GE Healthcare

CARESCAPE R860 SpiroDynamics Appliguide

Contents

Foreword

The purpose of this appliguide is to define the capabilities, potential benefits and application of a unique ventilator monitoring feature called SpiroDynamics* as it relates to the CARESCAPE R860 ventilator.

Our intent is to provide a specific approach for the measurement of online tracheal pressure, and information on the potential benefits it can provide to the caregiver and the patient.

Much of the information in this appliguide is drawn from an article entitled "Practical Assessment of Respiratory Mechanics," (Br J Anaesth 2003; 91: 92-105) authored by Ola Stenqvist, M.D.

Dr. Stenqvist is the creator of SpiroDynamics and FRC INview*, two solutions for the measurement of respiratory mechanics in ventilated patients for GE Healthcare.

Introduction

Delivering appropriate low lung pressure to ventilated patients is important, especially for patients presenting with Acute Respiratory Distress Syndrome (ARDS) or Acute Lung Injury (ALI)[1, 2]. Improperly high ventilator pressures can cause lung injury, promoting a systemic inflammatory reaction that can lead to multiple organ failure and even death.

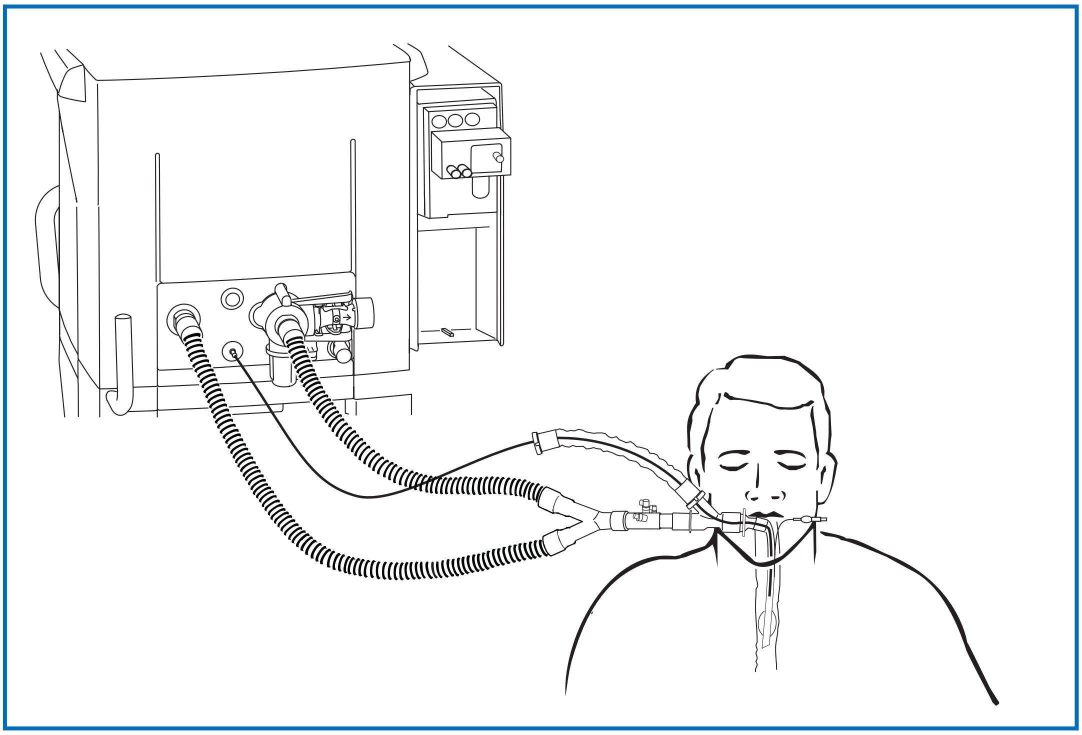
Some research projects have concluded that high tidal volume ventilation associated with elevated pressure delivery may lead to patient mortality, while "protective" ventilation – low tidal volumes, rapid ventilation rates and decreased pressure delivery – may reduce the possibility of organ failure[1, 2].

In clinical practice, ventilator settings are often set based on blood gas measurements rather than on direct lung mechanics measurements[1]. Other clinicians set ventilation parameters by assessing pressure and compliance measurements taken back at the ventilator or at the Y-piece[3]. These measurements do not take into account the impact of the high resistance of the endotracheal tube and the low resistance of the expiratory valve of the ventilator[1]. At the same time, measurements of compliance are typically calculated from the endpoints of inspiration and expiration, not taking into account the events that may occur during the breath cycle. Pressure/volume loops may also be assessed, but determining specific details such as where inflection points lie is often difficult. Due to the lack of detail in current respiratory monitoring functions, setting appropriate ventilatory parameters for a specific patient is difficult.

