



Flow-i and Flow-e step-by-step guide

How to perform lung recruitment
gently and efficiently

Based on clinical protocols by Dr. Carlos Ferrando.

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Important notes

- Suggestions are related to adult patients with healthy lungs undergoing surgery. The settings should only be regarded as examples of a typical recruitment maneuver.
- The responsible physician shall always base pre-selected values on the clinical judgment of the individual patient's physiology.
- Obese patients, or patients undergoing laparoscopy, may require higher pressures to achieve an open lung condition. They may also need higher PEEP values to keep the lungs open.
- Recruitment maneuvers in pediatric patients should be carefully applied. Lower opening pressures are required and PEEP values need to be carefully selected.
- To improve achievement, adequate sedation and relaxation are needed.
- Hemodynamics before and during the maneuver should be continuously checked. A transitory drop in cardiac output/arterial pressure may appear.

Abbreviations

| | |
|-----|---------------------------------------|
| RM | Recruitment Maneuver |
| OLA | Open Lung Approach |
| EIP | End Inspiratory Pressure |
| PPC | Postoperative Pulmonary Complications |

Explanations

Driving pressure = $EIP - PEEP$
in VC $EIP = \text{Plateau pressure}$

A lung-protective approach includes reducing the driving pressure, which has shown to be positively associated with survival.¹

Keeping patients' lungs healthy

Atelectasis affects over 90%²⁻⁵ of patients during general anesthesia, regardless of gender, age, health condition or length of surgery, showing the importance of a lung protective strategy.

Atelectasis persists even after they have left the operating room.⁶

An open lung approach (OLA), recruiting the lungs and keeping them open, aims to restore the functional lung volume.⁷

A recent study demonstrates that the risk for PPCs among patients is high when performing recruitment maneuvers by bag squeezing techniques.⁸

Efficient ventilator-controlled recruitment maneuvers (RM) don't have to be complicated or time-consuming.

In this step-by-step guide Dr. Carlos Ferrando will demonstrate how he uses the automatic stepwise RM function in the Flow-i Anesthesia Machine.



90%

are affected by atelectasis

Open-lung ventilation

– a physiological approach

The open lung approach (OLA) to ventilation involves increasing the level of Positive End Expiratory Pressure (PEEP), in combination with protective lung ventilation, to minimize post-operative complications (PPC) related to anesthesia.

The model below describes how to perform RMs with an open-lung approach (iPROVE algorithm).

The first steps include assessing the need for RM as well as asserting that the patient is sufficiently hemodynamic stable.

The following steps describe how to find the opening pressure, closing pressure and how to evaluate the efficiency of the RM. For detailed information, see case 1 and 2 in this guide.

The iProve algorithm

| | | |
|--------------------------------------------------------------------------------------------------|----|--------------------------------------------------------------------|
| Alveolar collapse (Air test* or LUS†) Yes ↓ | No | → Keep PEEP level (no RM) |
| Hemodynamic stability Yes ↓ | No | → 1. Vasopressors 2. Fluids 3. Inotrops |
| Individualized RM Opening pressure (LUS†, SpO ₂) ↓ | | |
| Individualized PEEP (PEEP Trial) Closing pressure (Cdyn, LUS†, SpO ₂) ↓ | | |
| Re-evaluation open-lung condition (Cdyn, Air-Test*) | | |

* **Air test : 5 min of breathing with 0.21 F_IO₂ (Air)**
 - SpO₂ ≤96% Positive (shunt induced by lung collapse)
 - SpO₂ ≥97% Negative

† **LUS:** Lung Ultra Sonic Examination

Case 1

Auto RM

April 11 2018, University Clinico Hospital, Valencia, Spain
Carlos Ferrando MD, PhD, DESA

Patient data

| | |
|-------------------------------------------------------------------------------------|------------------------|
| Gender | Woman |
| Age | 56 |
| RBW | 84 kg |
| PBW | 45 kg |
| Height | 152 cm |
| BMI | 36 kg/m ² |
| Medical history | None |
| Surgery | Bariatric |
| SpO₂ (0.21 F_iO₂) pre-operatively | 98% |
| SpO₂ (0.21 F_iO₂) 15 min after induction | 93% —Air-test positive |
| SpO₂ (0.21 F_iO₂) post-operatively | 98% |

In this case VC is used after RM and for PEEP titration, but PC or PRVC are also possible to use.

