Trilogy Evo dynamic lung parameters

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Introduction

Information related to the mechanical properties of the respiratory system (Resistance and Compliance) are important in prescribing mechanical ventilation. Instruments that measure these properties provide guidance in the form of quantitative assessments of the airways and the elasticity of lung tissue and chest wall. It is also useful to measure the pressures in the small airways of the lung at the beginning of a breath and at maximum inflation (AutoPEEP and plateau pressure) to assess the impact of mechanical ventilation on the patient. Dynamic parameter measurements can aid the clinician to:

1) diagnose the disease underlying respiratory failure;

2) monitor the status and progression of the disease;

3) measure the effects of treatments;

4) adjust ventilator settings to specific patient needs, minimising ventilator-induced complications, such as ventilator-induced lung injury (VILI)[1,2].

Non-invasive monitoring of these parameters and mechanical properties can now occur using the sensors within the ventilator along with algorithms that process sensor data during controlled and assisted breath delivery.

Trilogy Evo is able to estimate Lung Compliance, Airway Resistance, AutoPEEP and Plateau Pressure during normal mechanical ventilation therapy without a static manoeuvre. This provides continuous measurements of the mechanical properties of the respiratory system with the Trilogy Evo's Passive, Active Flow and Dual Limb circuits in both controlled and assisted mechanical ventilation modes:

Assist Control: A/C-PC and A/C-VC
Synchronised Intermittent Mandatory Ventilation: SIMV-PC and SIMV-VC

Note that in SIMV modes the dynamic parameters are not available for the patient-initiated and patient-cycled "pressure support" spontaneous breaths.

Description of parameters

Airway Resistance

Airway Resistance is the opposition to the motion of gas within the airways. It is defined as the ratio of driving pressure to the air flow[3]. Trilogy Evo estimates and shows this as **Dyn R** on the user interface. The term Dyn R refers to the fact that the Dyn R is measured without a static manoeuvre. Note that this calculation for airway resistance will include the contributions to resistance from a tracheal tube and any other added external resistance.

At the end of inhalation, the Trilogy Evo estimates the airway resistance by computing the ratio between the driving pressure from within the lung to the air flow. The flow term is corrected to take into account the contributions of

i) AutoPEEP, by subtracting the expiratory flow at the end of exhalation, and

ii) the elastic recoil of the lungs, by adding the tidal volume divided by the respiratory time constant, τ. (Respiratory time constant is the airway resistance times the combined compliance of the lung and chest wall)[4]. The equation used in Trilogy Evo for airway resistance is:

$$Dyn\ R = \frac{PIP - PEEP_e}{Q_p(t = EOI) - Q_p(t = EOE) + \frac{V_t}{\tau}}$$

Where,

PIP is the peak inspiratory pressure (pressure at the end of inhalation),

$PEEP_e$ is the extrinsic pressure (pressure applied by the ventilator) at the end of the breath,

V_t is the tidal volume,

Q_p (t=EOE) is the patient flow at the end of the exhalation (EOE) and,

Q_p (t=EOI) is the patient flow at the end of inhalation (EOI).

Note that the above equation can be rewritten as the equation of motion of the respiratory system[5], assuming that the muscle effort is 0 at the end of inhalation:

$$PIP - (PEEP_e + PEEP_i) = Dyn\ R * Q_p\ (t = EOI) + V_t\ /\ Dyn\ C$$

Where,

$PEEP_i$ is the AutoPEEP (see the AutoPEEP section) and,

$PEEP_e + PEEP_i$ is the total pressure in the lungs at the start of the inhalation.

Lung Compliance

Lung Compliance is the ratio between the tidal volume and the changes in pressure[5]. Trilogy Evo estimates and displays the integrated compliance of the pulmonary system, i.e. the combined compliance of the lung and chest wall, and this is displayed as **Dyn C** on the user interface. Again, the term Dyn C refers to the fact that the Dyn C is measured without a static manoeuvre.

The Dyn C is related to the Dyn R by the respiratory time constant, τ.

$$Dyn\ C = \frac{\tau}{Dyn\ R}$$

Note that the compliance of the respiratory system can be derived from the measurement of dynamic plateau pressure, $Dyn\ P_{plat}$, using the relationship between the tidal volume V_t, and the difference between the $Dyn\ P_{plat}$ and $PEEP$.

$$Dyn\ C = \frac{V_t}{Dyn\ P_{plat} - PEEP}$$

Where,

PEEP is the total pressure (intrinsic plus extrinsic) at the start of the breath ($PEEP = PEEP_e + PEEP_i$) and,

V_t is the tidal volume.

AutoPEEP

AutoPEEP or intrinsic *PEEP*, $PEEP_i$ is the resistive pressure at the end of exhalation, EOE, that occurs when a new breath is initiated before the previous breath is completed[2]. Trilogy Evo calculates it using the formula:

$$PEEP_i = - Dyn\ R * Q_p\ (t = EOE).$$

Trilogy Evo displays this parameter as AutoPEEP and it can be used as a guide to evaluate the presence of dynamic hyperinflation. This number represents the pressure in the small airways at the start of the breath in excess to the PEEP applied by the ventilator. In some complex cases when the resistance and compliance of the lung is changing during the breath, the displayed values may have some inaccuracies.

Plateau pressure

Plateau pressure is the maximum pressure applied to small airways and alveoli during positive-pressure mechanical ventilation[5] and Trilogy Evo estimates and displays it as **Dyn P_{plat}** on the user interface.

The small airway pressures at the end of inspiration are often referred to as 'plateau pressures' because in modern ICU ventilators this pressure is measured with an inspiratory hold manoeuvre. During the inspiratory hold manoeuvre, the pressure applied in all parts of the respiratory system 'plateaus' to an equilibrium pressure and can be measured non-invasively at the patient interface.[5]

Unfortunately, the hold manoeuvres interfere with the normal operation of the ventilator and respiratory rhythm of the patient. Also, hold manoeuvres are generally not done during NIV due to leaks. As a result, these are not suitable for continual monitoring of respiratory mechanics and patient status. This is a limitation, as in critically ill patients the mechanical properties of the respiratory systems can rapidly change.

Estimation of plateau pressures without an inspiratory hold has been made possible by approximating the airway as a single compartment mathematical linear model[6], or as a time and volume varying non-linear model[7] and applying mathematical formulas such as recursive least squares, RLS,[8,9,10] or RLS with forgetting factor[11]. Some of these algorithms require that the patient be fully passive during the measurement period. It is also possible to assess the plateau pressure when there is muscle activity with invasive measurements of esophageal pressure, P_{es}, with specialised equipment[10,12,13]. It has been shown that these techniques have been successfully used to track respiratory mechanical variations and track disease progression[14-16]. These methods are not suitable for non-invasive continuous monitoring of patient status in a homecare setting.

Trilogy Evo will accurately estimate plateau pressure without performing hold manoeuvres, without the use of invasive P_{es} measurements and during controlled or assisted ventilation when the patient is not completely passive.

