CARESCAPE™ R860
Invasive Modes of Ventilation

March 19, 2020

Objectives

By the end of this course, you should be able to:

- Describe Compliance, Elastance and Airway resistance
- Categorize the CARESCAPE R860 ventilation modes
- Describe tube compensation, leak compensation and trigger compensation
- Identify and describe the CARESCAPE R860 modes of ventilation
- Discuss advantages and disadvantages for Volume Control, Pressure Control, Pressure Regulated Volume Control, and Airway Pressure Release Ventilation

Mechanics of Ventilation

Lung Compliance

Compliance = ΔVolume/ΔPressure (mL/cmH2O)

Change in volume over the change in pressure

- A measure of the ease of expansion of the lungs and thorax, determined by pulmonary volume and elasticity.

- A high degree of compliance indicates a loss of elastic recoil of the lungs, as in old age or emphysema.

- Decreased compliance means that a greater change in pressure is needed for a given change in volume, as in atelectasis, edema, fibrosis, pneumonia, or absence of surfactant.

Static Compliance = Exhaled Tidal Volume (Vte)/Plateau Pressure (Pplat) – Positive End Expiratory Pressure (PEEP)

Dynamic Compliance = Exhaled Tidal Volume (Vte)/Peak Inspiratory Pressure (PIP) – Positive End Expiratory Pressure (PEEP)

Normal adult compliance 40-70 ml/cmH2O
In children about 1ml/cmH2O/kg

R. Kacmarek, Ph.D, RRT, C. Mack, M.M., RRT, and S. Dimas, RRT.(1990). The Essentials of Respiratory Care. 3rd ed. St. Louis: Mosby-Year Book, Inc., pp.27,30,67-70.
C. Scanlan, EdD, RRT, C. Spearman, BS, RRT, R. Sheldon, MD, FCCP, FACP, and D. Egan, MD. (1990). Egan's Fundamentals of Respiratory Care. 5th ed. St. Louis: The CV Mosby Company, pp. 183-188.

Elastance

Elastance = ΔPressure/ ΔVolume (cmH2O/mL)

Change in pressure over the change in volume

- A measure of the tendency of something to recoil toward its original dimensions upon removal of a distending or compressing force.

- Compliance and elastance are inversely related.

- If compliance increases then elastance decreases
- If compliance decreases then elastance increases

R. Kacmarek, Ph.D, RRT, C. Mack, M.M., RRT, and S. Dimas, RRT.(1990). The Essentials of Respiratory Care. 3rd ed. St. Louis: Mosby-Year Book, Inc., pp.27,30,67-70.
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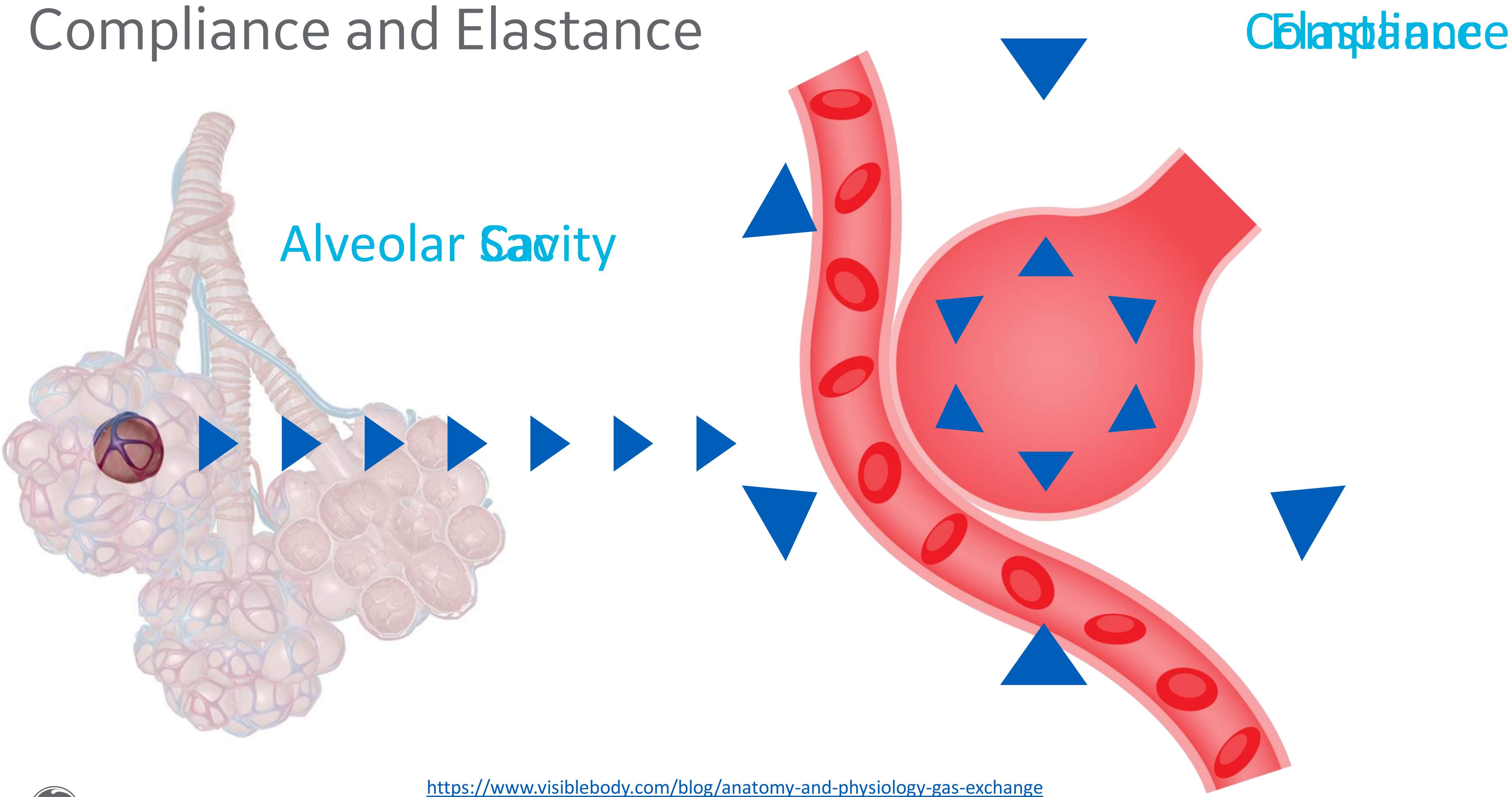
Compliance and Elastance



https://www.visiblebody.com/blog/anatomy-and-physiology-gas-exchange

Airway Resistance

Raw = Δ Pressure/Flow (cmH2O/L/sec)

Change in pressure over flow

- Airway resistance is the friction caused by the movement of air throughout the respiratory system

- Types of flow:
  - Laminar flow: smooth, even non-tumbling flow
  - Turbulent flow: rough, tumbling uneven flow pattern
    - The pressure gradient necessary to maintain turbulent flow is much higher than that necessary to maintain laminar flow.
  - Tracheobronchial flow: is a combination of laminar and turbulent flow which is maintained throughout the respiratory system

- Airway resistance decreases with increased airway diameter, bronchodilation, laminar flow and increase in lung volume

- Airway resistance increases with decreased airway diameter, bronchoconstriction, turbulent flow and decrease in lung volume

Normal airway resistance is 0.5-2.5cmH2O/L/sec at a flow rate of 0.5 L/sec

R. Kacmarek, Ph.D, RRT, C. Mack, M.M., RRT, and S. Dimas, RRT.(1990). The Essentials of Respiratory Care. 3rd ed. St. Louis: Mosby-Year Book, Inc., pp.27,30,67-70.
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Airway Resistance

Raw is normal or decreases

When the Raw increases

Modes of Ventilation Categories

Modes of Ventilation: Introduction and Overview

Define categories of ventilation

Control Modes:

Positive pressure ventilation in which the ventilator is in control mode, with its cycle entirely controlled by the apparatus and not influenced by the patient's efforts at spontaneous ventilation.

Synchronized Modes:

Synchronized Intermittent Mechanical Ventilation is a variation of IMV, in which the ventilator breaths are synchronized with patient inspiratory effort, with added pressure support.

Support Modes:

The patient initiates every breath and the ventilator delivers support with the preset pressure value. With support from the ventilator, the patient also regulates his own respiratory rate and tidal volume.

Modes of Ventilation

Ventilator mode can be defined as a set of operating characteristics that control how the ventilator functions.

Operating mode can be described by:

- The way a ventilator is triggered into inspiration and cycled into expiration.

- What variables are limited during inspiration.

- Whether or not the mode allows mandatory, spontaneous, or supported breaths.

Modes of Ventilation: Control Modes

Control Modes: Introduction and Overview

Each breath is initiated, limited and terminated by the ventilator.

Patients can breathe spontaneously between control breaths, but the ventilator does not respond to the spontaneous effort.

Mode	Primary Settings	Inspiratory Flow Pattern	Breath Timing	Patient Synchrony	Safety
AC/VC	Tidal Volume FiO2 PEEP Flow	Constant	Rate I:E, Tinsp or Tpause Insp Pause	Insp Trigger Bias Flow	Plimit Pmax
AC/PC	Inspiratory Pressure FiO2 PEEP	Decelerating	Rate I:E or Tinsp	Insp Trigger Bias Flow Rise TIme	Pmax
AC/PRVC	Tidal Volume FiO2 PEEP	Decelerating	Rate I:E or Tinsp	Insp Trigger Bias Flow Rise TIme	Pmax Pmin

Modes of Ventilation: Synchronized Modes

Synchronized Modes: Introduction and Overview

Synchronized Intermittent Mechanical Ventilation in which the ventilator breaths are synchronized with patient inspiratory effort, with added pressure support.

Mode	Primary Settings	Inspiratory Flow Pattern	Breath Timing	Patient Synchrony	Safety
SIMV VC	Tidal Volume Flow FiO2 PEEP PS	Constant	Rate Tinsp or Tpause Insp Pause	Insp Trigger Exp Trigger Bias Flow PS Rise Time	Plimit Pmax
SIMV PC	Inspiratory Pressure FiO2 PEEP PS	Decelerating	Rate Tinsp	Insp Trigger Exp Trigger Bias Flow Rise Time PS Rise Time	Pmax
SIMV PRVC BiLevel VG	Tidal Volume FiO2 PEEP PS	Decelerating	Rate Tinsp	Insp Trigger Exp Trigger Bias Flow Rise Time PS Rise Time	Pmax Pmin
BiLevel	Inspiratory Pressure FiO2 PEEP PS	Decelerating	Rate Tinsp	Insp Trigger Exp Trigger Bias Flow Rise Time PS Rise TIme	Pmax

Adapted from DOC1931778 and CARESCAPE R860 URM

Modes of Ventilation: Support Modes

Support Modes: Introduction and Overview

The ventilator supplies pressure support in response to the spontaneous breathing with no set rate; pressure support can also be added to SIMV modes of ventilation.

The patient must be spontaneously breathing and the ventilator must recognize and respond to the spontaneous effort, based on the patient's inspiratory flow.

Mode	Primary Setting	Inspiratory Flow Pattern	Breath Timing	Patient Synchrony	Safety
CPAP/PS	PEEP PS FiO2	Decelerating	Patient Controlled	Insp Trigger Exp Trigger Bias Flow PS Rise Time	Pmax Minimum Rate Backup Pinsp Backup Tinsp
VS	Tidal Volume FiO2 PEEP	Decelerating	Patient Controlled	Tsupp Insp Trigger Exp Trigger Bias Flow PS Rise Time	Pmax Pmin Minimum Rate Backup Tinsp
APRV*	Phigh Plow FiO2	Decelerating	Thigh Tlow	Insp Trigger Bias Flow Rise Time	Pmax

* Indicates these modes could be either control or spontaneous modes of ventilation depending on patient effort

Ventilation Mode Features:

Tube Compensation
Leak Compensation
Trigger Compensation

Tube Compensation

- To set Tube compensation, a Tube Type and Tube Diameter must be set in the New Patient or Current Patient menu
  - The options for tube compensation are:
    - Endotrach
    - Trach
    - ---
      - When --- is selected, the ventilator will not compensate for tube resistance

- Provides additional pressure to compensate for the difference between the lung pressure and breathing circuit pressure during the inspiratory phase of pressure controlled and pressure-supported breaths
  - Can be used to offset all or a percentage of the additional resistive pressure created by the endotracheal tube

NOTE: Tube compensation increases the pressure delivered to the patient. The pressure delivered with tube compensation is limited to Pmax - 5 cmH2O. Make sure that Pmax is set appropriately for the patient when using tube compensation.