1. Patient settings

- Enter the patient data. ①
- Start by using the recommended values for the calculated PBW (6 ml/kg). ②
- Do adjustments to reach desired baseline ventilation. ③



2. Baseline ventilation identified

- TV=290 ml, RR=16, PEEP=7. ①
- Driving pressure 18–6=12 cmH₂O. ②
- Prerecruitment C_{dyn}=24. ③



3. Set ventilation mode

- To enable Auto RM switch to PC. ①



4. Insp./Exp. hold

- Measure the baseline static compliance as a reference. In this case Cstat=27. **1**



5. Auto RM settings

- Open up the tab for the recruitment maneuver.
- Individualize the settings.
- In this case:
 - Stepwise increase in EIP up to 40 cmH₂O. **1**
 - Stepwise increase in PEEP up to 20 cmH₂O. **2**
 - EEP after RM=10 cmH₂O. **3**
 - Time at Target: 18 sec. **4**
- Duration: 1 min and 7 sec. **5**
- Accept. **6**



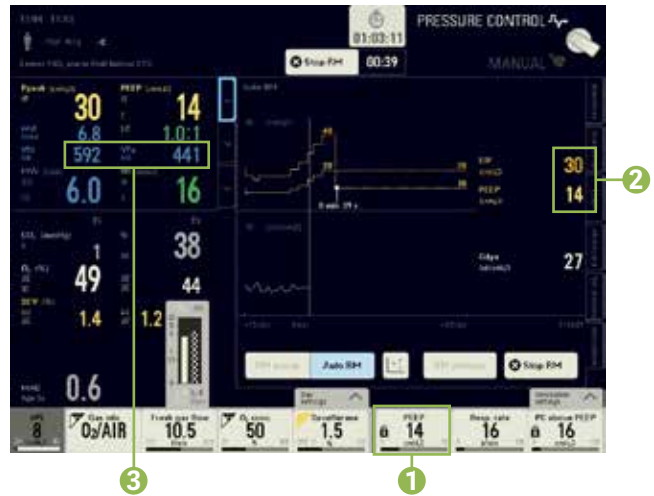
6. Start Auto RM

- Press Start RM. **1**



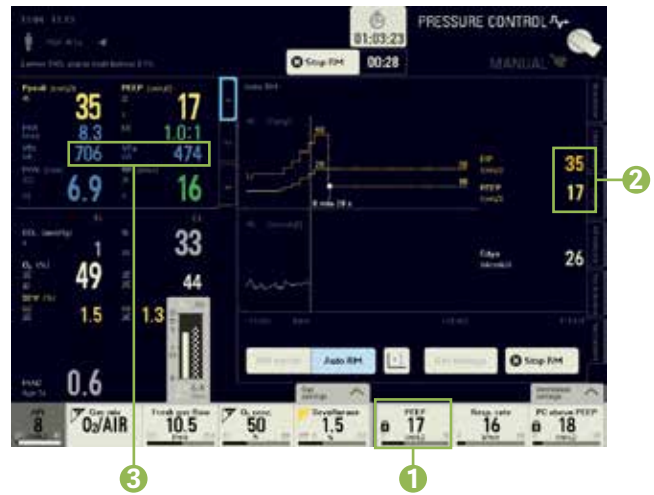
7. Ongoing recruitment maneuver

- PEEP 14 cmH₂O. ①
- Driving pressure 16 cmH₂O. ②
- Increase in TV. ③



8. Ongoing recruitment maneuver

- PEEP 17 cmH₂O. ①
- Driving pressure 18 cmH₂O. ②
- Increase in TV. ③



9. Recruitment maneuver completed

- It is important to change to predefined parameters after the RM to avoid insufficient ventilation. ①



10. Pressure Control: pre-adjusted anesthesia machine settings

- PEEP 10 cmH₂O. **1**
- Driving pressure 10 cmH₂O (Observe that the TV is much higher after RM). **2**