INview Suite of Respiratory Monitoring Solutions

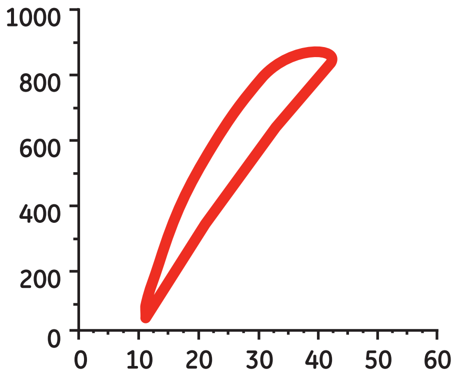
GE Healthcare, along with Dr. Ola Stenqvist, has developed technologies for the measurement of a patient's respiratory mechanics while on the CARESCAPE R860.

SpiroDynamics measures tracheal pressure and provides multi-phase compliance values continuously, irrespective of ventilator settings. The measurements are captured with an intratracheal pressure sensor that can be used with standard endotracheal tubes. Designed in the same manner as a closed suction catheter, GE's disposable sensor is simple to insert and is continuously purged. In this system, the sensor is inserted into the endotracheal tube proximal to the Y-piece and connects directly into the CARESCAPE R860 ventilator at the auxiliary pressure port.

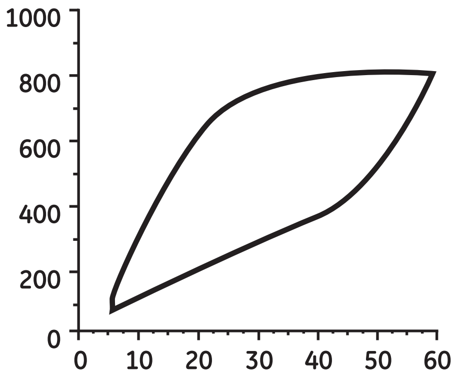


Why Measure Tracheal Pressure?

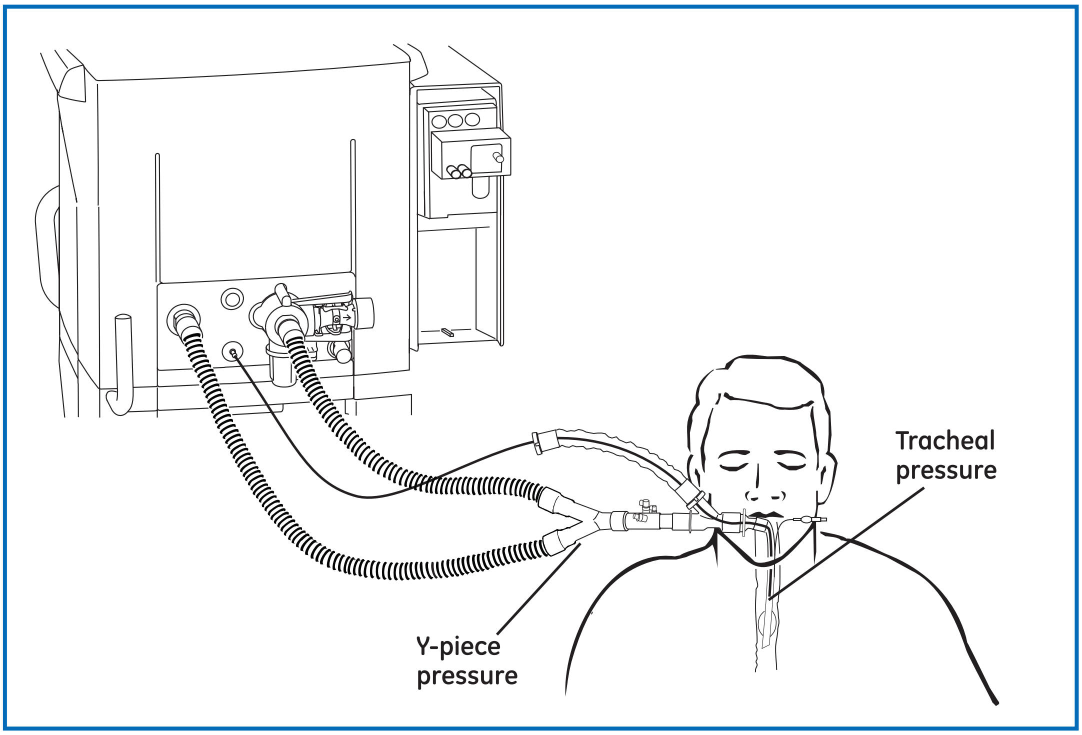
The in-line placement of the intratracheal sensor provides a more accurate measurement of pressure delivery to the lungs[1, 3]. By measuring the pressure at the end of the patient's airway, the resistance of the endotracheal tube is removed from the spirometry loop[2]. An endotracheal tube can represent up to 70 percent of the resistance between the Y-piece and the patient's lungs. SpiroDynamics excludes the effect of endotracheal tube resistance on the pressure measurements and the pressure/volume loops, allowing the clinician to obtain a better view of the actual pressure delivered to the patient's lungs.