Leak Compensation

- When leak compensation is selected, a general message will show leak compensation is on
- When the ventilator detects a leak in the breathing circuit and leak compensation is active, the ventilator will respond in the following ways:
  - Flow and volume waveforms and measured volume data are adjusted to account for leaks
- The ventilator will adjust the tidal volume delivered to compensate for leaks in the following volume controlled modes:
  - A/C VC
  - A/C PRVC
  - SIMV VC
  - SIMV PRVC
  - BiLevel VG
  - VS
- The maximum tidal volume adjustment depends on the patient type:
  - Adult – 25% of the set tidal volume
  - Pediatric – 100% of the set tidal volume or 100ml, which ever is less
  - Neonatal – 100% of the set tidal volume

NOTE: The exhaled volume of the patient can differ from the measured exhaled volume due to leaks

Trigger Compensation

- Adjusts the flow trigger to compensate for leaks
  - Leaks can cause the ventilator to initiate breath automatically (auto-triggering)

- Trigger compensation reduces the need to manually adjust the inspiratory trigger setting to prevent auto-triggering.

Modes of Ventilation- Control Modes

Assist Control Volume Control (A/C VC)

- The ventilator delivers mechanical breaths of the set tidal volume
he set respiratory rate
sure required to deliver the tidal volume
ent's lung compliance and resistance
ble to synchronize mechanical breath to
ous efforts and to allow triggering of
breaths.
ent can initiate spontaneous breaths at the
g the expiratory phase
es an inspiratory flow based on the set
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d maintained during the inspiratory phase
re is below the pressure limit
is reached, the gas flow is reduced to
re limit level for the remainder of the
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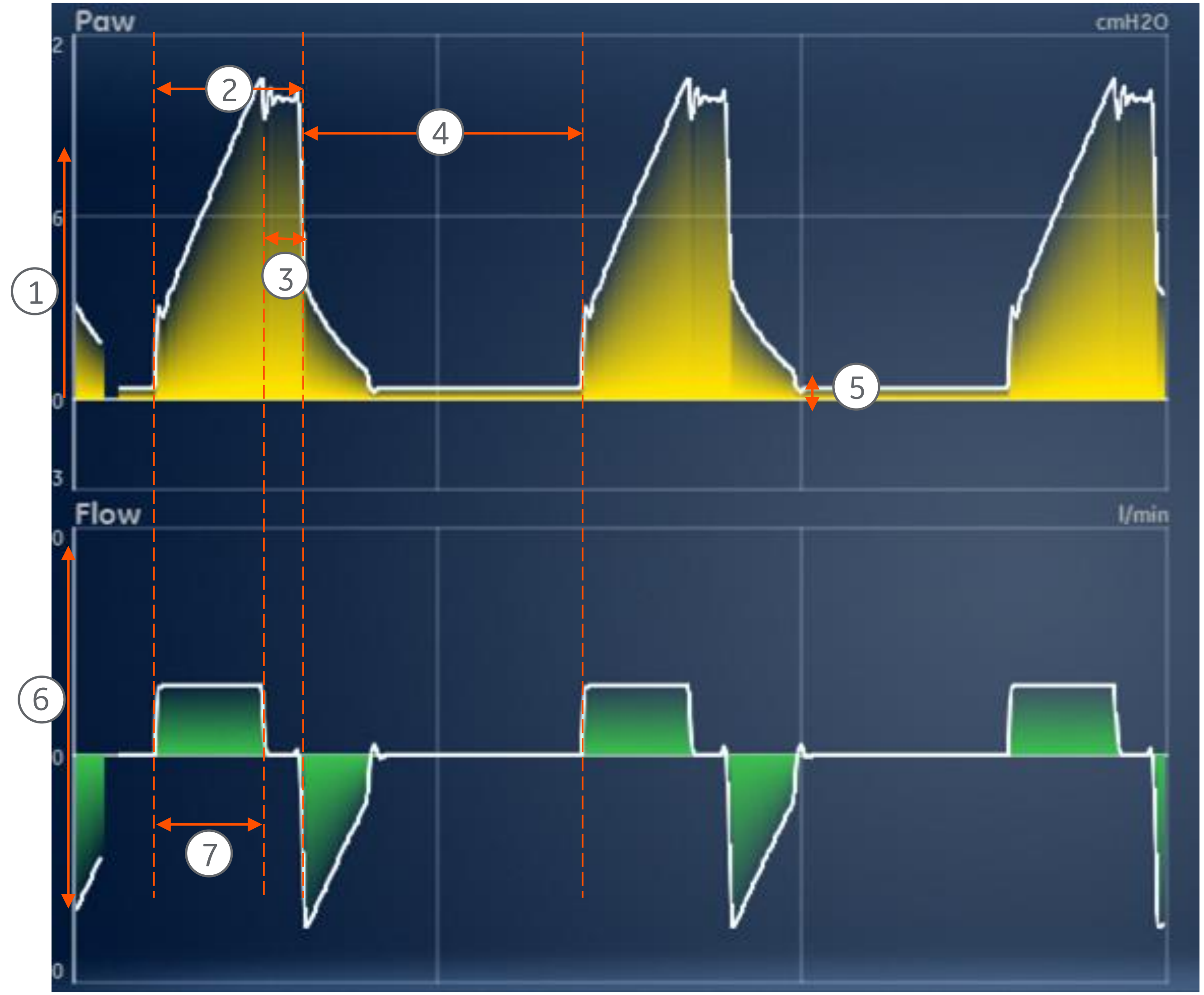
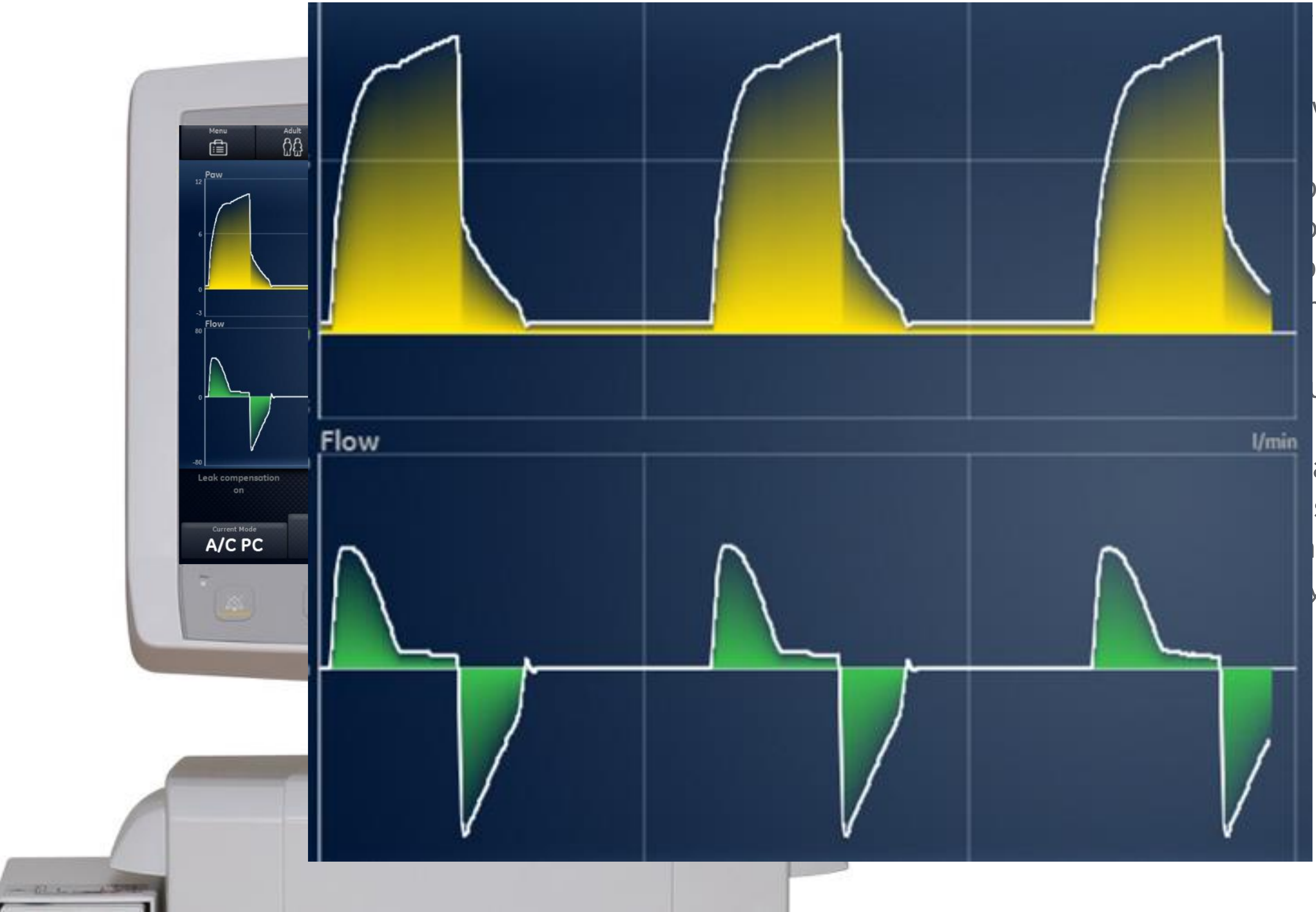
y flow as needed to maintain the set tidal
ent breaths

Assist Control Volume Control (A/C VC)



1. Airway pressure (Paw) waveform
2. Inspiratory time (Tinsp)
3. Inspiratory pause (Tpause)
4. Expiratory time (Texp)
5. PEEP
6. Flow waveform
7. Tidal volume (VT)

Assist Control Pressure Control (A/C PC)