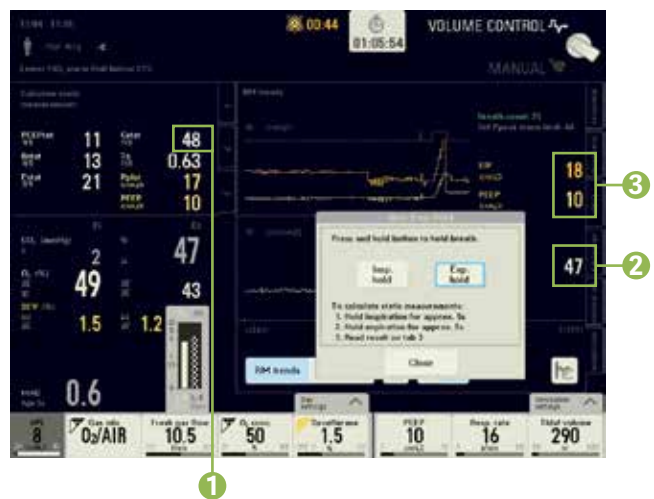
11. Change back to Volume Control

- Same settings as before the maneuver to establish protective ventilation.
 - TV=290 ml. **1**
 - RR=16. **2**
 - PEEP=10 (to keep the lung open after the recruitment maneuver). **3**



12. Final outcome!

- Static compliance=48 cmH₂O. **1**
- Cdyn=47 cmH₂O. **2**
- Driving pressure reduced from 12 to 8 cmH₂O (18-10). **3**



Case 2

Auto RM including PEEP titration

March 23 2018, University Clinic Hospital, Valencia, Spain
Carlos Ferrando MD, PhD, DESA

Patient data

| | |
|-------------------------------------------------------------------------------------|--------------------------------------------------|
| Gender | Woman |
| Age | 67 |
| RBW | 75 kg |
| PBW | 36 kg |
| Height | 145 cm |
| BMI | 38 kg/m ² |
| Medical history | Arterial hypertension, Diabetes, Dyslipidemia |
| Surgery | Hepatic metastasectomy |
| SpO₂ (0.21 F_iO₂) pre-operatively | 98% |
| SpO₂ (0.21 F_iO₂) 15 min after induction | 92% — Air-test positive |
| SpO₂ (0.21 F_iO₂) post-operatively | 98% |

In this case VC is used after RM and for PEEP titration, but PC or PRVC are also possible to use.

1. Patient settings

- Enter the patient data. ①
- Start by using the recommended values for the calculated PBW (6 ml/kg). ②
- Do adjustments to reach the desired baseline ventilation. ③



2. Baseline ventilation identified

- TV=250 ml, RR=18, PEEP=5. ①
- Driving pressure 12-5=7 cmH₂O. ②
- Prerecruitment Cdyn=36. ③



3. Insp./Exp. hold

- Measure a baseline static compliance as a reference. In this case Cstat=43. ①



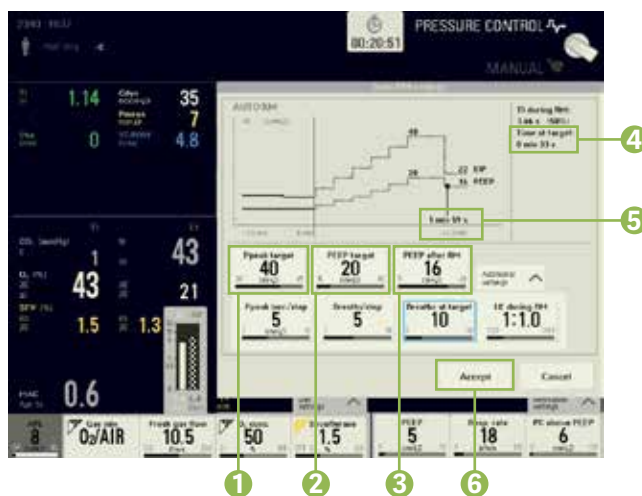
4. Set ventilation mode

- To enable Auto RM switch to PC. ①



5. Auto RM settings

- Stepwise increase in EIP up to 40 cmH₂O. ①
- Stepwise increase in PEEP up to 20 cmH₂O. ②
- Selected PEEP after RM=16 cmH₂O (to enable a PEEP titration). ③
- Time at Target: 33 sec ④
- Duration: 1 min and 59 sec. ⑤
- Accept. ⑥