Trilogy Evo calculates the Dyn P_{plat} using:

$$Dyn\ P_{plat} = \frac{V_t}{Dyn\ C} + PEEP_e + PEEP_i$$

A/C-PC Passive
Nighttime

Pressure Control 12 cmH2O
PEEP 6 cmH2O
Breath Rate 14 BPM
Insp. Time 1.0 s

MAP 8.7 cmH2O
PIF 38.0 L/min
I:E Ratio 1:3.3
%Spont Trig 0 %
Dyn C 64 mL/cmH2O
Dyn R 10 cmH2O/L/s
Dyn Pplat 14 cmH2O
AutoPEEP 0 cmH2O
Leak 28.1 L/min

PIP 18.0 cmH2O
Vte 517 mL
RR 14 BPM
MinVent 7.4 L/min

12:45pm

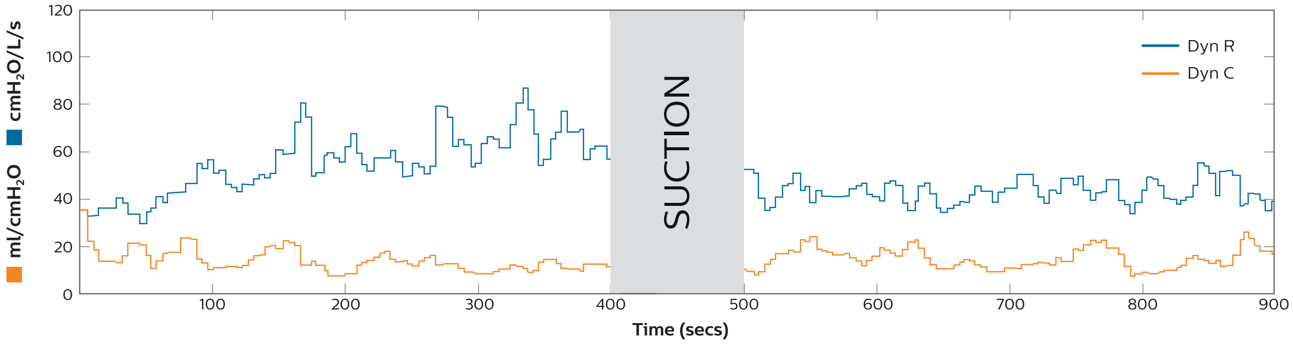
Applications for use

Trilogy Evo can monitor lung parameters, without a hold manoeuvre, while promoting the patient's respiratory muscle activation, which has shown to be beneficial to weaning and the liberation of patients from the ventilator[17–19].

Having access to dynamic lung parameters in the home care setting is new and best practices will still need to be determined. There are however, a number of ways that these parameters could be utilised including:

- Long term trending of lung parameters to see if any pathophysiology changes are occurring (i.e.. decrease in compliance as fibrosis worsens or increase in resistance corresponding to inflammation in the airways).
- Assistance in determining the appropriateness of initial ventilator settings during therapy titration.
- Assistance in evaluating changes in ventilator prescription settings as they impact respiratory mechanics and patient ventilator synchrony.
- Additional information to help determine any short-term response to pharmacological treatments (Dyn R and Dyn C).
- Indication of an accumulation of secretions in the airway requiring intervention (increase in Dyn R) (See Figure 1).
- Indication of dynamic hyperinflation due to ventilator patient asynchrony such as limited expiratory time, expiratory air flow limitation or hyperventilation (AutoPEEP).
- Assistance to use protective lung strategies and minimise lung injury (Dyn P_{plat}).
- Assistance to ensure open lung ventilation preventing atelectasis and hyperextension during mechanical ventilation (Dyn C), e.g. by indicating the need of a lung recruitment manoeuvre.

Example of secretion accumulation (Fig 1)



Pediatric patient with tracheostomy tube on Trilogy Evo had an increase in resistance noted over a 300 second period that was resolved after suctioning.

Results

The Trilogy Evo meets the specified requirements for all test cases included in Appendix A.

The lung parameters, test cases settings and the Trilogy Evo settings are contained in Appendix B.

The accuracy requirements are shown here.

	Accuracy
Dyn R	+/- (3 + 20% measured value)
Dynamic C	+/- (3 + 20% measured value)
Dyn P_{plat}	+/- (2 + 4% measured value)
AutoPEEP	+/- (2 + 8% measured value)

Conclusion

In this paper we describe how Trilogy Evo accurately estimates the lung mechanics, plateau pressure and AutoPEEP, without performing hold manoeuvres, and non-invasively, without using esophageal catheteters. Among the discussed advantages, this represents a breakthrough because it provides clinicians with measurements of critical respiratory parameters and metrics associated with ventilation. The Trilogy Evo provides these measurements:

1. continuously without interrupting normal therapy;
2. for patients in assist-control or SIMV modes with both mandatory and assisted breaths and;
3. with the passive circuit, in the presence of leaks or with open valve circuits such as the active flow and dual limb.

These three listed above have been unachievable with the traditional static manoeuvre.

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Appendix A

Validation of method

The methods developed within the Trilogy Evo Ventilator have been validated through extensive bench testing.

Dynamic Resistance testing

The actual resistance values were determined using two different types of resistances. For assist control breathing tests, the resistance was programmed into the software of the Ingmar Medical ASL5000 Breathing Simulator, which allow for simulation of active breaths. In the passive lung tests with the Michigan Instruments TTL test lung, the resistances were controlled using the Hans-Rudolph 7100 series of calibrated resistors. In order to be consistent with the units reported by Trilogy Evo, the control resistances were converted to BTPS conditions using the following conversion,

$$R_{BTPS} = R_{ATP} * \frac{P_{atm} + (PEEP + P\,control) * 98.0655 \frac{Pa}{cmH_2O} - P_{ws}}{101325\ Pa} * \frac{273.15\ K + T_{amb}}{310.15\ K}$$

Where:

R_{ATP} is the actual resistance programmed into the ASL or reported on the label of the 7100 HR resistor.