SpiroDynamic loop using the intratracheal sensor.



Pressure sensing taken at the Y-piece.



A. Measuring by Traditional Methods

Measuring airway pressure (P_{aw}) and tidal volume (TV) at the ventilator or at the patient connection are the most common methods used for obtaining lung mechanics[1, 2]. Often these parameters are paired to display the information in graphical or spirometry loop format. Pressure/volume loops can continuously trace the breathing cycle to allow the clinician to assess the patient's ventilation over time.

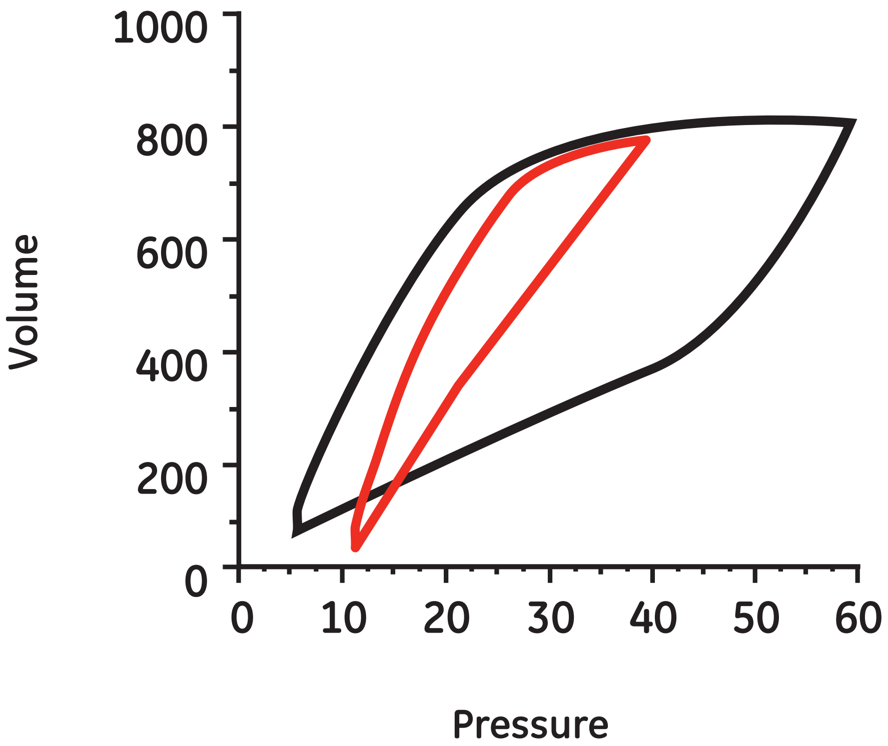
The resistance of a patient's artificial airway affects the pressure measured at the patient connection[1, 2]. The peak inspiratory pressure measured at the ventilator is generally much greater than tracheal or alveolar pressure in the patient. The difference between the pressures relies on the resistance of the tube and the inspiratory flow at the end of inspiration[1, 2]. Tube resistance can also be impacted by secretions and kinking[1]. Since clinicians utilize these pressures to help establish appropriate ventilator therapy, it is paramount that users have the most accurate information possible in order to make the best clinical decision. SpiroDynamics provides true tracheal pressure measurements, allowing the user to set the ventilator specific to the most accurate pulmonary mechanics available.

With normal I:E ratios (< 1:2) generally allowing sufficient expiratory time, there is little risk of incomplete expiration and the proximal pressure will give the correct end-expiratory pressure ($PEEP_e$) of the patient[1]. However, air may become trapped in the lungs, creating intrinsic PEEP ($PEEP_i$) in the following situations:

- Insufficient expiratory time (decreased T_{exp})
- Large TVs
- High respiratory rates
- High compliances
- Increased expiratory resistance
- Early collapse of unstable alveoli during expiration due to lung disease or injury

A. Measuring by Traditional Methods (continued)

While the current method of measurement does give some information about the dynamic conditions in the circuit, it is generally not accurate enough to provide total PEEP measurements without using a procedure to measure intrinsic PEEP. SpiroDynamics loops and the dynostatic curve allow clinicians the ability to see the total PEEP as represented graphically.