- The ventilator delivers mechanical breaths at the set inspiratory
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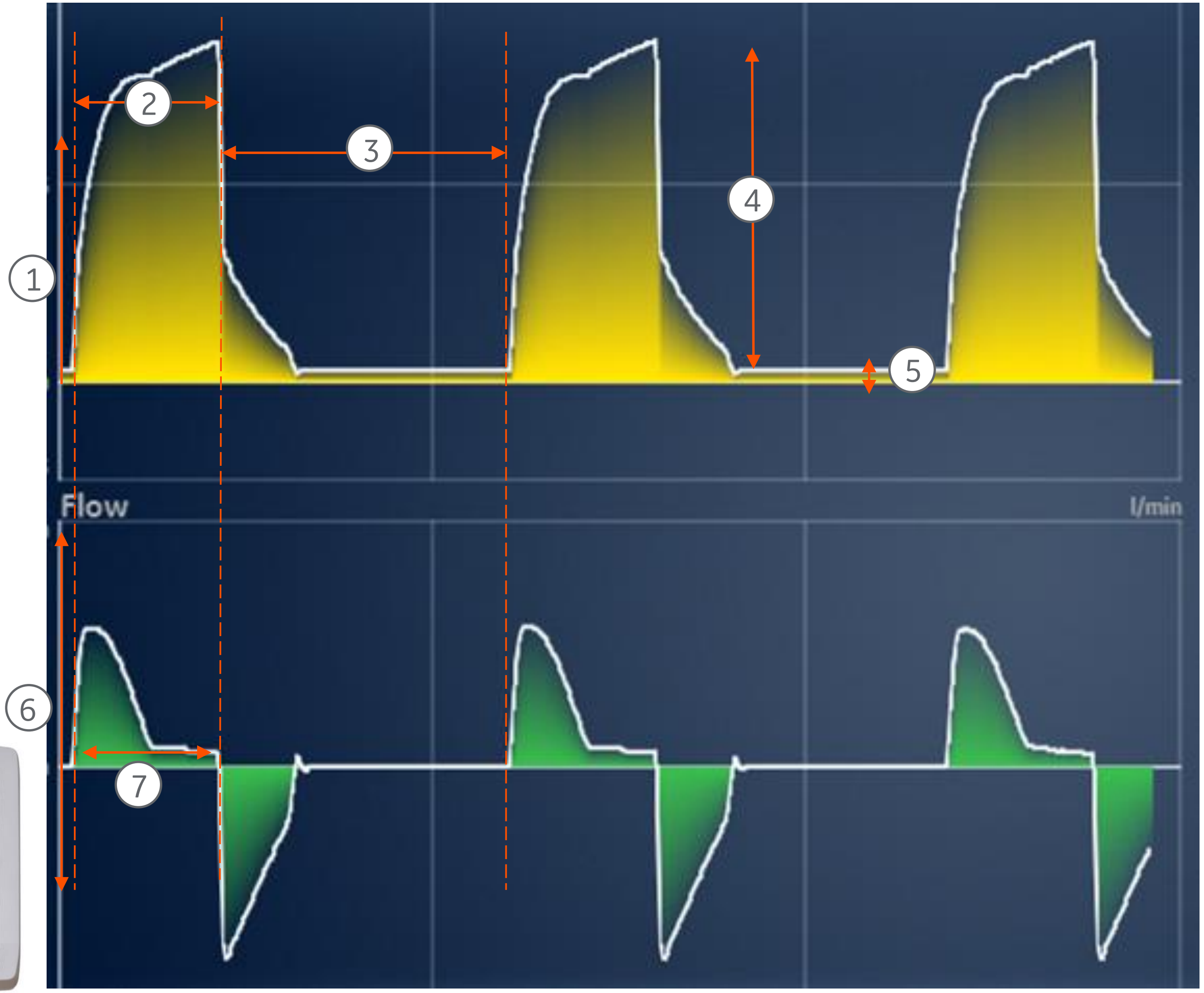
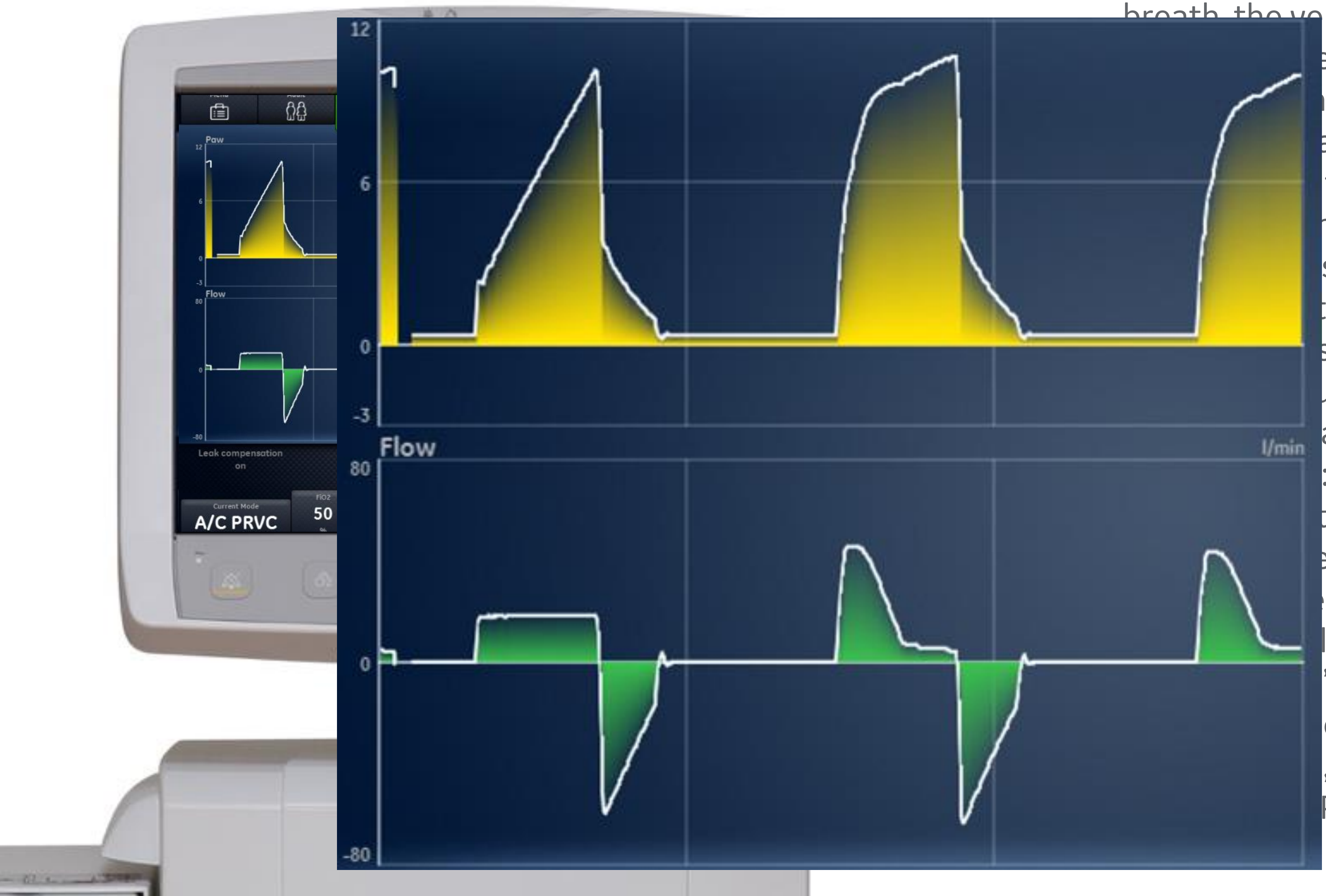
Assist Control Pressure Control (A/C PC)



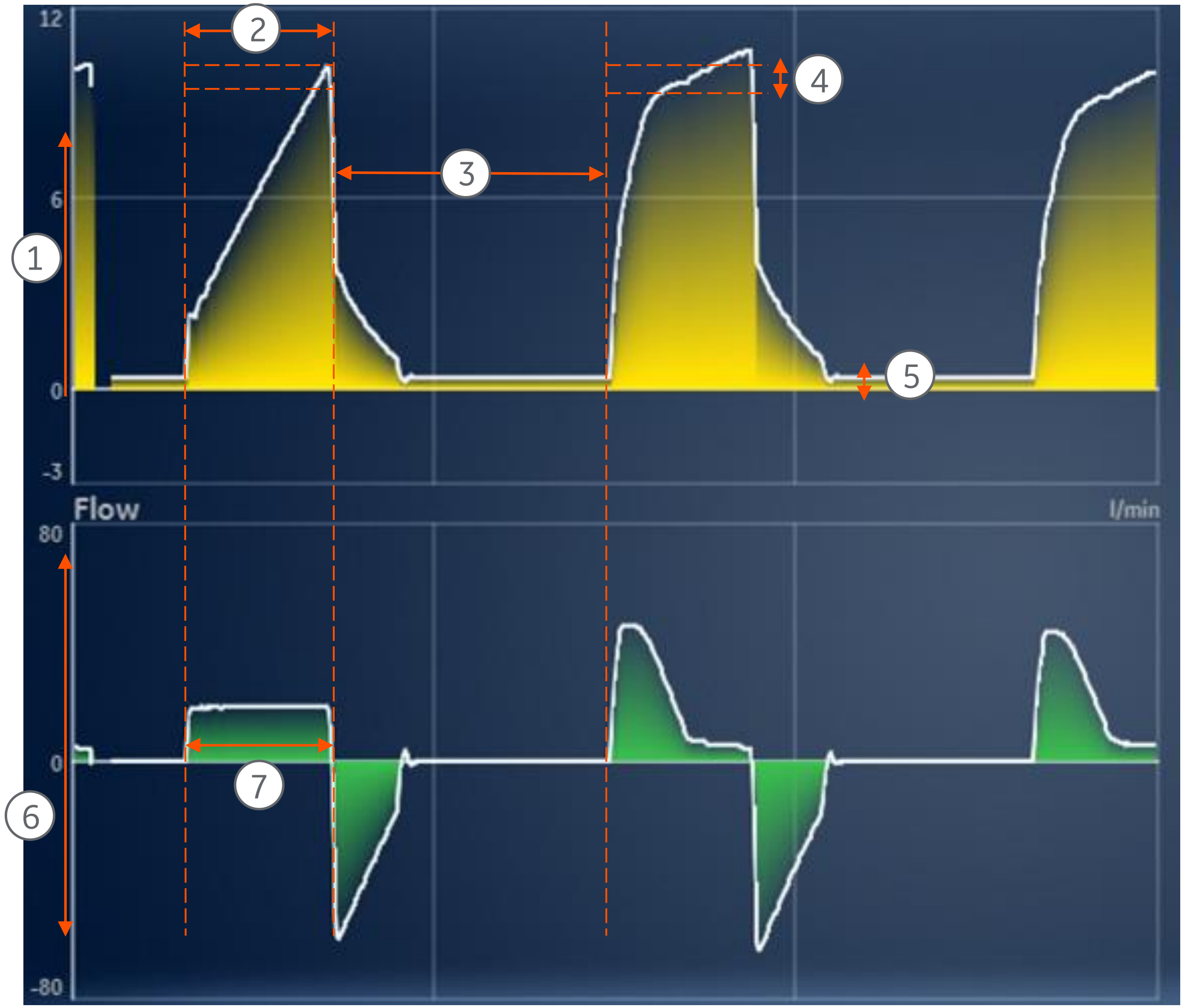
1. Airway pressure (Paw) waveform
2. Inspiratory time (Tinsp)
3. Expiratory time (Texp)
4. Inspiratory pressure (Pinsp)
5. PEEP
6. Flow waveform
7. Tidal volume (VT)

Assist Control Pressure Regulated Volume Control (A/C PRVC)



- The ventilator delivers mechanical breaths of the set tidal volume at intervals based on the set respiratory rate. For each breath, the ventilator adjusts the inspiratory pressure to use
essure required to deliver the tidal volume.
tilation settings may be different if breath timing
ave been changed
the patient's lung compliance, the ventilator
ne-controlled ventilation for 10 seconds or 2
s, whichever is longer when the mode is initiated.
the patient's lung compliance, the inspiratory
s established for subsequent breaths.
usting the inspiratory pressure the following
ange is used:
: PEEP + Pmin
t: Pmax-2 cmH2O
ence in inspiratory pressure between breath
xceed +/- 3 cmH2O
l is available to synchronize mechanical breath
's spontaneous efforts and to allow triggering of
chanical breaths.
, the patient can initiate spontaneous breaths
PEEP level during the expiratory phase

Assist Control Pressure Regulated Volume Control (A/C PRVC)



1. Airway pressure (Paw) waveform
2. Inspiratory time (Tinsp)
3. Expiratory time (Texp)
4. Variable pressure to deliver set TV
5. PEEP
6. Flow waveform
7. Tidal volume (VT)

Modes of Ventilation-
Synchronized Modes

Synchronized Intermittent Mandatory Ventilation Volume Control (SIMV VC)