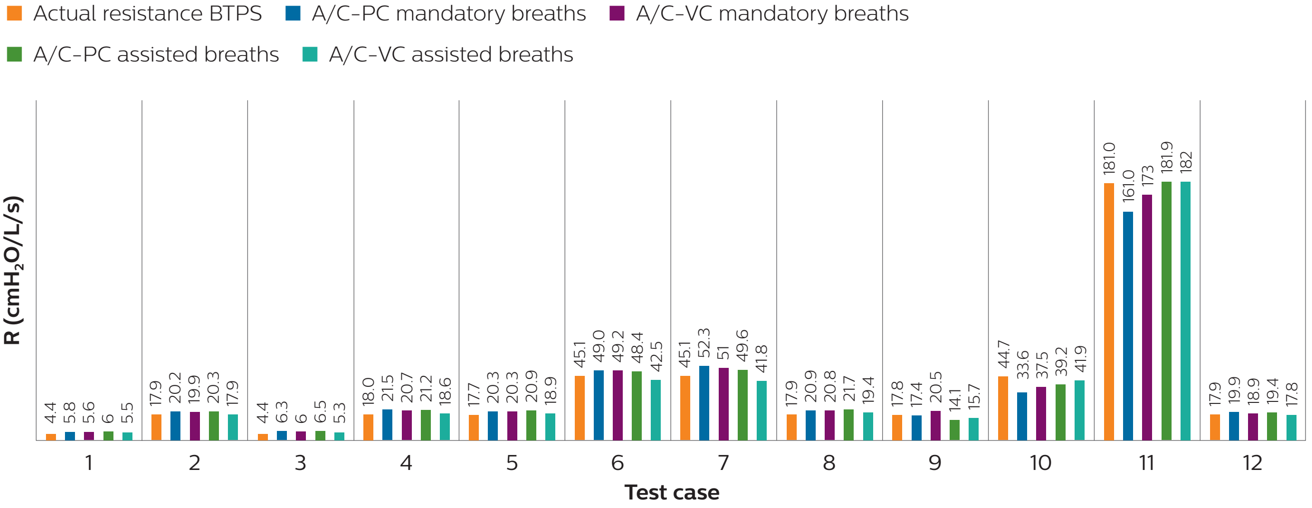
P_{atm} was the atmospheric pressure in Pa during the test.

PEEP + P control is the peak pressure applied by the ventilator during the test in cmH_2O.

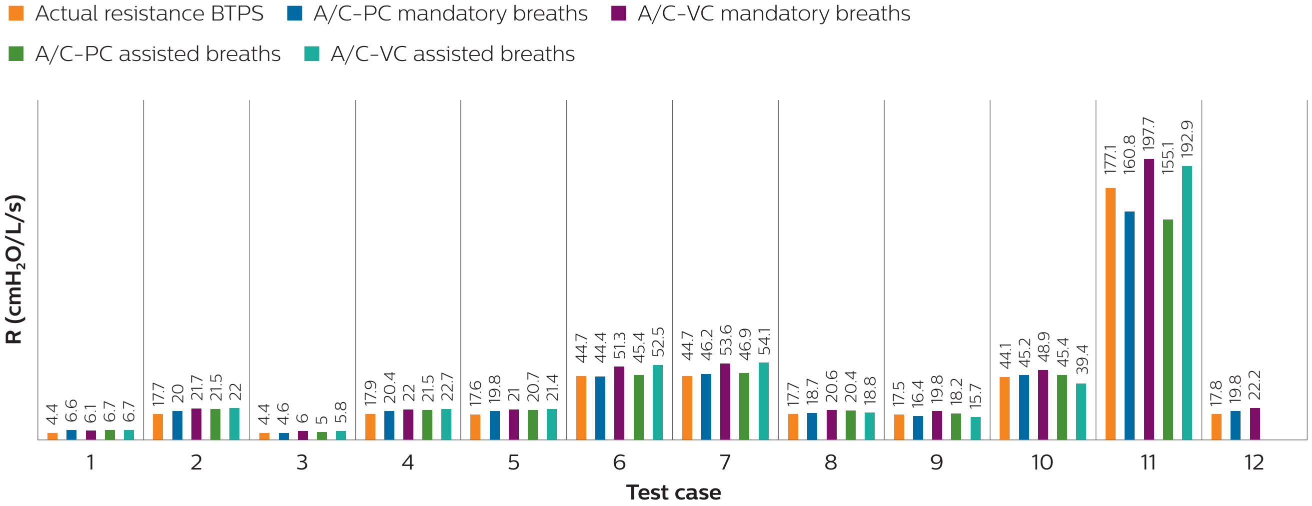
P_{ws} is the pressure of water vapor in saturated air at 37°C (6633.128 Pa).

T_{amb} was the ambient temperature during the test.

Dyn R – passive circuit (Fig 2)



Dyn R – dual limb circuit (Fig 3)



Dynamic Compliance testing

The actual compliance values were determined using three types of test fixtures. For assist control breathing tests, the ASL5000 Breathing Simulator was programmed with compliance. In tests with passive lungs the adult cases used the a spring to set compliance on the Michigan Instruments TTL test lung. And, for pediatric cases compliance was set using a calibrated isothermal test lung.

In order to be consistent with the units reported by Trilogy Evo, the control compliance was converted to BTPS conditions using the following conversion,

$$C_{BTPS} = C_{ATP} * \frac{101325\ Pa}{P_{atm} + (PEEP + P\ control) * 98.0655 \frac{Pa}{cmH_2O} - P_{ws}} * \frac{310.15\ K}{273.15\ K + T_{amb}}$$

Where:

C_{ATP} is the actual compliance programmed into the ASL, set on the TTL or labeled on the isothermal test chamber,

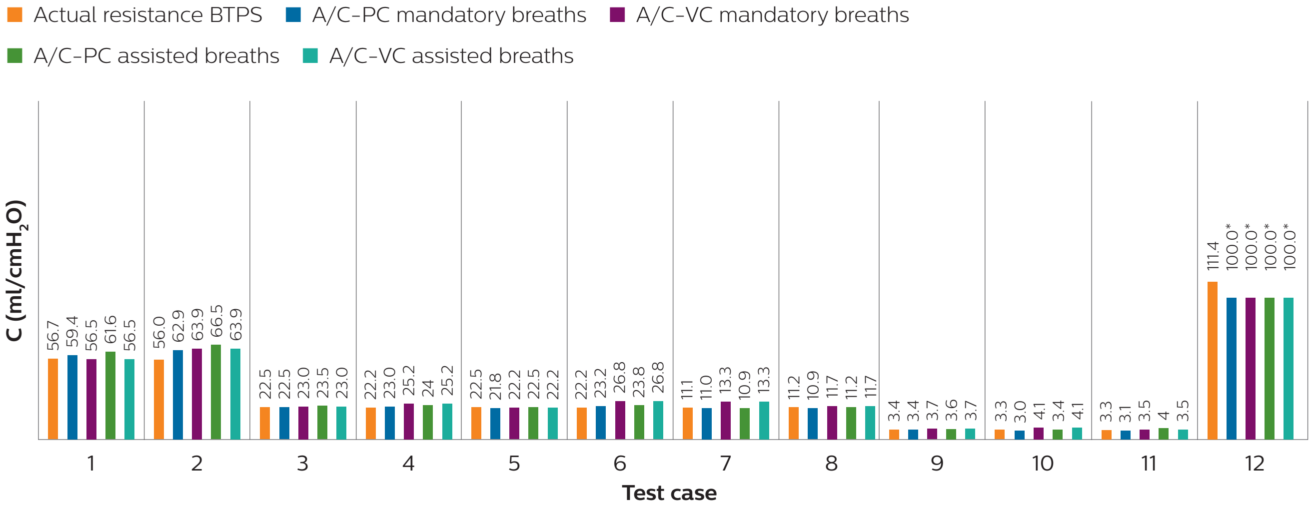
P_{atm} was the atmospheric pressure in Pa during the test, at ambient temperature and pressure.