Comparison of SpiroDynamics loop (shown in red)
compared to normal Spirometry loop (shown in black).

B. Measuring with SpiroDynamics

SpiroDynamics is based on a validated algorithm that analyzes a tracheal Pressure/Volume (P/V) loop[1]. Auxiliary pressure (Paux) measurements are captured through the intratracheal sensor placed at the tip of the patient's airway and synchronized with volume measurements to create a loop. At the end of the breath, the SpiroDynamics software analyzes the P/V loop and estimates the pressure and compliance in the alveoli throughout the breath cycle.

Once a complete breath is captured, the loop is divided into isovolumetric segments. Each segment, or isovolume plane, has an inspiratory and an expiratory pressure, and an inspiratory and expiratory flow associated with it. While flow is not explicitly displayed in the loop, it is used to calculate alveolar pressure. Assuming inspiratory and expiratory resistances are equal at each isovolume plane, the alveolar pressure is calculated according to the following equation[1]:

Pinsp = Pelastic + $\dot{V}$insp x Rinsp therefore, Rinsp = (Pinsp – Pelastic)/$\dot{V}$insp

Pexp = Pelastic + $\dot{V}$exp x Rexp therefore, Rexp = (Pexp – Pelastic)/$\dot{V}$exp

As Rinsp @ Rexp,

Palveolar = Pelastic = (Pexp x $\dot{V}$insp – Pinsp x $\dot{V}$exp)/)$\dot{V}$insp – $\dot{V}$exp