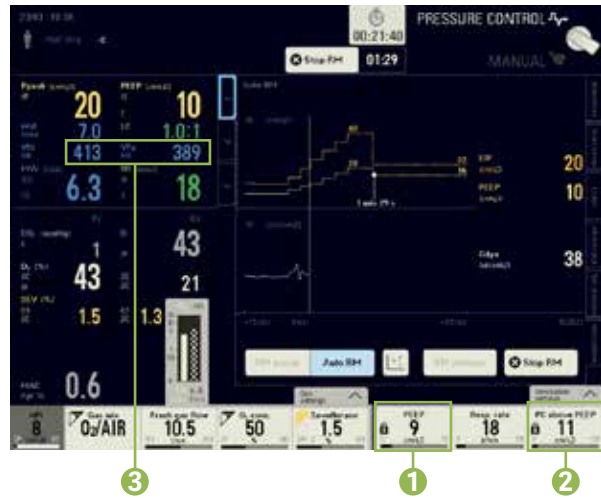
6. Start Auto RM

- Press Start RM. ①



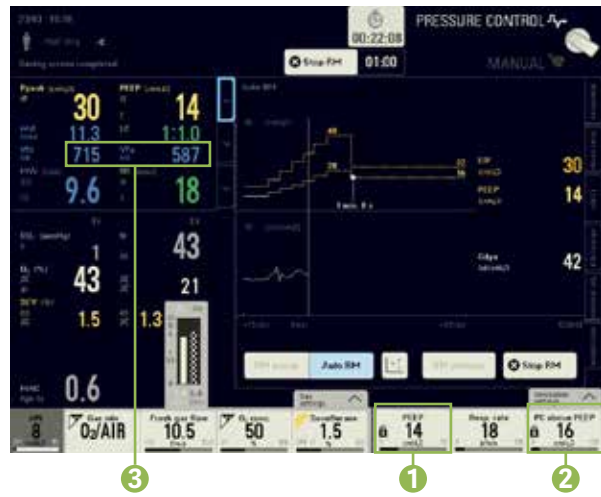
7. Ongoing recruitment maneuver

- PEEP 9 cmH₂O. ①
- Driving pressure 11 cmH₂O. ②
- Increase in TV. ③



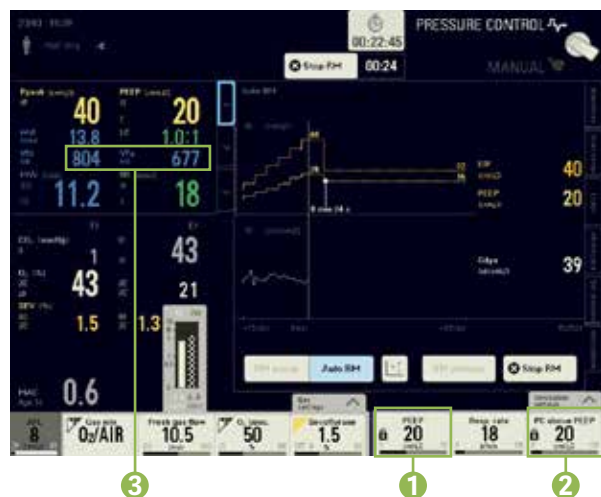
8. Ongoing recruitment maneuver

- PEEP 14 cmH₂O. ①
- Driving pressure 16 cmH₂O. ②
- Increase in TV. ③



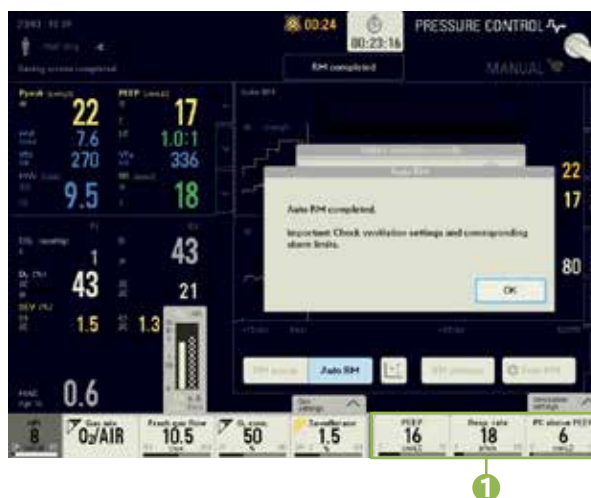
9. Ongoing recruitment maneuver

- PEEP 20 cmH₂O. ①
- Driving pressure 20 cmH₂O. ②
- Increase in TV. ③



10. Recruitment maneuver completed

- Automatic change to predefined parameters after the RM. ①



11. PEEP alarm

- The high PEEP alarm is re-activated after the recruitment as a reminder that the PEEP level is high. ①



12. PEEP titration

- PEEP titration trial in Volume Control. ①
 - Adjust the baseline ventilation settings.
- TV=250 ml, RR=18. ②
- Decrease the PEEP step of 2 cmH₂O for approx. 10 breaths each step and search for PEEP for best Cdyn. ③
- The breath count is displayed in green color. ④



13. PEEP titration

- When there is a clear drop in Cdyn, start searching for the PEEP value with highest Cdyn and lowest driving pressure. **1**
- In this case PEEP 12 cmH₂O. **2**



14. Perform a re-recruitment

- Press Auto RM. **1**
- Go back to PC to enable the recruitment maneuver. **2**



15. Re-recruitment settings

- Set the PEEP after RM to 12 cmH₂O=just above closing pressure. **1**
- Keep the other settings from the previous recruitment. **2**
- Accept and start the 2nd recruitment. **3**



16. Change back to Volume Control

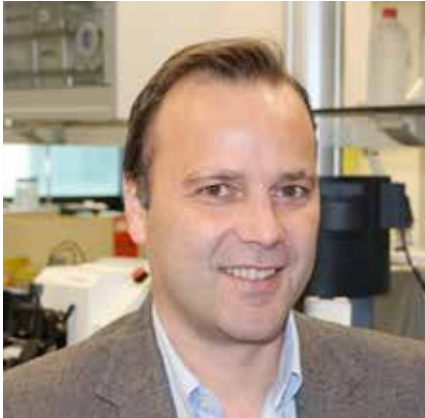
