.[15]

   • Set an EndPEEP value that results in a Ptranspulm value of 2–5 cmH2O at the end of expiration.
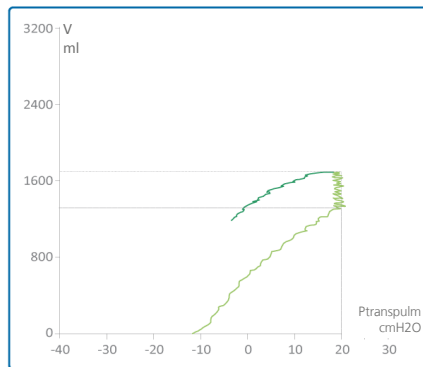
10. Reference

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