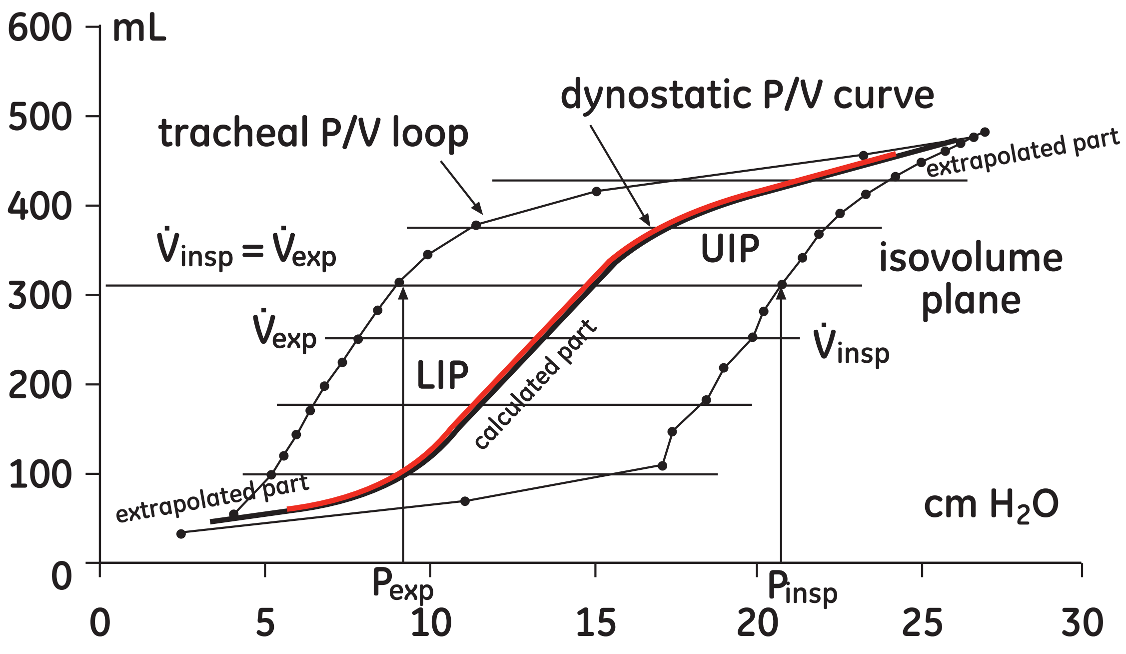
P = pressure

$\dot{V}$ = flow

R = resistance

insp = inspiratory

exp = expiratory



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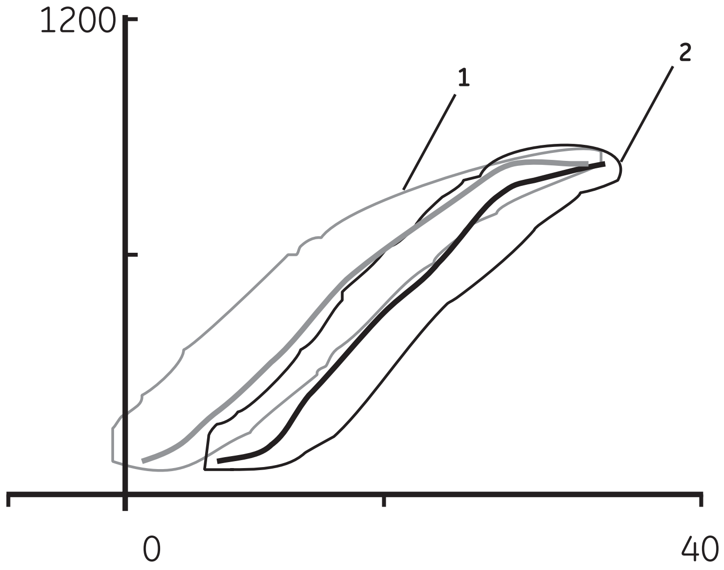
Acta Anaestesiologica Scandinavica 2000; 44: 578.

B. Measuring with SpiroDynamics (continued)

Once the alveolar pressures have been calculated for each of the isovolume segments, a line is drawn connecting them. This line is referred to as the dynostatic curve and represents an estimate of the alveolar compliance (volume per pressure) during a breath cycle.

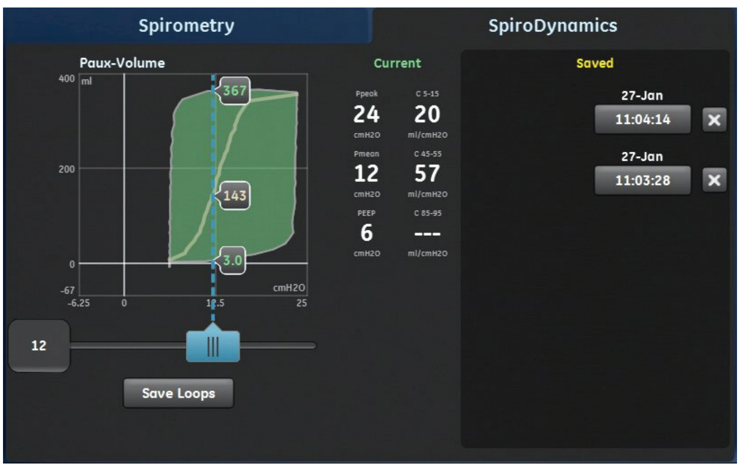
On the CARESCAPE R860 display, the tracheal P/V loop is shown along with three compliance measurements, peak auxiliary pressure, PEEPe, and airway resistance values for each breath. Compliance values are calculated at three points along the dynostatic curve: 5-15%, 45-55%, and 85-95% of the breath. If compliance varies considerably throughout the breath, upper and/or lower inflection points will be apparent on the dynostatic curve.

1. Reference loop and curve
2. Real-time loop and curve



The SpiroDynamics loop, numeric data and the Dynostatic curve are displayed on every third breath when the respiratory rate is 15 breaths per minute or less. Once the patient's respiratory rate goes above 15 then the SpiroDynamics information will be displayed on every 5th breath.

Up to six loop and curve sets can be saved in memory. Once six sets are saved, the second oldest saved set is deleted at the next save. The oldest saved loop and curve set are always maintained in memory unless the user specifically deletes it. After a loop and curve set are saved, they can be displayed at the same time as the current loop and curve set providing the ability to compare the current to the past measurements. Up to two saved sets can be displayed along with the current loop and curve set.



C. Limitations

SpiroDynamics calculations have limitations and may not be calculated in the following cases:

- CPAP mode with Psupport < 5 $cmH_{2}0$
  The algorithm is invalid under these conditions.
- When Paux is constant
  The change in auxiliary pressure must be > 4.5 $cmH_{2}0$ to be recognized as a breath.
- When RR measured < 3/minute
- Tidal volume = 0 for the entire breath
  The breath cannot be split into its isovolume planes.
- Spontaneous breaths in the BiLevel mode
  Breaths at Phigh can disrupt the algorithm's breath timing measurement.