- After completed RM, select Volume Control. ①
- Same settings as before the maneuver to establish protective ventilation. ②
 - TV=250 ml.
 - RR=18.
 - PEEP=12 (to keep the lung open after the recruitment maneuver).



17. Final outcome!

- Driving pressure reduced from 7 cmH₂O (12–5) to 4 cmH₂O (16–12). ①
- Cdyn increased from 36 ml/cmH₂O to 78 ml/cmH₂O. ②





Biography: Dr. Carlos Ferrando

Anesthesiologist. MD, PhD, DESA.
Head of Surgical ICM, University Clinic
Hospital, Barcelona. CIBER Enfermedades
Respiratorias. ISCIII, Madrid.

- National and international speaker (46 congresses to date), all related to mechanical ventilation.
- Forty PubMed publications (18 of them as first author).
- Worked in 20 internationally-funded research projects as a research collaborator and principal investigator.
- Edited seven books on topics related to respiratory physiology and pathophysiology, mechanical ventilation, research in anesthesiology, and quality in health. Also, authored 47 book chapters.
- Currently leading a research group focusing on strategies to optimize and individualized intra-operative anesthesia machinery management, etc.

Learn more

Click to view the 2 minute video where Dr. Carlos Ferrando explains why lung recruitment is so important for all patients:

www.getinge.com/whylungrecruitment



The views, opinions and assertions stated by the physician are strictly those of the physician and their practice and do not necessarily reflect the views of Getinge.

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Further reading

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