PEEP + P control is the peak pressure applied by the ventilator during the test in cmH_2O.

P_{ws} is the pressure of water vapor in saturated air at 37°C (6633.128 Pa).

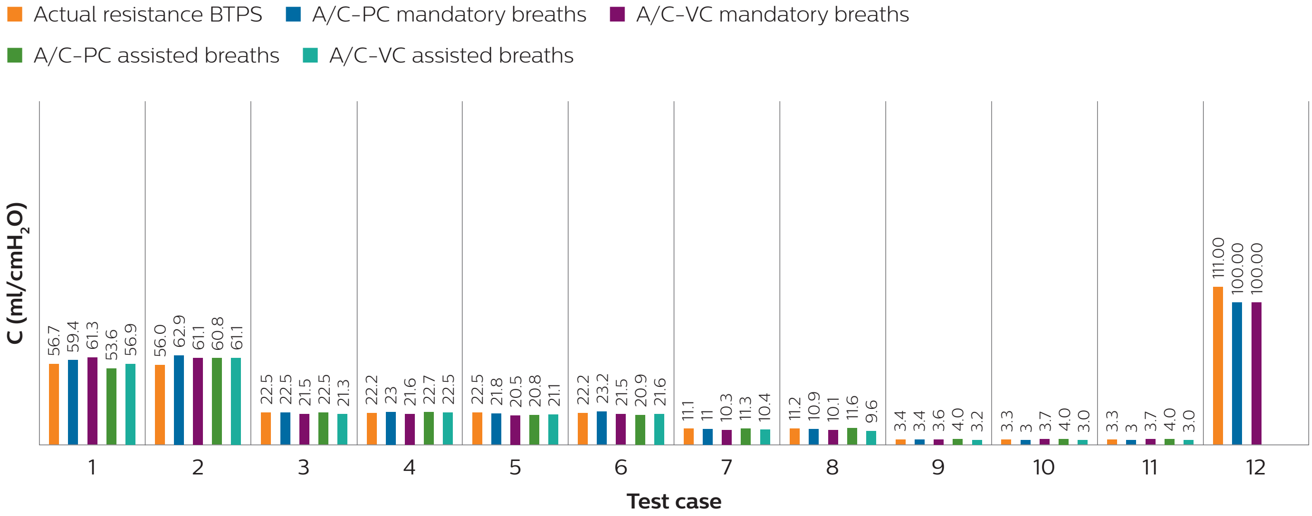
T_{amb} was the ambient temperature during the test.

Dyn C - passive circuit (Fig 4)



* Trilogy Evo caps the compliance at 100 ml/cmH_2O

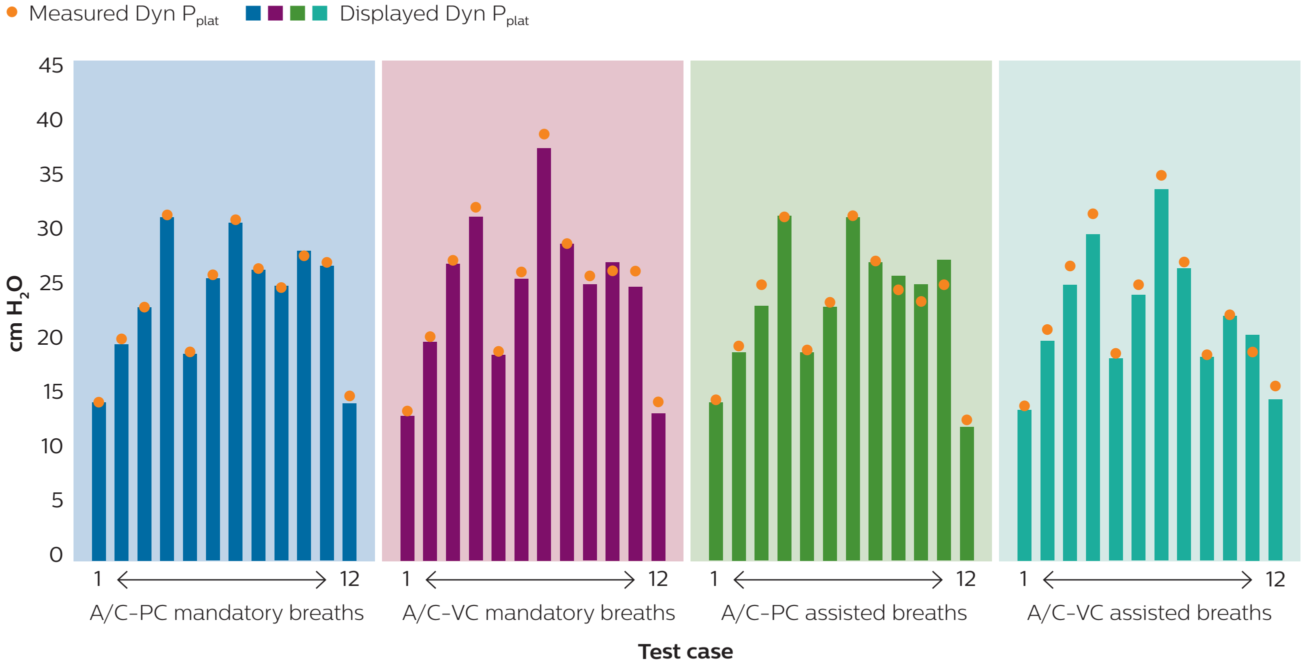
Dyn C - dual limb circuit (Fig 5)



