vyaire™ MEDICAL

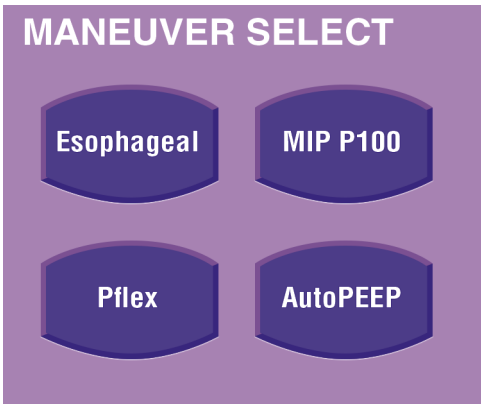
Avea™

critical care ventilation

ENHANCED PULMONARY MONITORING USER GUIDE

Table of contents

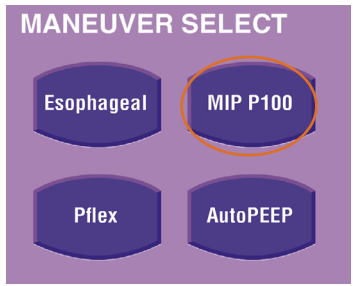
Avea ventilator maneuvers



MIP/P_{100} Maneuver screen

Maximum Inspiratory Pressure (MIP):

The P_{100} maneuver measures the negative deflection in the pressure tracing during the patient's active effort to demand a breath. During the maneuver, the inspiratory flow valve remains closed so no inspiratory flow is delivered.



Controls

Duration: This control determines the maximum time the maneuver will last. Normal ventilation suspends and resumes after the set time has elapsed.

Range: 5 to 30 sec

Default: 10 sec

Controls *(continued)*

Sensitivity: This control allows the clinician to set the maneuver sensitivity appropriate to patient ability. This setting establishes the level below PEEP that the airway pressure must drop before a determination of the onset of a patient effort is determined. Once patient effort is detected, the timer for the maneuver duration starts. Maneuver sensitivity does not affect ventilator trigger sensitivity.

Range: 0.1 to 5 cmH_2O

Default: 3 cmH_2O

> **NOTE:** An excessively high setting of the maneuver sensitivity can affect the accuracy of timing for P_{100} determination.

Start/Stop: This maneuver begins when **START** is pressed. The maneuver immediately terminates when **STOP** is pressed. When **STOP** is pressed, normal ventilation can resume.

> **NOTE:** If Start is pressed during a mandatory inspiratory breath, the maneuver does not begin until the ventilator cycles into exhalation and the minimum expiratory time of 150 msec has elapsed.

Maximum inspiratory pressure (MIP)

MIP is the maximum negative airway pressure a patient achieves during an expiratory hold maneuver. It can be a good indicator of inspiratory muscle strength, useful in the weaning process and a means of determining the progression of neuromuscular disease.

Range: -60 to 120 cmH_2O

Normal: -70 to -100 cmH_2O *(adults)*

-20 to -100 cmH_2O *(pediatrics)*

Readiness for extubation < -20 cmH_2O

NOTE: Patient effort can vary based on many factors *(e.g., disease process, level of sedation, comprehension of instructions, motivation)*. MIP decreases in conditions such as kyphoscoliosis, advanced age, chronic obstructive pulmonary disease (COPD) and neuromuscular disease.

Respiratory drive (P_{100})

The P_{100} is the negative pressure that occurs 100 ms after an inspiratory effort has been detected while the inspiratory valve is closed. Because it normally takes at least 300 ms for the patient to become aware of the occluded airway, P_{100} is a good test of the respiratory center output. Because no change in lung volume or airflow occurs during this initial 300 ms, abnormalities in lung mechanics do not affect the measurement.

P_{100} = Pend 100 – PEEPaw

Range: 60 to 120 cmH_2O

Normal: -1 to -4 cmH_2O *(adults)*

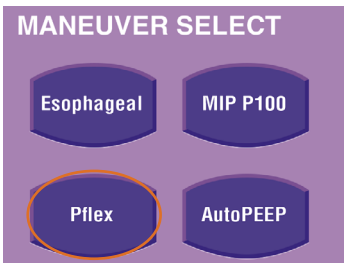
-0.5 to -4 cmH_2O *(pediatrics)*

A high value *(more negative)* result reflects patient drive and strength. However, a value more negative than -5 cmH_2O may also indicate a high respiratory drive that increases work of breathing and subsequent fatigue. Therefore, it is important to conduct a thorough patient assessment if this measurement is to be the patient's readiness to wean from ventilatory support.