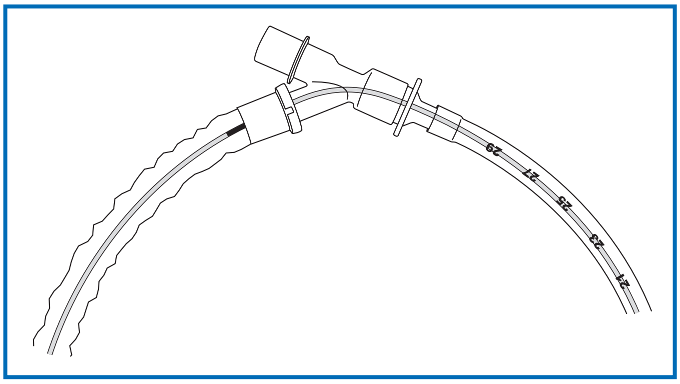
D. The Intratracheal Pressure Sensor

An intratracheal pressure sensor has been developed for use with SpiroDynamics software to measure tracheal pressure in ventilated patients. This accessory is attached between the patient airway and the Y-piece, and is connected to the auxiliary pressure port on the CARESCAPE R860. If other accessories such as in-line suction or a D-lite sensor are used, the intratracheal pressure sensor must be proximal to the other accessories.

The sensor includes a pressure-sensing line connected to a sleeve which encloses a catheter. The catheter has a 2.0 mm outer diameter and is manually guided into the patient's airway. Numbers on the catheter correspond to the numbers on an endotracheal tube, and provide a placement method. The tip of the catheter should be placed within 2 cm of the tip of the endotracheal or tracheostomy tube for the most accurate measurements.

Prior to using the sensor on a patient, it should be purged and zeroed. Both can be done through the user interface on the CARESCAPE R860. Turning the purge flow on starts a continuous flow of 33 mL/min and will prevent mucous from building up in the catheter, which may distort or prevent measurements. Zeroing the Paux sensor after turning the purge flow on but before inserting the catheter into the breathing circuit creates a baseline for the Paux measurement, ensuring the accuracy of the readings.

The intratracheal sensor was designed to attach directly to standard size endotracheal tubes. A small guide is molded into the catheter's female connector port to assist in guiding the catheter into the airway opening, preventing the catheter from catching on the edge of the airway's male connection.