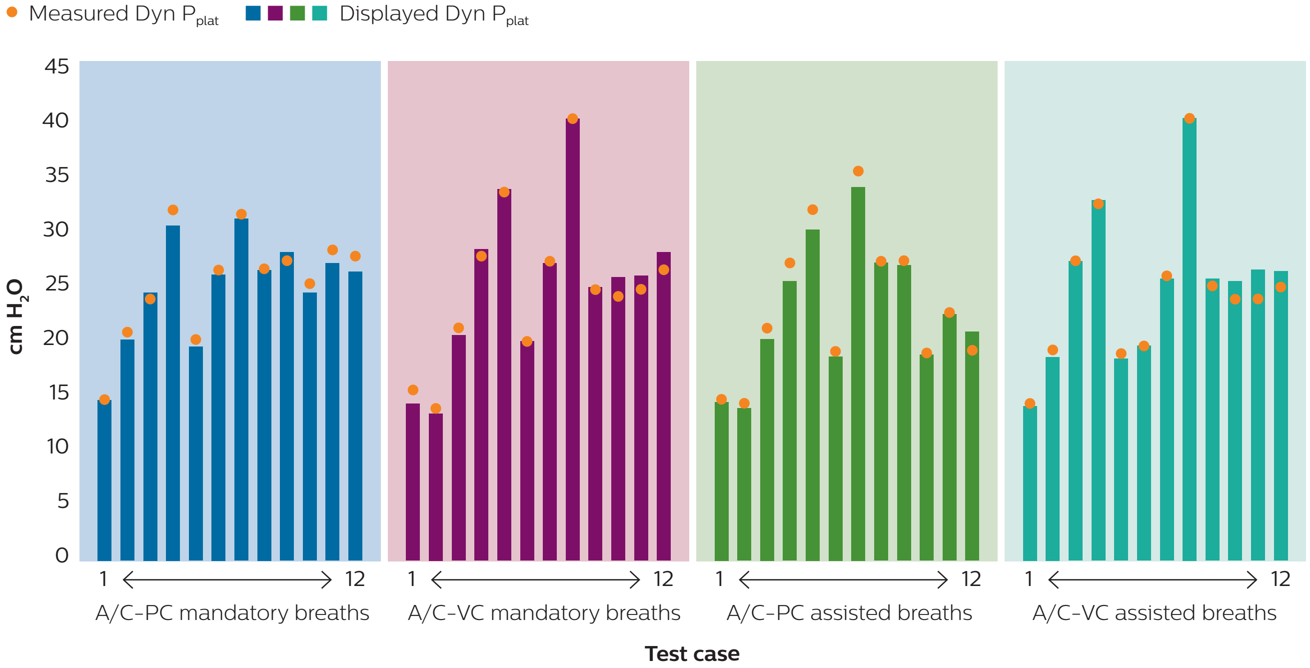
Dynamic Plateau Pressure testing

The Michigan instruments TTL test lung was used for all testing of dynamic plateau pressures. The Michigan lung provides a pressure pickoff inside the lung bellows (i.e., simulating the alveolar pressure). The plateau pressure was recorded as the maximum measured pressure during the breaths.

Dyn P_{plat} – passive circuit (Fig 6)



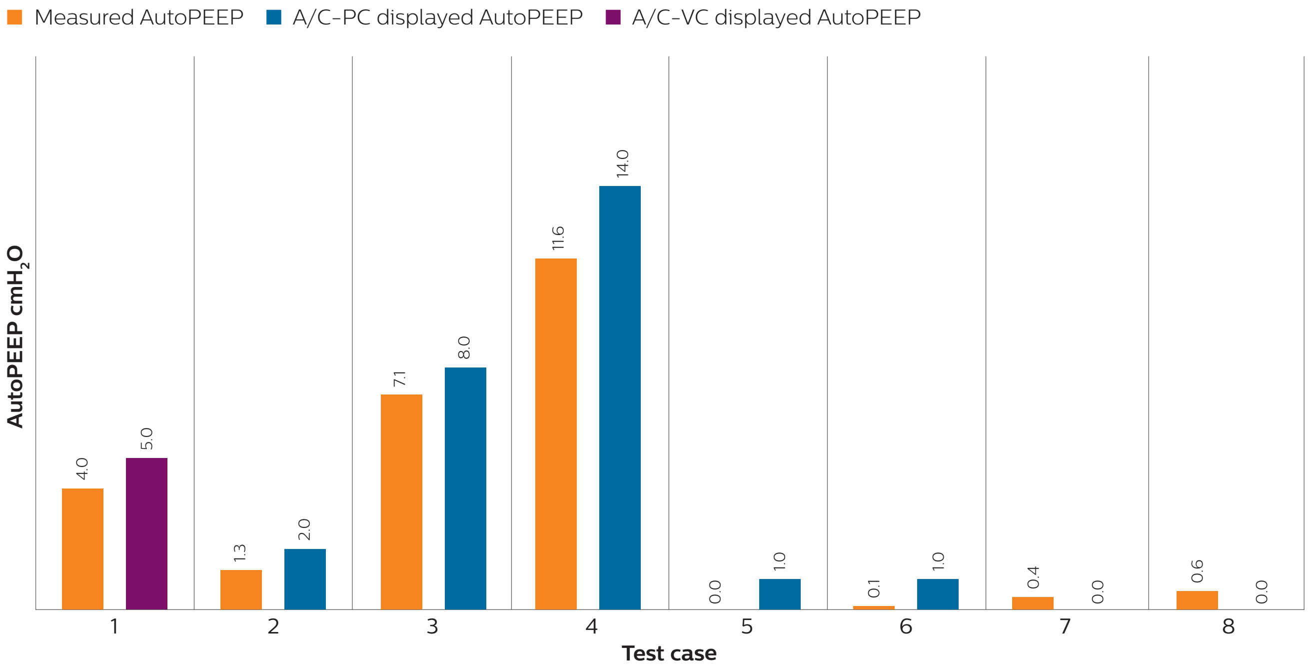
Dyn P_{plat} – dual limb circuit (Fig 7)