rs synchronized mechanical breaths of
at intervals based on the set respiratory
aneous efforts are delivered as
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atient's lung compliance and resistance
settings may be different if breath timing
d Flow) have been changed
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and maintained during the inspiratory
ay pressure is below the pressure limit
nit is reached, the gas flow is reduced to
ssure limit level for the remainder of the
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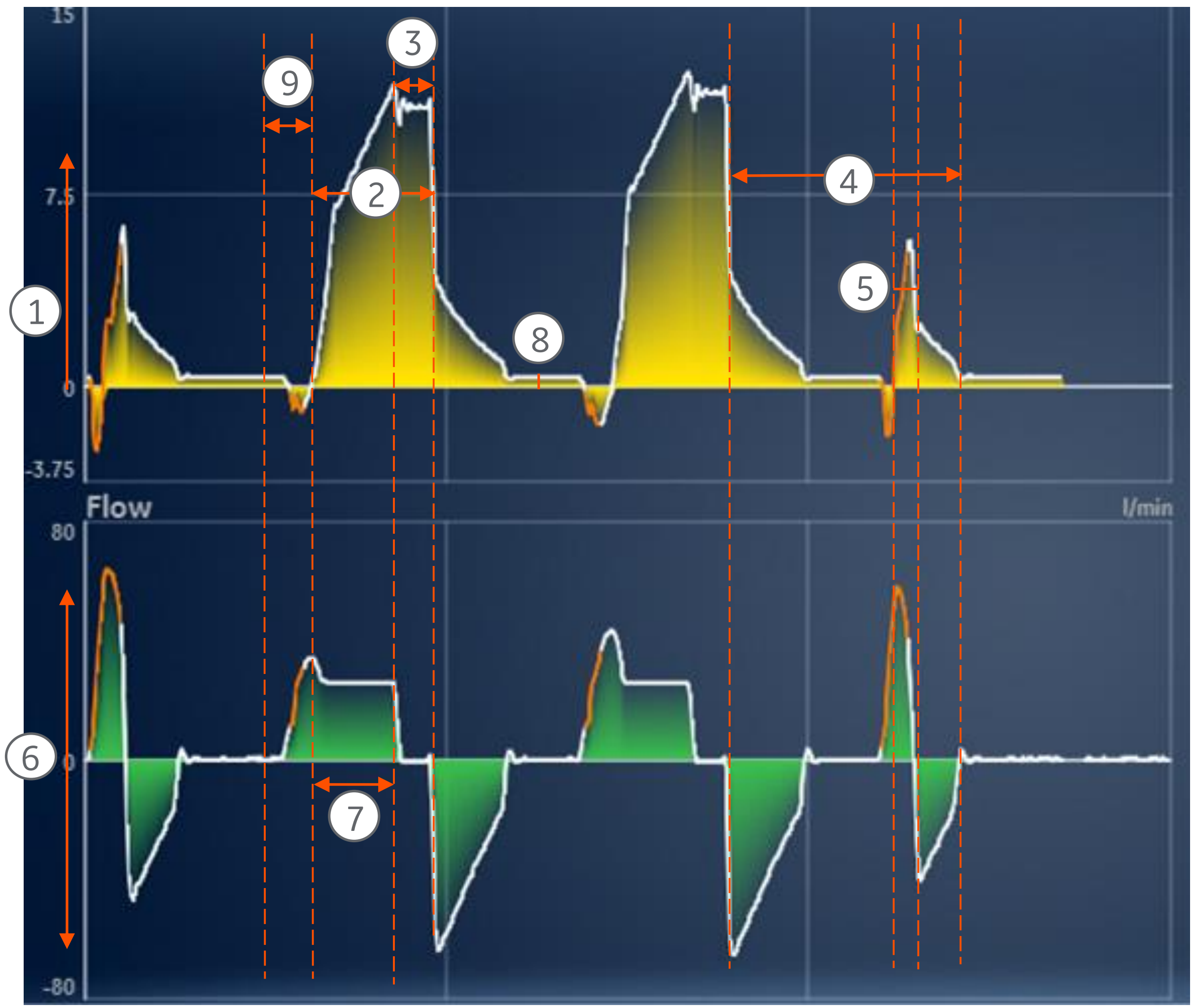
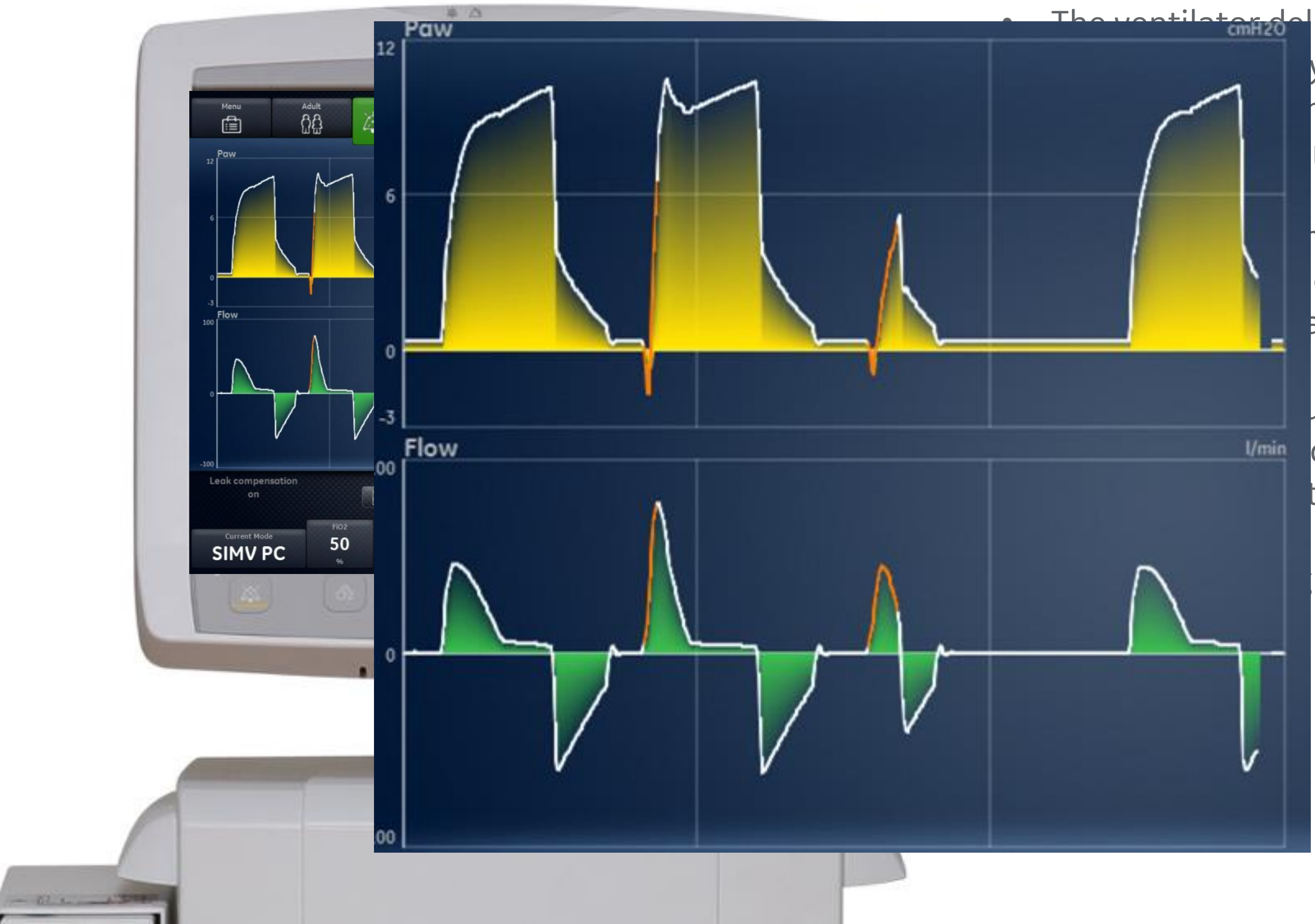
piratory flow as needed to maintain the set
ubsequent breaths

Synchronized Intermittent Mandatory Ventilation Volume Control (SIMV VC)



1. Airway pressure (Paw) waveform
2. Inspiratory time (Tinsp)
3. Inspiratory pause (Tpause)
4. Spontaneous breathing period
5. Pressure-supported breath
6. Flow waveform
7. Tidal volume (VT)
8. PEEP
9. Trigger window

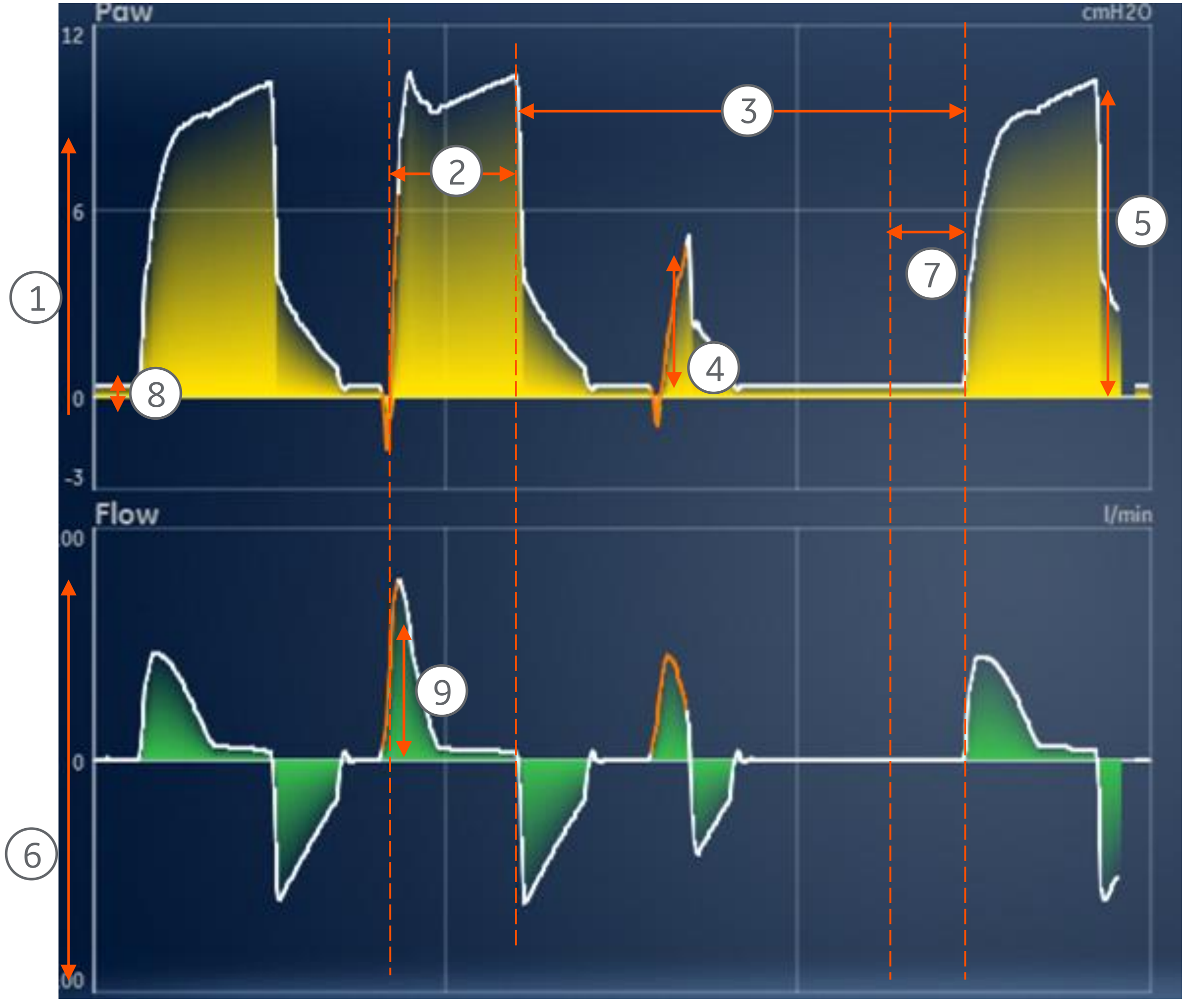
Synchronized Intermittent Mandatory Ventilation Pressure Control (SIMV PC)



- The ventilator delivers synchronized mechanical breaths at
y pressure level for a set inspiratory time at
n the set respiratory rate. All other
rts are delivered as pressure-supported