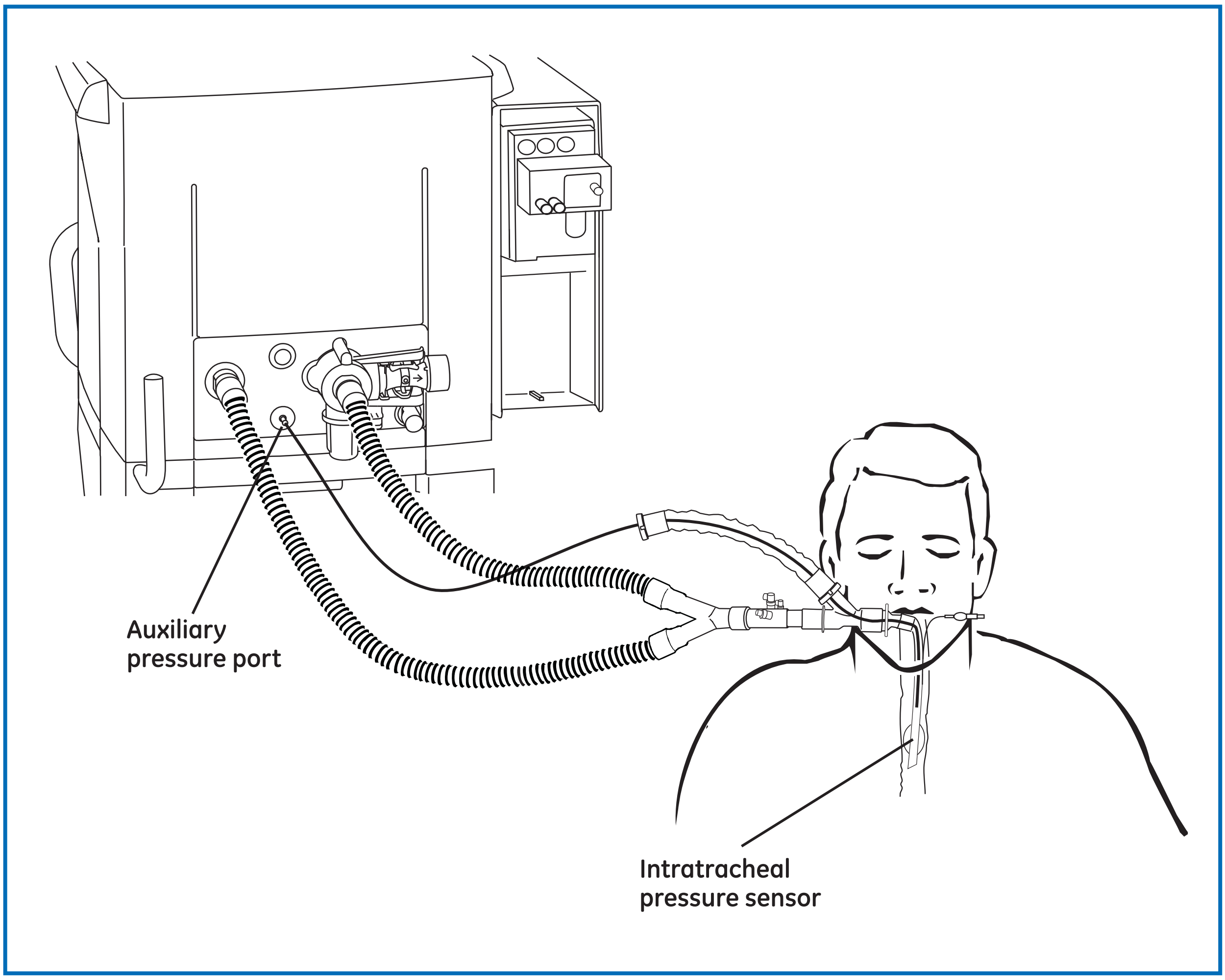


D. The Intratracheal Pressure Sensor (continued)

Some endotracheal tube connectors may not fully extend into the catheter's female connector, creating a gap where the catheter can get stuck upon insertion. In these instances, it is recommended that the user should advance the catheter slightly outside the connector and then guide the catheter into the patient's airway prior to connecting the sensor.

Use of the sensor should not inhibit standard respiratory treatments. The sensor may remain in the circuit during therapy, nebulization, and other procedures. However, while the sensor may remain in the circuit, it must be withdrawn from the airway before a suction catheter can be guided into the airway.

The sensor is only to be used for pressure sensing. It cannot be used for suctioning the patient or for suctioning gases. The sensor has been designed for use with endotracheal tubes having an internal diameter equal to or larger than 6.5mm.



E. Applications

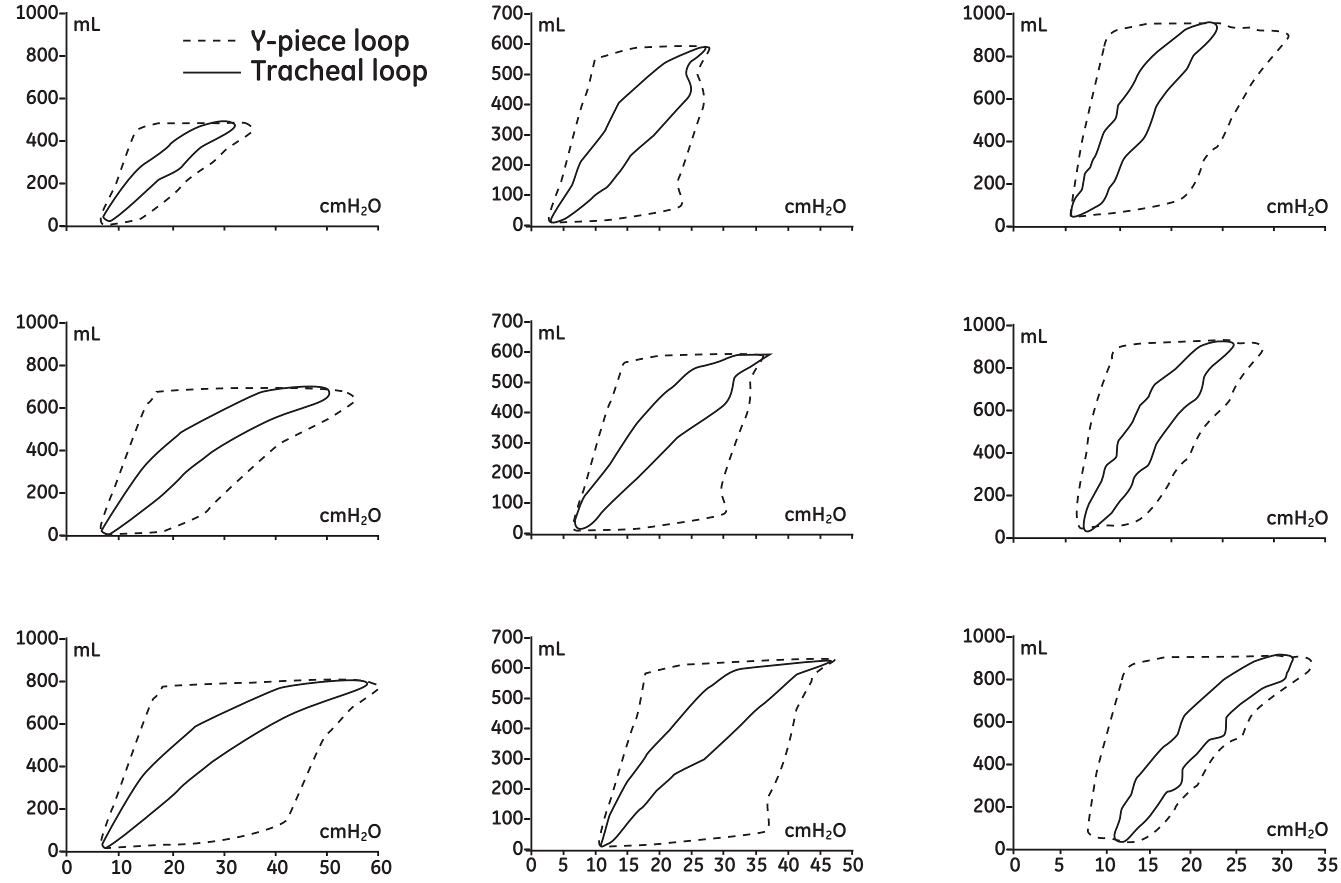
The P/V loops shown below are from three different patients at different ventilator settings. Tracheal P/V loops are shown within traditional P/V loops[2].