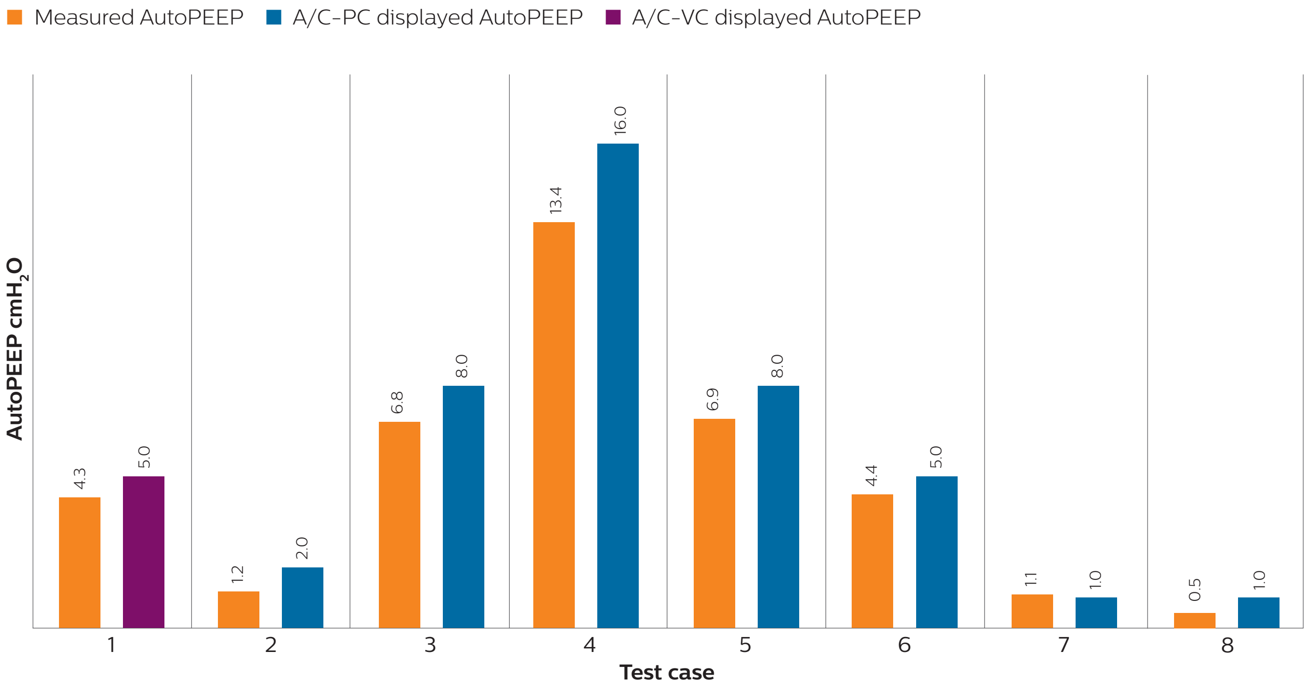
AutoPEEP testing

The Michigan Instruments TTL test lung provides a pressure pickoff inside the lung bellows (i.e., simulating the alveolar pressure). AutoPEEP is generated by providing mandatory machine breaths prior to the lung completely exhaling. The pressure measured inside the chamber just prior to the machine's start of inspiration will be recorded as the AutoPEEP.

AutoPEEP - passive circuit (Fig 8)



AutoPEEP - dual limb circuit (Fig 9)



Appendix B

Dyn R, Dyn C and Dyn P$_{plat}$

Passive circuit pressure control – mandatory breaths (applies to Fig 2 – 7)

ASL5000 settings						Trilogy Evo settings						
Test case	**Residual capacity (l)**	**Resistance (cmH$_2$O/L/s)**	**Compliance (ml/cmH$_2$O)**	**Breath rate (bpm)**	**P$_{mus}$ profile**	**Intended delivered volume (ml)**	**PIP – PEEP (cmH$_2$O)**	**PEEP (cmH$_2$O)**	**Breath rate (bpm)**	**T$_{insp}$ (sec)**	**Rise time**	**Trigger sensitivity**
1	0.5	5	50	0	0 cmH$_2$O	500	10	5	20	1.0	1	off
2	0.5	20	50	0	0 cmH$_2$O	500	17	10	20	1.0	1	off
3	0.5	5	20	0	0 cmH$_2$O	400	18	5	20	1.0	1	off
4	0.5	20	20	0	0 cmH$_2$O	500	25	10	20	1.0	1	off
5	0.5	20	20	0	0 cmH$_2$O	300	16	5	20	1.0	1	off
6	0.5	50	20	0	0 cmH$_2$O	300	26	10	20	1.0	1	off
7	0.5	50	10	0	0 cmH$_2$O	300	32	5	20	1.0	1	off
8	0.5	20	10	0	0 cmH$_2$O	200	17	10	20	1.0	1	off
9	0.5	20	3	0	0 cmH$_2$O	50	15	5	30	0.6	1	off
10	0.5	50	3	0	0 cmH$_2$O	50	19	10	30	0.6	1	off
11	0.5	200	3	0	0 cmH$_2$O	50	30	5	30	0.6	1	off
12	0.5	20	100	0	0 cmH$_2$O	1000	27	5	12	1.0	1	off

* Sensitive Auto-Trak

Dyn R, Dyn C and Dyn P$_{plat}$

Passive circuit volume control – mandatory breaths (applies to Fig 2 – 7)

ASL5000 settings						Trilogy Evo settings						
Test case	**Residual capacity (l)**	**Resistance (cmH$_2$O/L/s)**	**Compliance (ml/cmH$_2$O)**	**Breath rate (bpm)**	**P$_{mus}$ profile**	**Intended delivered volume (ml)**	**PIP – PEEP (cmH$_2$O)**	**PEEP (cmH$_2$O)**	**Breath rate (bpm)**	**T$_{insp}$ (sec)**	**Rise time**	**Trigger sensitivity**
1	0.5	5	50	20	0 cmH2O	500	10	5	0	1.0	1	Auto-Trak
2	0.5	20	50	20	0 cmH2O	500	17	10	0	1.0	1	Auto-Trak
3	0.5	5	20	20	0 cmH2O	500	18	5	0	1.0	1	Auto-Trak
4	0.5	20	20	20	0 cmH2O	500	25	10	0	1.0	1	Auto-Trak
5	0.5	20	20	20	0 cmH2O	300	16	5	0	1.0	1	Auto-Trak
6	0.5	50	20	20	0 cmH2O	300	31	10	0	1.0	1	Sens AT*
7	0.5	50	10	20	0 cmH2O	300	32	10	0	1.0	1	Sens AT*
8	0.5	20	10	20	0 cmH2O	200	17	10	0	1.0	1	Auto-Trak
9	0.5	20	3	30	0 cmH2O	50	17	5	0	0.6	1	Auto-Trak
10	0.5	50	3	30	0 cmH2O	50	28	10	0	0.6	1	Sens AT*
11	0.5	200	3	30	0 cmH2O	50	37	5	0	0.6	1	0.5 lpm
12	0.5	20	100	12	0 cmH2O	1000	30	5	0	1.0	1	8 lpm

* Sensitive Auto-Trak

Dyn R, Dyn C and Dyn P_{plat}

Passive circuit pressure control – assisted breaths (applies to Fig 2 – 7)

ASL5000 settings						Trilogy Evo settings						
Test case	**Residual capacity (l)**	**Resistance ($cmH_2O/L/s$)**	**Compliance (ml/cmH_2O)**	**Breath rate (bpm)**	**P_{mus} profile**	**Intended delivered volume (ml)**	**PIP - PEEP (cmH_2O)**	**PEEP (cmH_2O)**	**Breath rate (bpm)**	**T_{insp} (sec)**	**Rise time**	**Trigger sensitivity**
1	0.5	5	50	20	5 cmH_2O (12%, 0.5%, 3%)	500	10	5	0	1.0	1	Auto-Trak
2	0.5	20	50	20	5 cmH_2O (12%, 0.5%, 3%)	500	17	10	0	1.0	1	Auto-Trak
3	0.5	5	20	20	5 cmH_2O (12%, 0.5%, 3%)	500	18	5	0	1.0	1	Auto-Trak
4	0.5	20	20	20	5 cmH_2O (12%, 0.5%, 3%)	500	25	10	0	1.0	1	Auto-Trak
5	0.5	20	20	20	5 cmH_2O (12%, 0.5%, 3%)	300	16	5	0	1.0	1	Auto-Trak
6	0.5	50	20	20	5 cmH_2O (12%, 0.5%, 3%)	300	23	10	0	1.0	1	Sens AT*
7	0.5	50	10	20	5 cmH_2O (12%, 0.5%, 3%)	300	32	10	0	1.0	1	Sens AT*
8	0.5	20	10	20	5 cmH_2O (12%, 0.5%, 3%)	200	17	10	0	1.0	1	Auto-Trak
9	0.5	20	3	30	5 cmH_2O (12%, 0.5%, 3%)	50	16	5	0	0.6	1	Auto-Trak
10	0.5	50	3	30	5 cmH_2O (12%, 0.5%, 3%)	50	16	10	0	0.6	1	Sens AT*
11	0.5	200	3	30	5 cmH_2O (12%, 0.5%, 3%)	50	27	5	0	0.6	1	0.5 lpm
12	0.5	20	100	12	5 cmH_2O (12%, 0.5%, 3%)	1000	29	5	0	1.0	1	8 lpm