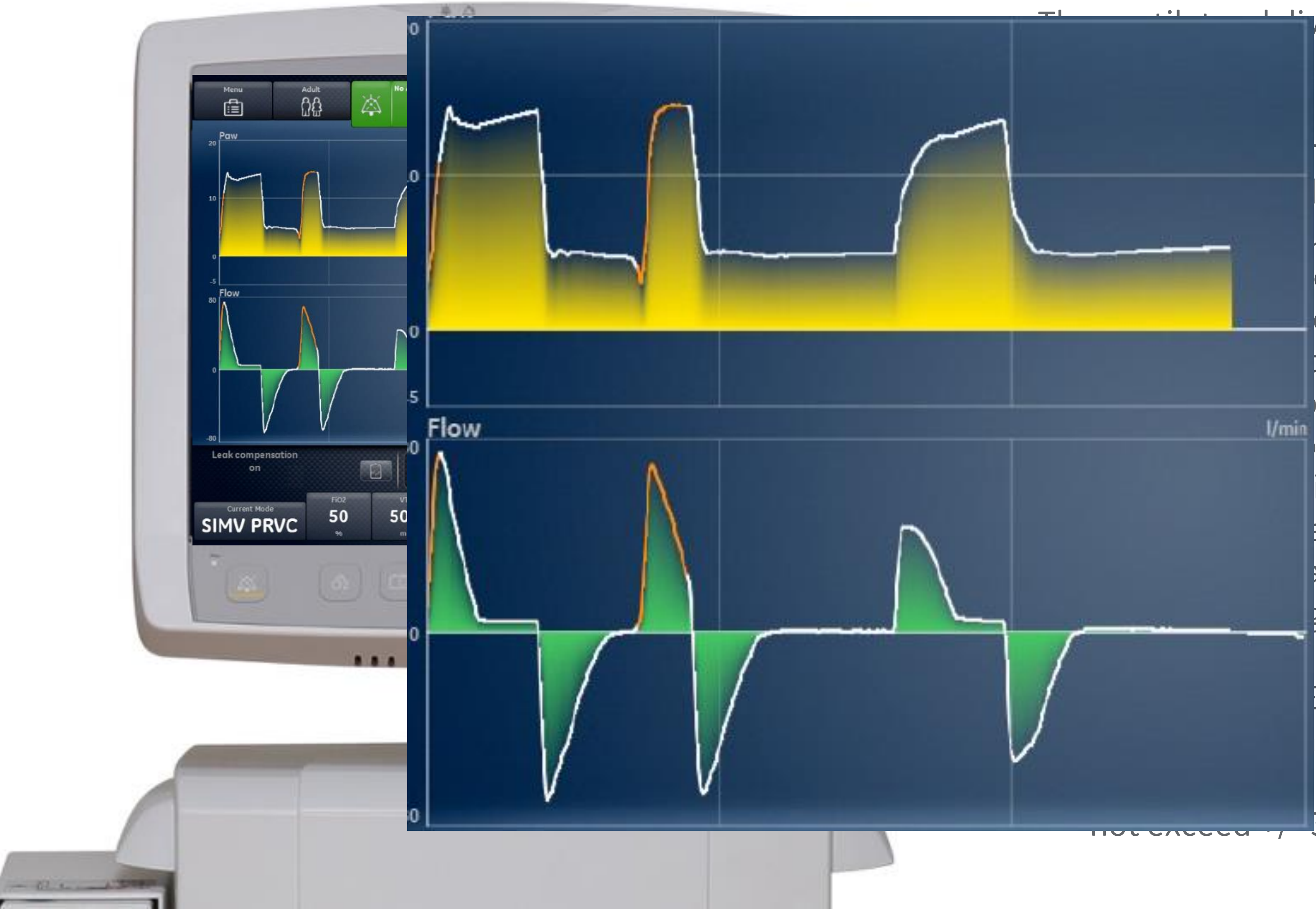
me delivered depends on the patient’s
ce
ation is available
pressurizes the circuit to the set
ure
o the patient decreases after the pressure
the pressure setting
decreases to maintain the set pressure for
inspiratory time

Synchronized Intermittent Mandatory Ventilation Pressure Control (SIMV PC)



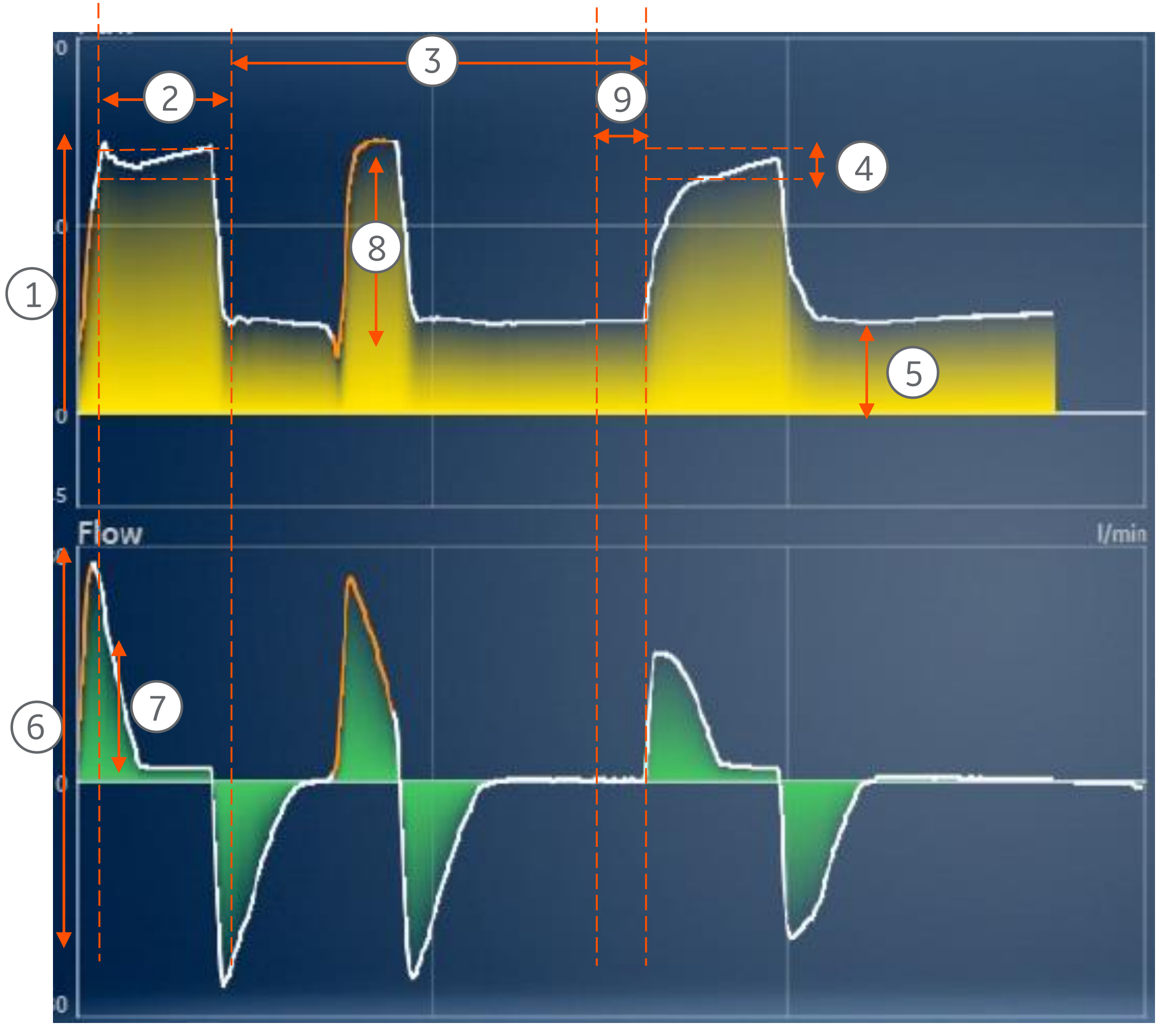
1. Airway pressure (Paw) waveform
2. Inspiratory time (Tinsp)
3. Spontaneous breathing time
4. Pressure-supported breath
5. Inspiratory pressure (Pinsp)
6. Flow waveform
7. Trigger window
8. PEEP
9. Tidal Volume (VT)

Synchronized Intermittent Mandatory Ventilation Pressure Regulated Volume Control (SIMV PRVC)



ers synchronized mechanical breaths of the
intervals based on the set respiratory rate.
al breath, the ventilator adjusts the
e to use the lowest pressure required to
lume. All other spontaneous efforts are
ure-supported breaths.
on settings may be different if breath timing
een changed
tion is available
atient's lung compliance, the ventilator
ntrolled ventilation for 10 seconds or 2
ichever is longer when the mode is initiated.
atient's lung compliance, the inspiratory
ablished for subsequent breaths.
g the inspiratory pressure the following
is used:
P + Pmin
ax-2 cmH2O
n inspiratory pressure between breath does
3 cmH2O

Synchronized Intermittent Mandatory Ventilation Pressure Regulated Volume Control (SIMV PRVC)

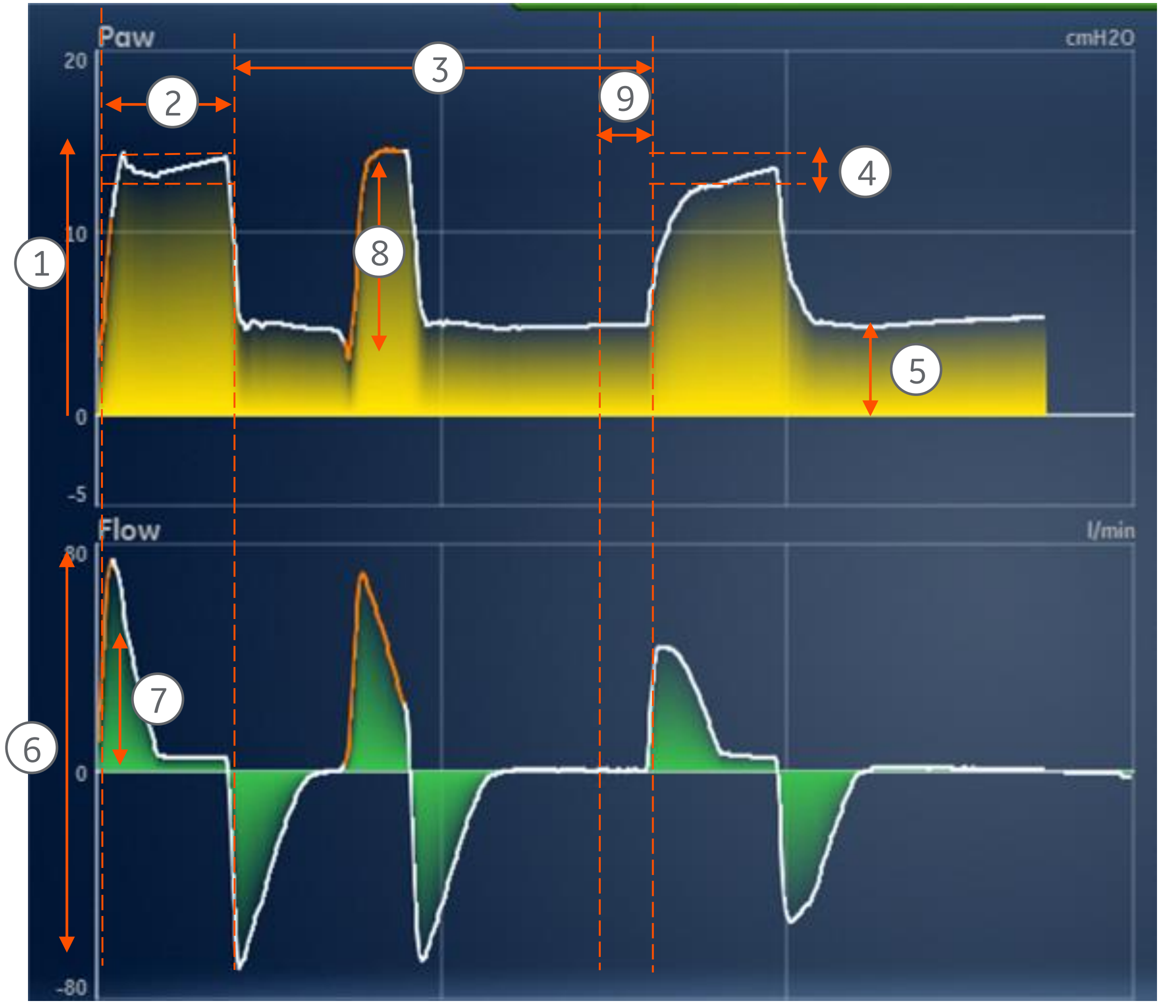


1. Airway pressure (Paw) waveform
2. Inspiratory time (Tinsp)
3. Spontaneous breathing time
4. Variable pressure
5. PEEP
6. Flow waveform
7. Tidal volume (VT)
8. Pressure supported breath
9. Trigger window

BiLevel Airway Pressure Ventilation Volume Guaranteed (BiLevel VG)