Left column: Indicates how an increase in tidal volume during VC ventilation affects the loops, (top to bottom)[2].

Middle column: Indicates how an increase in PEEP during PC ventilation affects the loops, (top to bottom)[2].

Right column: Indicates how increasing inspiratory time during VC ventilation affects the loops, (top to bottom)[2].

In all of these examples, it is evident that the tracheal P/V loop provides more clarity in the detail of the graphic display by removing the interference caused by the circuit and patient airway. Attributes of the loops, such as the endpoints of inspiration and expiration, development of overdistention and the identification of inflection points can be seen in detail. In addition, the loops on the right show obvious formation of intrinsic PEEP within the patient as the inspiratory time is changed. These events are not evident on a traditional patient spirometry loop, but are obvious on a SpiroDynamics P/V loop.



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Potential Benefits of Measuring Lung Mechanics with SpiroDynamics

The clinical implications of tracheal pressure monitoring with SpiroDynamics include:

- Tracheal pressure measurement reduces artificial airway resistance interference from the SpiroDynamics P/V loop
- Three-point compliance measurement
- Ability to monitor true tracheal pressure regardless of ventilator setting or ventilator mode
- Dynostatic curve provides an estimated alveolar pressure
- Provides the clinician with enhanced information to assess lung function from the beginning, middle and end compliance values
- Enhanced detection of intrinsic PEEP

Summary

SpiroDynamics uses tracheal pressure measurements combined with volume delivery to provide improved pulmonary function monitoring of patients on the CARESCAPE R860. The dynostatic curve provides estimates of the alveolar pressure and three – point lung compliance values from the beginning, middle and end of the breath are displayed. The resulting P/V loops provide an improved view of the patient's lung mechanics because the intratracheal catheter reduces the interference caused by the artificial airway's resistance between the ventilator and the patient's lungs. The overlay of the dynostatic curve onto the P/V loop results in a more detailed view of lung mechanics, providing lung compliance estimates over the entire range of pressures and volumes encountered during each breath.[1]

It is a simple, reliable method for capturing information about the lung mechanics of the patient. SpiroDynamics can be used by the clinician to help assess and fine-tune ventilator settings for patients, including those presenting with ARDS/ALI[2].

Troubleshooting

Symptom	Problem	Solution
SpiroDynamic data shows as dashes.	Data collection was interrupted.	Check that the intratracheal catheter is set up properly.
The SpiroDynamics real-time loop and curve are not showing in the graph.	The catheter reading is not correct.	Check that the intratracheal catheter is set up properly and is attached to the system.
The SpiroDynamics loop and data are being displayed at an interval greater than three breaths.	SpiroDynamics is displayed for every third breath when the respiratory rate is 15 or less.	The SpiroDynamics data is displayed on every fifth breath with a respiratory rate > 15 breaths/minute.

References

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   British Journal of Anesthesiology. 2003; 91(1):92-105.

2. Karason S., Stenqvist O. “Pressure/Volume Curves in ARDS: Old and New Aspects.” Refresher Course: European Society of Anesthesiologists. 2001
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3. Sondergaard S, Karason S, Wiklund J, Lundin S, Stenqvist O.
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Additional Resources

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