* Sensitive Auto-Trak

Dyn R, Dyn C and Dyn P_{plat}

Passive circuit volume control – assisted breaths (applies to Fig 2 – 7)

ASL5000 settings						Trilogy Evo settings						
Test case	**Residual capacity (l)**	**Resistance ($cmH_2O/L/s$)**	**Compliance (ml/cmH_2O)**	**Breath rate (bpm)**	**P_{mus} profile**	**Intended delivered volume (ml)**	**PIP - PEEP (cmH_2O)**	**PEEP (cmH_2O)**	**Breath rate (bpm)**	**T_{insp} (sec)**	**Rise time**	**Trigger sensitivity**
1	0.5	5	50	20	5 cmH_2O (12%, 0.5%, 3%)	500	10	5	0	1.0	1	Auto-Trak
2	0.5	20	50	20	5 cmH_2O (12%, 0.5%, 3%)	500	18	10	0	1.0	1	Auto-Trak
3	0.5	5	20	20	5 cmH_2O (12%, 0.5%, 3%)	500	23	5	0	1.0	1	Auto-Trak
4	0.5	20	20	20	5 cmH_2O (12%, 0.5%, 3%)	500	27	10	0	1.0	1	Auto-Trak
5	0.5	20	20	20	5 cmH_2O (12%, 0.5%, 3%)	300	17	5	0	1.0	1	Auto-Trak
6	0.5	50	20	20	5 cmH_2O (12%, 0.5%, 3%)	300	27	10	0	1.0	1	Sens AT*
7	0.5	50	10	20	5 cmH_2O (12%, 0.5%, 3%)	300	35	10	0	1.0	1	Sens AT*
8	0.5	20	10	20	5 cmH_2O (12%, 0.5%, 3%)	200	19	10	0	1.0	1	Auto-Trak
9	0.5	20	3	30	5 cmH_2O (12%, 0.5%, 3%)	50	14	5	0	0.6	1	Auto-Trak
10	0.5	50	3	30	5 cmH_2O (12%, 0.5%, 3%)	50	14	10	0	0.6	1	Sens AT*
11	0.5	200	3	30	5 cmH_2O (12%, 0.5%, 3%)	50	28	5	0	0.6	1	0.5 lpm
12	0.5	20	100	12	5 cmH_2O (12%, 0.5%, 3%)	1000	25	5	0	1.0	1	8 lpm

* Sensitive Auto-Trak

Dyn R, Dyn C and Dyn P_{plat}

Dual limb circuit pressure control – mandatory breaths (applies to Fig 2 – 7)

ASL5000 settings						Trilogy Evo settings						
Test case	**Residual capacity (l)**	**Resistance (cmH$_2$O/L/s)**	**Compliance (ml/cmH$_2$O)**	**Breath Rate (bpm)**	**Pmus Profile**	**Intended Delivered Volume (ml)**	**P Control (cmH$_2$O)**	**PEEP (cmH$_2$O)**	**Breath Rate (bpm)**	**Tinsp (sec)**	**Rise Time**	**Trigger Sensitivity**
1	0.5	5	50	0	0 cmH$_2$O	500	10	5	20	1.0	1	off
2	0.5	20	50	0	0 cmH$_2$O	500	18	10	20	1.0	1	off
3	0.5	5	20	0	0 cmH$_2$O	400	18	5	20	1.0	1	off
4	0.5	20	20	0	0 cmH$_2$O	500	25	10	20	1.0	1	off
5	0.5	20	20	0	0 cmH$_2$O	300	16	5	20	1.0	1	off
6	0.5	50	20	0	0 cmH$_2$O	300	25	10	20	1.0	1	off
7	0.5	50	10	0	0 cmH$_2$O	300	32	5	20	1.0	1	off
8	0.5	20	10	0	0 cmH$_2$O	200	18	10	20	1.0	1	off
9	0.5	20	3	0	0 cmH$_2$O	50	13	5	30	0.6	1	off
10	0.5	50	3	0	0 cmH$_2$O	50	22	10	30	0.6	1	off
11	0.5	200	3	0	0 cmH$_2$O	50	22	5	30	0.6	1	off
12	0.5	20	100	0	0 cmH$_2$O	1000	27	5	12	1.0	1	off

* Sensitive Auto-Trak

Dyn R, Dyn C and Dyn P_{plat}

Dual limb circuit volume control – mandatory breaths (applies to Fig 2 – 7)

ASL5000 settings						Trilogy Evo settings						
Test case	**Residual capacity (l)**	**Resistance (cmH$_2$O/L/s)**	**Compliance (ml/cmH$_2$O)**	**Breath rate (bpm)**	**P_{mus} profile**	**Intended delivered volume (ml)**	**PIP - PEEP (cmH$_2$O)**	**PEEP (cmH$_2$O)**	**Breath rate (bpm)**	**T_{insp} (sec)**	**Rise time**	**Trigger sensitivity**
1	0.5	5	50	20	0 cmH$_2$O	500	10	5	0	1.0	1	Auto-Trak
2	0.5	20	50	20	0 cmH$_2$O	500	21	10	0	1.0	1	Auto-Trak
3	0.5	5	20	20	0 cmH$_2$O	500	25	5	0	1.0	1	Auto-Trak
4	0.5	20	20	20	0 cmH$_2$O	500	32	10	0	1.0	1	Auto-Trak
5	0.5	20	20	20	0 cmH$_2$O	300	20	5	0	1.0	1	Auto-Trak
6	0.5	50	20	20	0 cmH$_2$O	300	34	10	0	1.0	1	Sens AT*
7	0.5	50	10	20	0 cmH$_2$O	300	45	10	0	1.0	1	Sens AT*
8	0.5	20	10	20	0 cmH$_2$O	200	22	10	0	1.0	1	Auto-Trak
9	0.5	20	3	30	0 cmH$_2$O	50	18	5	0	0.6	1	Auto-Trak
10	0.5	50	3	30	0 cmH$_2$O	50	17	10	0	0.6	1	Sens AT*
11	0.5	200	3	30	0 cmH$_2$O	50	42	5	0	0.6	1	0.5 lpm
12	0.5	20	100	12	0 cmH$_2$O	1000	33	5	0	1.0	1	8 lpm

* Sensitive Auto-Trak

Dyn R, Dyn C and Dyn P_{plat}

Dual limb circuit pressure control – assisted breaths (applies to Fig 2 – 7)