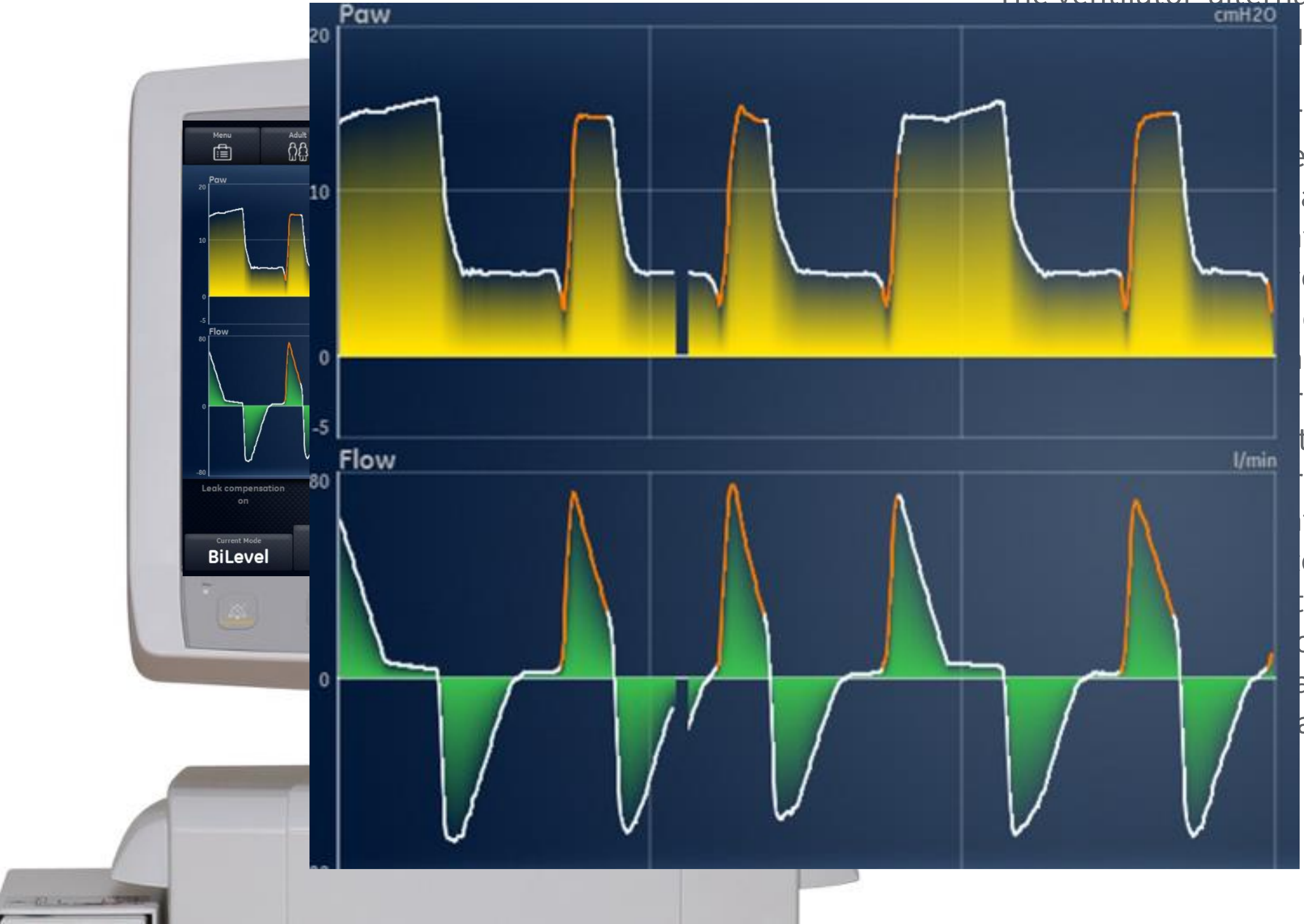
- The ventilator alternates between a set PEEP and the minimum pressure to deliver the set tidal volume based on the set rate and inspiratory time.
- itiates a breath at the PEEP level, a pressure th at the PS settings is delivered.
- atient's lung compliance, the ventilator ntrolled ventilation for 10 seconds or 2 ichever is longer when the mode is initiated.
- atient's lung compliance, the inspiratory blished for subsequent breaths.
- the inspiratory pressure the following is used:
- P + Pmin
- ax-2 cmH2O
- n inspiratory pressure between breath does 3 cmH2O
- pressure alarm is active for the current breath's pressure target is 0.5 cmH2O lower
- is also available

BiLevel Airway Pressure Ventilation Volume Guaranteed (BiLevel VG)



1. Airway pressure (Paw) waveform
2. Inspiratory time (Tinsp)
3. Spontaneous breathing time
4. Variable pressure
5. PEEP
6. Flow waveform
7. Tidal volume (VT)
8. Pressure supported breath
9. Trigger window

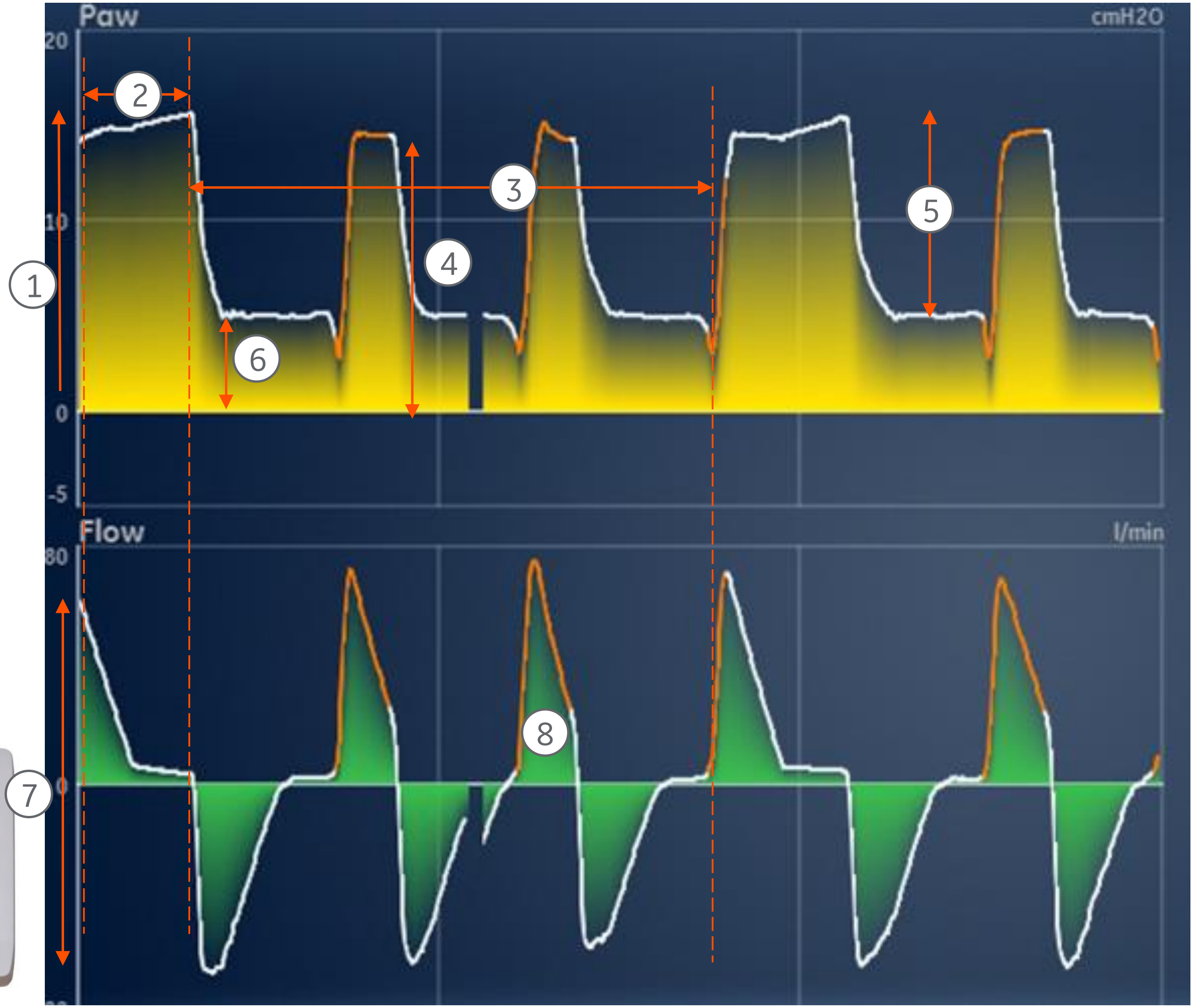
BiLevel Airway Pressure Ventilation (BiLevel)*



- The ventilator alternates between the set PEEP level and the
re level based on the set rate and

reath spontaneously at either level
es a breath at the PEEP level, a pressure-
at the set PS setting is delivered.
th is initiated during the high pressure
el of inspiratory pressure provided
d Pinsp settings.
n Pinsp, the ventilator provides the
e to support the breath
than PS, the ventilator provides no
e support.
th is initiated near the end of Thigh, the
o deliver at Pinsp or PS, whichever is
s the Exp Trigger or the maximum
or the pressure-supported breath. The
ansition to the PEEP level.
available

BiLevel Airway Pressure Ventilation (BiLevel)*



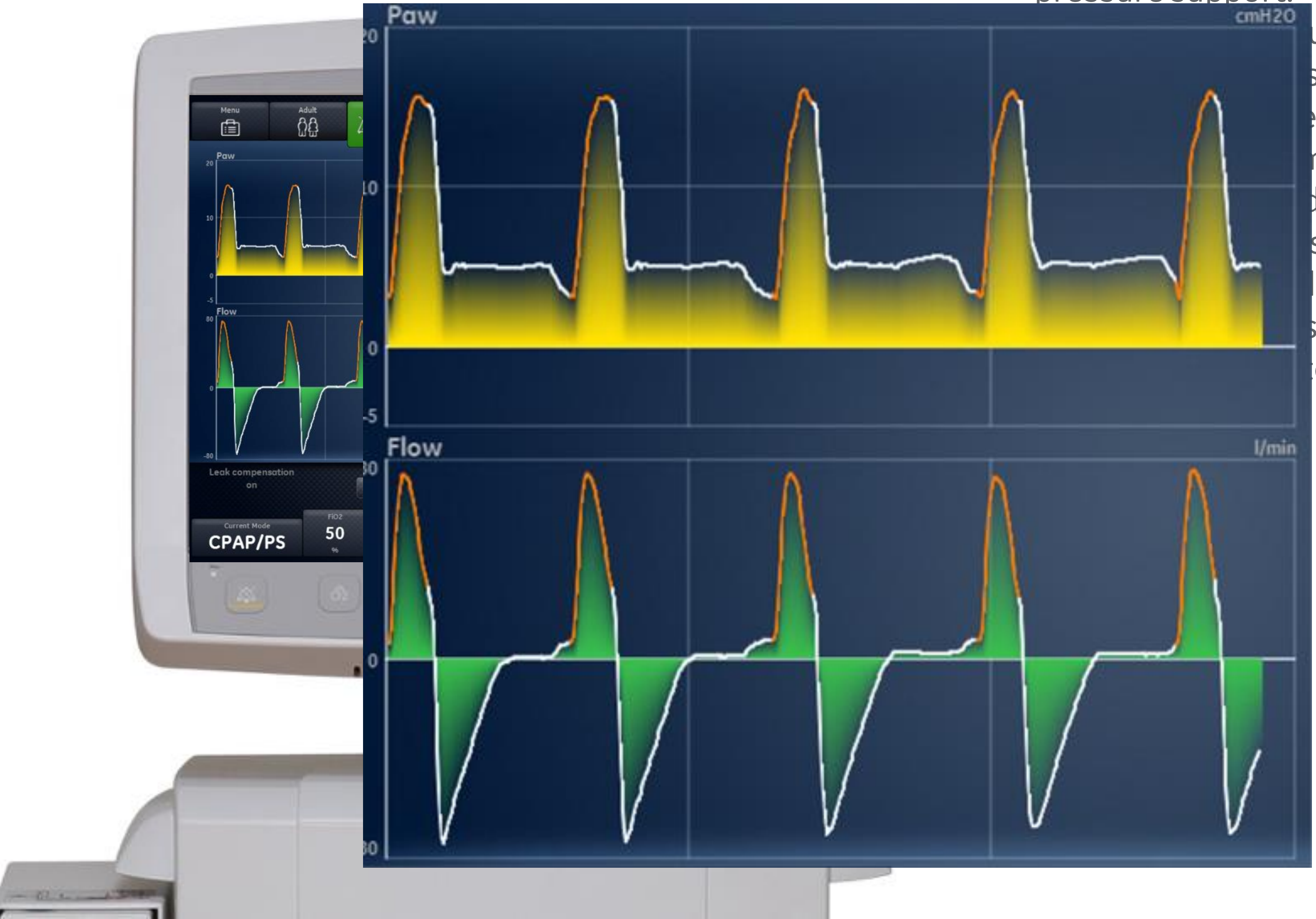
1. Airway pressure (Paw) waveform
2. Tinsp
3. Exp time
4. Pressure Support (PS)
5. Pinsp
6. PEEP
7. Flow waveform
8. Tidal Volume (VT)

Modes of Ventilation- Support Modes

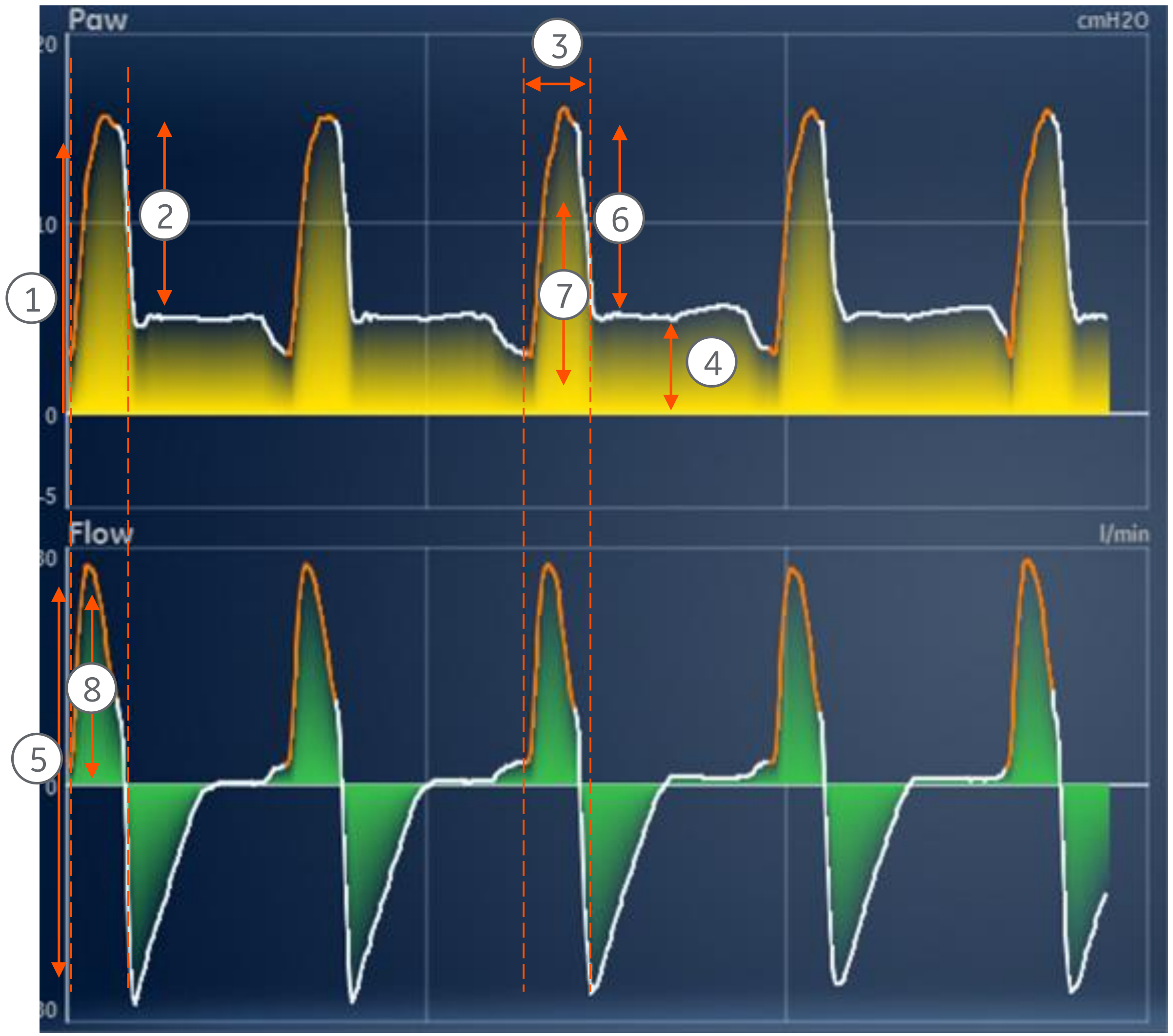
Continuous Positive Airway Pressure /Pressure Support (CPAP/PS)

- The ventilator maintains a PEEP level and provides pressure support.

used on spontaneously breathing patients
s spontaneous breaths and determines
e, timing, and tidal volume.
n Rate is set, the ventilator will deliver a
d mechanical breath if the patient's
s less than the minimum rate.
l breath will be delivered at the Backup
ssure setting for the time duration of the
tory Time setting.
is also available



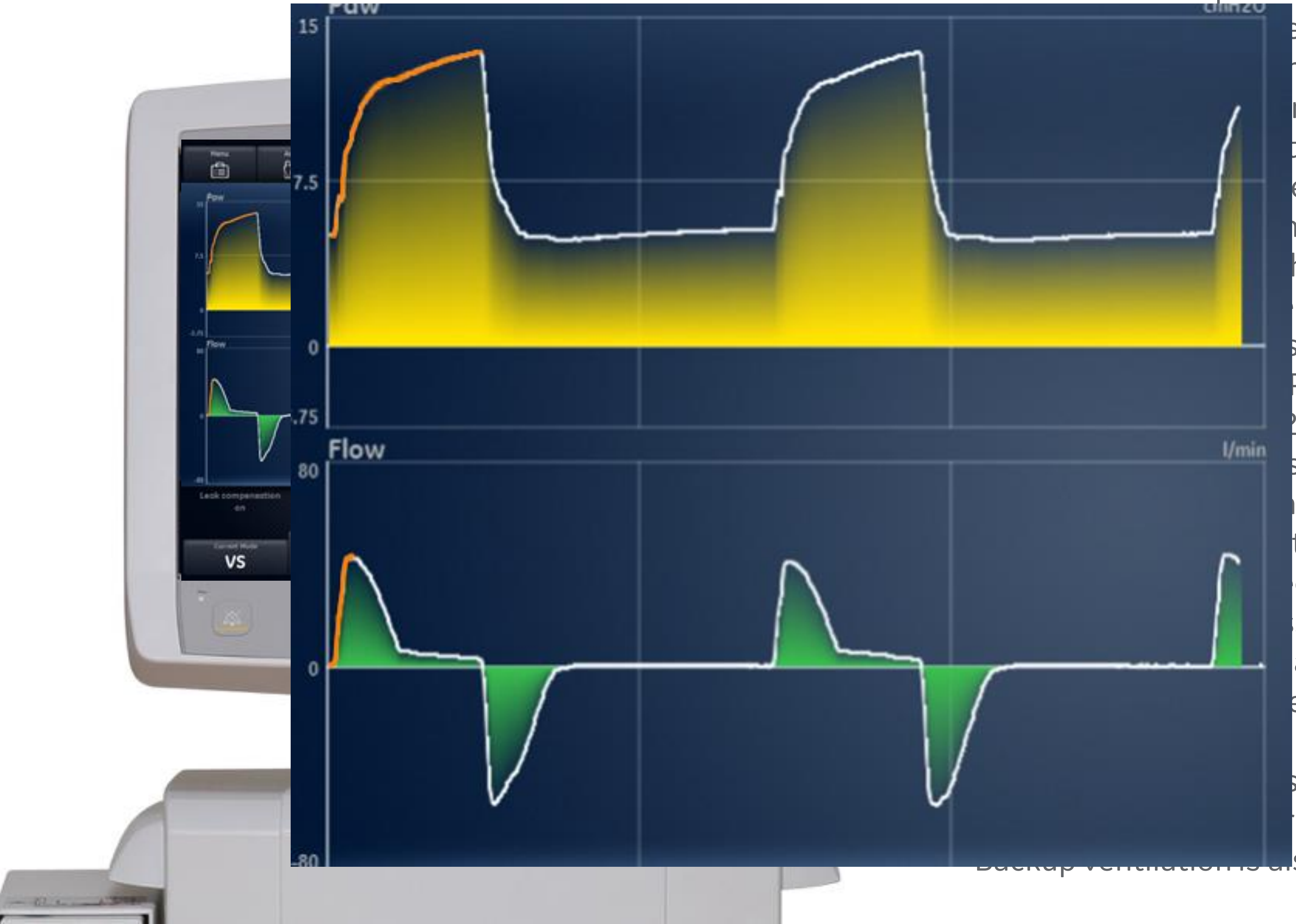
Continuous Positive Airway Pressure /Pressure Support (CPAP/PS)



1. Airway pressure (Paw) waveform
2. Pressure support (PS)
3. Inspiratory time (Backup Tinsp)
4. PEEP
5. Flow waveform
6. Backup Pinsp
7. Minimum rate backup breath
8. Tidal volume (TV)

Volume Support (VS)

- The patient initiates spontaneous breaths and determines respiratory rate and timing. The ventilator maintains a PEEP level and provides support to deliver the set tidal volume.
  - Intended for spontaneously breathing patients



…e ventilator adjusts the inspiratory pressure
…ressure required to deliver the tidal volume.
…nt's lung compliance, the ventilator delivers
…ilation for 10 seconds or 2 breath periods,
…en the mode is initiated.
…t's lung compliance, the inspiratory
…hed for subsequent breaths.
…inspiratory pressure the following
…sed:
…Pmin
… cmH2O
…spiratory pressure between breaths does
…H2O
…te is set, the ventilator will deliver a
…chanical breath if the patient's
…s than the minimum rate.
…ath will be delivered at the Backup PRVC
…e duration of the Backup Inspiratory Time

…ssure alarm is active for the current breath,
…ressure target is 0.5 cmH2O lower
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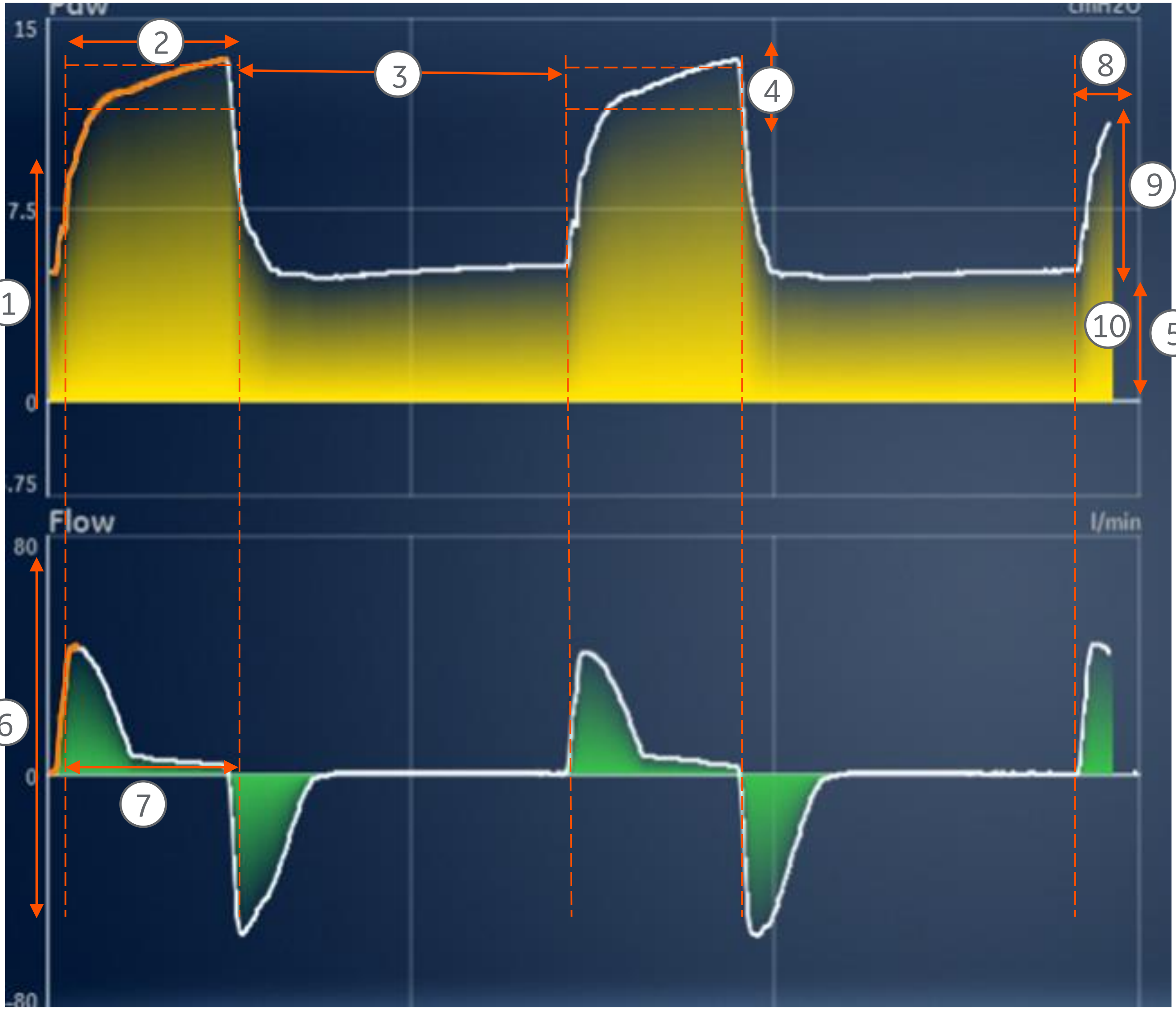
Volume Support (VS)