ASL5000 settings						Trilogy Evo settings						
Test case	**Residual capacity (l)**	**Resistance ($cmH_2O/L/s$)**	**Compliance (ml/cmH_2O)**	**Breath rate (bpm)**	**P_{mus} profile**	**Intended delivered volume (ml)**	**PIP - PEEP (cmH_2O)**	**PEEP (cmH_2O)**	**Breath rate (bpm)**	**T_{insp} (sec)**	**Rise time**	**Trigger sensitivity**
1	0.5	5	50	20	5 cmH_2O (12%, 0.5%, 3%)	500	10	5	0	1.0	1	Auto-Trak
2	0.5	20	50	20	5 cmH_2O (12%, 0.5%, 3%)	500	19	10	0	1.0	1	Auto-Trak
3	0.5	5	20	20	5 cmH_2O (12%, 0.5%, 3%)	500	22	5	0	1.0	1	Auto-Trak
4	0.5	20	20	20	5 cmH_2O (12%, 0.5%, 3%)	500	26	10	0	1.0	1	Auto-Trak
5	0.5	20	20	20	5 cmH_2O (12%, 0.5%, 3%)	300	16	5	0	1.0	1	Auto-Trak
6	0.5	50	20	20	5 cmH_2O (12%, 0.5%, 3%)	300	26	10	0	1.0	1	Sens AT*
7	0.5	50	10	20	5 cmH_2O (12%, 0.5%, 3%)	300	32	10	0	1.0	1	Sens AT*
8	0.5	20	10	20	5 cmH_2O (12%, 0.5%, 3%)	200	18	10	0	1.0	1	Auto-Trak
9	0.5	20	3	30	5 cmH_2O (12%, 0.5%, 3%)	50	14	5	0	0.6	1	Auto-Trak
10	0.5	50	3	30	5 cmH_2O (12%, 0.5%, 3%)	50	14	10	0	0.6	1	Sens AT*
11	0.5	200	3	30	5 cmH_2O (12%, 0.5%, 3%)	50	21	5	0	0.6	1	0.5 lpm

* Sensitive Auto-Trak

Dyn R, Dyn C and Dyn P_{plat}

Dual limb circuit volume control – assisted breaths (applies to Fig 2 – 7)

ASL5000 settings						Trilogy Evo settings						
Test case	**Residual capacity (l)**	**Resistance ($cmH_2O/L/s$)**	**Compliance (ml/cmH_2O)**	**Breath rate (bpm)**	**P_{mus} profile**	**Intended delivered volume (ml)**	**PIP - PEEP (cmH_2O)**	**PEEP (cmH_2O)**	**Breath rate (bpm)**	**T_{insp} (sec)**	**Rise time**	**Trigger sensitivity**
1	0.5	5	50	20	5 cmH_2O (12%, 0.5%, 3%)	500	10	5	0	1.0	1	Auto-Trak
2	0.5	20	50	20	5 cmH_2O (12%, 0.5%, 3%)	500	18	10	0	1.0	1	Auto-Trak
3	0.5	5	20	20	5 cmH_2O (12%, 0.5%, 3%)	500	23	5	0	1.0	1	Auto-Trak
4	0.5	20	20	20	5 cmH_2O (12%, 0.5%, 3%)	500	27	10	0	1.0	1	Auto-Trak
5	0.5	20	20	20	5 cmH_2O (12%, 0.5%, 3%)	300	17	5	0	1.0	1	Auto-Trak
6	0.5	50	20	20	5 cmH_2O (12%, 0.5%, 3%)	300	27	10	0	1.0	1	Sens AT*
7	0.5	50	10	20	5 cmH_2O (12%, 0.5%, 3%)	300	35	10	0	1.0	1	Sens AT*
8	0.5	20	10	20	5 cmH_2O (12%, 0.5%, 3%)	200	19	10	0	1.0	1	Auto-Trak
9	0.5	20	3	30	5 cmH_2O (12%, 0.5%, 3%)	50	16	5	0	0.6	1	Auto-Trak
10	0.5	50	3	30	5 cmH_2O (12%, 0.5%, 3%)	50	19	10	0	0.6	1	Sens AT*
11	0.5	200	3	30	5 cmH_2O (12%, 0.5%, 3%)	50	36	5	0	0.6	1	0.5 lpm

* Sensitive Auto-Trak

AutoPEEP

AutoPEEP passive circuit (applies to Fig 8)

Michigan test lung settings						Trilogy Evo settings						
Test case	**C (ml/cmH$_2$O)**	**R (cmH$_2$O/L/s)**	**P_{mus} (cmH$_2$O)**	**T_{insp} (sec)**	**Breath rate (bpm)**	**Mode**	**V_t**	**PEEP (cmH$_2$O)**	**P Control (cmH$_2$O)**	**Breath rate (bpm)**	**T_{insp} (sec)**	**Trigger sensitivity**
1	100	20	0	0.5	0	**A/C-VC**	700	5	–	20	1.2	off
2	20	20	5	0.5	30	**A/C-PC**	550	5	30	12	0.7	2
3	20	50	13	0.5	30	**A/C-PC**	375	5	43	12	0.7	2
4	50	20	0	0.5	0	**A/C-PC**	600	5	40	40	0.7	off
5	3	200	0	0.5	0	**A/C-PC**	35	10	11	50	0.6	off
6	3	200	5 (3)	0.5	40	**A/C-PC**	35	10	8	0	0.6	1
7	2.5	200	0	0.5	0	**A/C-PC**	35	10	16	50	0.6	off
8	2.5	200	5 (3)	0.5	40	**A/C-PC**	35	10	10	0	0.6	1

AutoPEEP dual limb circuit (applies to Fig 9)

Michigan test lung settings						Trilogy Evo settings						
Test case	**C (ml/cmH$_2$O)**	**R (cmH$_2$O/L/s)**	**P_{mus} (cmH$_2$O)**	**T_{insp} (sec)**	**Breath rate (bpm)**	**Mode**	**V_t**	**PEEP (cmH$_2$O)**	**P Control (cmH$_2$O)**	**Breath rate (bpm)**	**T_{insp} (sec)**	**Trigger sensitivity**
1	100	20	0	0.5	0	**A/C-VC**	700	5	–	20	1.2	off
2	20	20	5	0.5	30	**A/C-PC**	550	5	35	12	0.7	2
3	20	50	13	0.5	30	**A/C-PC**	375	5	45	12	0.7	1
4	50	20	0	0.5	0	**A/C-PC**	600	5	45	45	0.6	off
5	3	200	0	0.5	0	**A/C-PC**	35	10	25	50	0.6	off
6	3	200	5	0.5	40	**A/C-PC**	35	10	20	0	0.6	0.5
7	1	200	0	0.5	0	**A/C-PC**	35	10	40	50	0.6	off
8	1	200	5	0.5	40	**A/C-PC**	35	10	35	0	0.6	1

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