1. Airway pressure (Paw) waveform
2. Spontaneous inspiratory time
3. Spontaneous breathing period
4. Variable pressure
5. PEEP
6. Flow waveform
7. Tidal Volume (VT)
8. Inspiratory time (Backup Tinsp)
9. Backup Pinsp
10. Minimum rate backup breath

Airway Pressure Release Ventilation (APRV)*

- The ventilator alternates between a set high (Phigh)
e level.
on spontaneously breathing patients
eliver the set (Phigh) pressure for the set
ime.
eliver the set (Plow) pressure for the set
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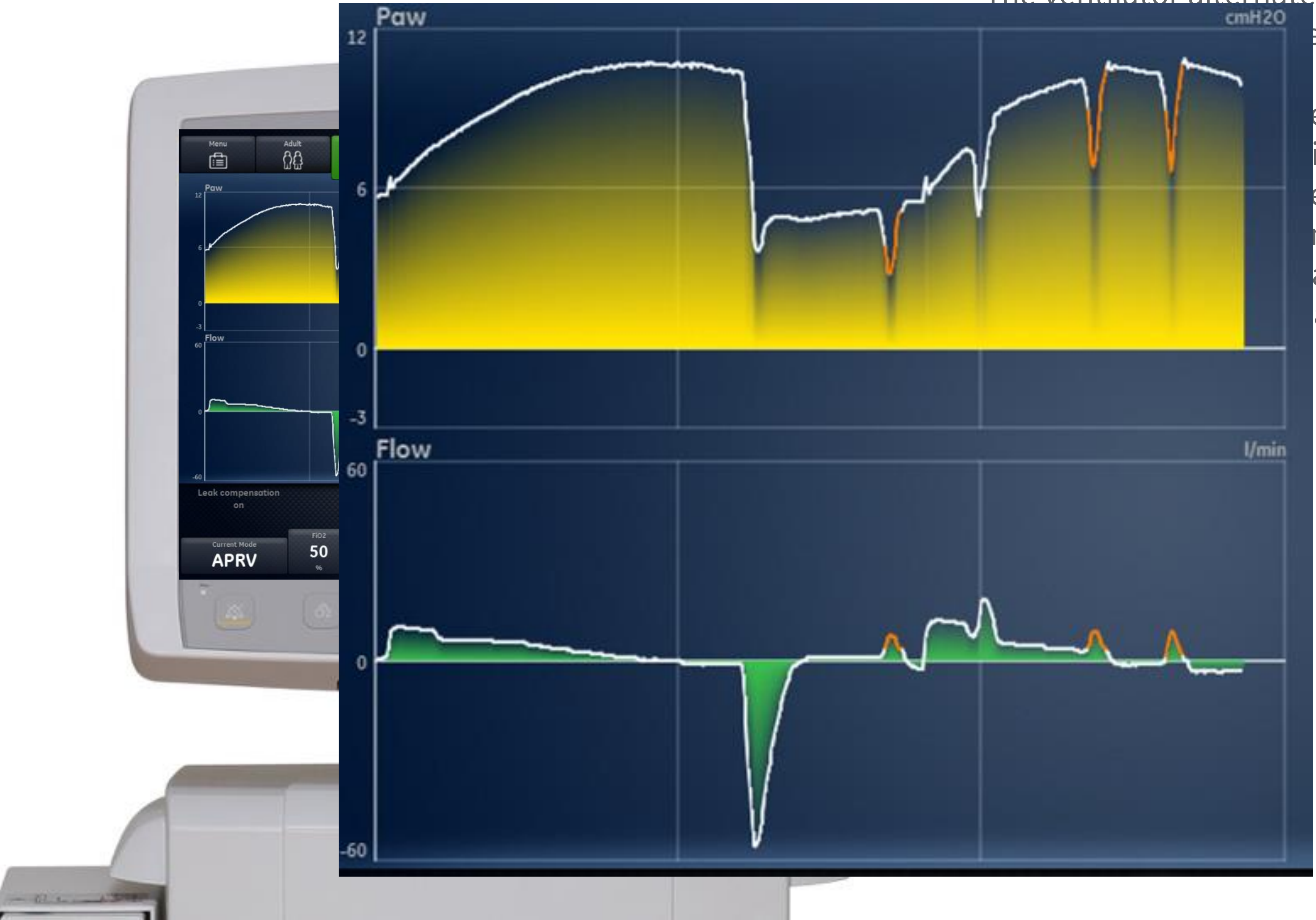
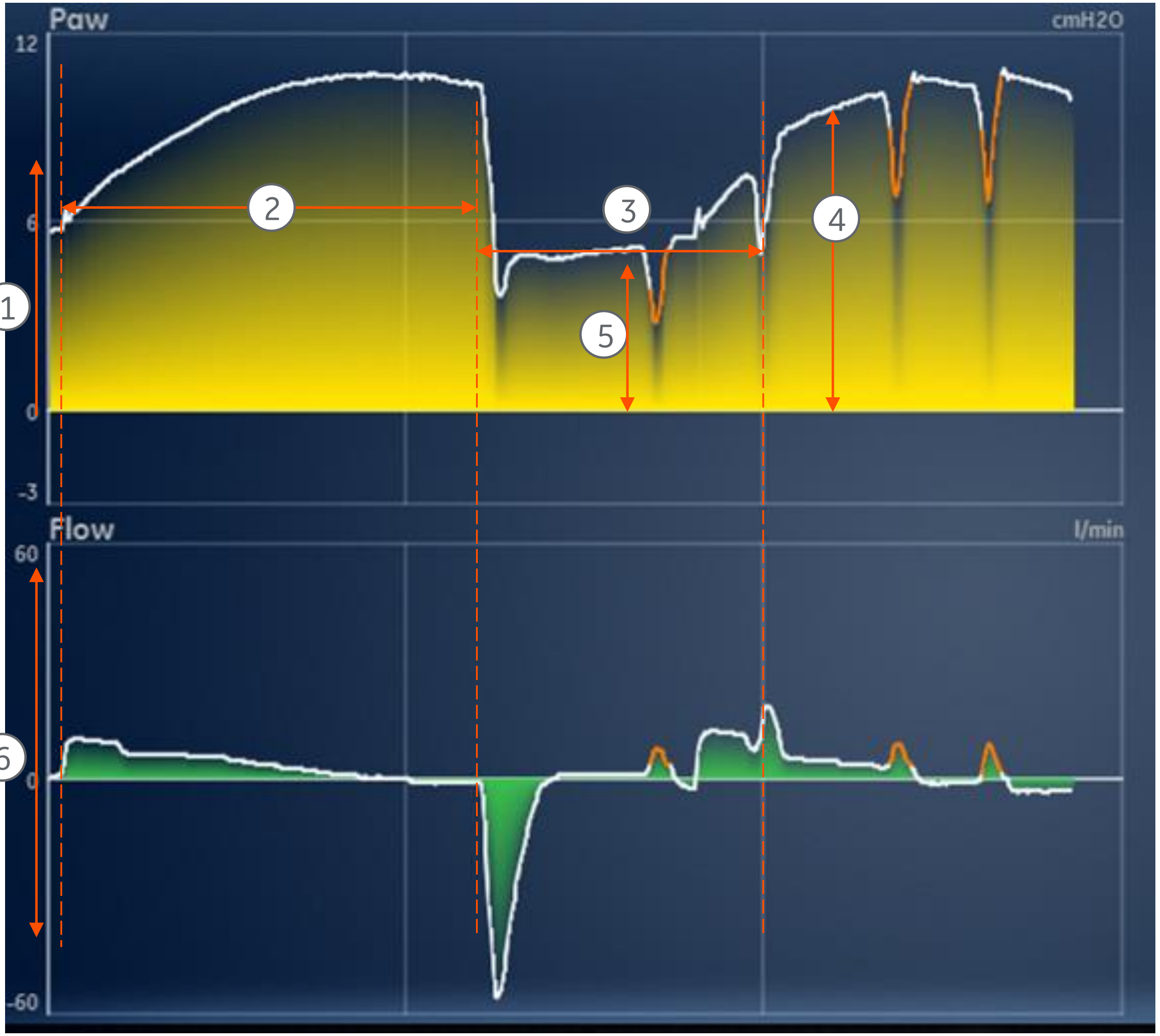
ate spontaneous breaths at either level
ailable



Airway Pressure Release Ventilation (APRV)*



1. Airway pressure (Paw) waveform
2. Thigh
3. Tlow
4. Phigh
5. Plow
6. Flow waveform

Modes of Ventilation Advantages and Disadvantages

Advantages and Disadvantages of Volume Control and Pressure Control

	Advantages	Disadvantages
Volume Control	• Constant tidal volume • Consistent alveolar ventilation • Easily identify changes in PIP and Pplat as respiratory mechanics change	• Constant flow rate • Increase in potential asynchronies • Varying pressures
Pressure Control	• PIP and peak alveolar pressures are constant • Flow varies with patient demand	• Varying tidal volumes

Hess DR, Kacmarek RM. Chapter 7: Pressure and Volume Ventilation. In: *Essentials of Mechanical Ventilation*. 4th ed. New York: McGraw Hill Education; 2019:70.

Advantages and Disadvantages of Pressure Regulated Volume Control

	Advantages	Disadvantages
Pressure Regulated Volume Control	• Targeted tidal volume • Pressure automatically adjusts based on lung compliance and airway resistance • Decelerating waveform • Variable inspiratory flow to meet patient's demand	• Pressure adjusts based on the tidal volume of the last breath • Asynchronies may occur with variable patient effort

Hess DR, Kacmarek RM. Chapter 8: Advanced Modes of Mechanical Ventilation. In: *Essentials of Mechanical Ventilation*. 4th ed. New York: McGraw Hill Education; 2019:74.

Advantages and Disadvantages of Airway Pressure Release Ventilation

	Advantages	Disadvantages
Airway Pressure Release Ventilation	• Uses "Open lung" concept • Maximize and maintain alveolar recruitment • Improve Oxygenation • Potential lung protective effect • Preservation of spontaneous breathing • Less need for sedation and neuromuscular blocking agents • Better ventilation to dependent lung regions • Better cardiac filling with spontaneous breathing • Reduce the risk of ventilator induced diaphragmatic dysfunction	• Increased work of breathing and oxygen consumption with spontaneous breathing • May create asynchrony and discomfort • Potential risks for volutrauma • Large tidal volume swings with spontaneous effort • Increased transpulmonary pressures • Greater need for clinical trials to demonstrate better clinical outcomes over conventional ventilation

Daoud EG, Farag HL, Chatburn RL. Airway Pressure Release Ventilation: What Do We Know? *Respiratory Care.* 2012;57(2):282. doi:10.4187/respcare.01238
Mireles-Cabodevila E, Kacmarek RM. Should Airway Pressure Release Ventilation Be the Primary Mode in ARDS? *Respiratory Care.* 2016;61(6):761. doi:10.4187/respcare.04653
Myers TR, Macintyre NR. Does Airway Pressure Release Ventilation Offer Important New Advantages in Mechanical Ventilator Support? *Respiratory Care.* 2007;52(4):452.

Conclusion

This concludes the CARESCAPE R860 Modes of Ventilation.

In this course, you learned about:

- Compliance, Elastance and Airway resistance
- CARESCAPE R860 ventilation modes categories
- Tube compensation, leak compensation and trigger compensation
- The CARESCAPE R860 modes of ventilation
- The advantages and disadvantages of volume control, pressure control, pressure regulated volume control and airway pressure release ventilation

Disclaimers
Always refer to device manufacturers user reference manual for specific application of your CARESCAPE R860.
Use this information as guidance and each patient may require clinical decisions not covered in this information.
Ensure proper clinically appropriate alarm limits are set and monitored.

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