Inflection Point (Pflex) Maneuver screen

The Pflex Maneuver is performed on patients during mandatory ventilation. Once the maneuver tidal volume is delivered, the ventilator cycles into exhalation and returns to normal ventilation at the current ventilator settings. The pressure/volume (P_{AW}/Vol) loop freezes with upper and lower inflection points that are automatically calculated and displayed on the inspiratory portion of the P_{AW}/Vol loop.

The lower inflection point indicates the point that collapsed airways begin to reopen. This can be affected by both airway closure and alveolar collapse, causing the point to be farther to the right because more pressure is required to open the airways. Alveoli are continually recruited throughout the steep portion of the PV curve. The upper inflection point represents the point that further applied pressure results in overdistention.



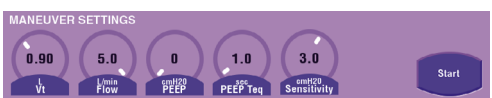
Inflection Point (Pflex) Maneuver screen *(continued)*

The user can override the calculated Pflex values by moving the Pflex indicators to a new point along the PV loop and pressing the appropriate key. The corresponding Pflex values and delta Pflex volume change to represent values based on the current position of the indicators. The ventilator can store up to four PV loops and their respective inflection points simultaneously.

NOTE: Once the values have been redefined by the operator, the original values cannot be restored. Normal ventilation suspends for the duration of the maneuver. The maneuver terminates if a patient effort is detected. The message bar provides text stating that patient effort was detected.

Controls

Tidal volume *(volume)*: This control determines the volume of gas delivered to the patient during the maneuver.



Range: 0.1 to 2.5 L *(adults)*
25 to 500 mL *(pediatrics)*

Default: 0.25 L *(adults)*
25 mL *(pediatrics)*

NOTE: The tidal volume is not circuit-compliance compensated.

Controls *(continued)*

Peak flow: This control sets the peak flow.

Range: 0.5 to 5 L/min **Default:** 1 L/min

NOTE: A square wave flow pattern is used.

Maneuver PEEP: This control determines the baseline pressure when the maneuver begins.

Range: 0 to 50 cmH_2O **Default:** 0 cmH_2O

NOTE: The maneuver PEEP can be set independently of the PEEP used during normal ventilation.

PEEP equilibration time (PEEP Teq): This control allows for airway pressure equilibration prior to the maneuver. When the maneuver begins, PEEP is set for the Equilibration Time.

Range: 0 to 30 sec **Default:** 1 sec

Sensitivity: Establishes the level below the peak airway pressure that the pressure must drop to terminate the P_{flex} maneuver. Maneuver sensitivity has no effect on ventilator trigger sensitivity.

Range: 0.1 to 5 cmH_2O **Default:** 3 cmH_2O

NOTE: The maneuver terminates if a patient effort is detected, and a message displays.

Controls *(continued)*

Start/Stop: This maneuver begins when Start is pressed and immediately terminates when Stop is pressed, a patient effort is detected or the maneuver tidal volume has been delivered. Once the maneuver terminates, normal ventilation resumes.

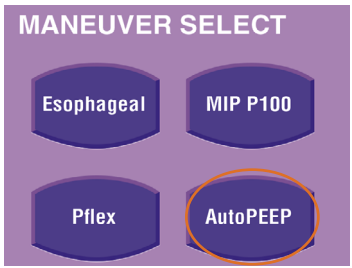
Normal: < 5 cmH_2O *(lower)*

28 to 32 cmH_2O *(upper-adults)*

20 to 26 cmH_2O *(upper-pediatrics)*

After the maneuver completes, the operator may reselect the upper and lower points using the cursor. The tidal volume delivered between the two points is represented by the delta tidal volume.

AutoPEEPaw Maneuver screen



AutoPEEP occurs when insufficient expiratory time or dynamic flow limitation is present, which results in gas trapping. This is common in asthma or severe COPD.

AutoPEEPaw: This function measures airway pressure at the end of exhalation before the beginning of the next mandatory inspiration. During this maneuver, the ventilator executes an expiratory hold with both the inspiratory and expiratory valves closed. The ventilator establishes the AutoPEEPaw measurement when the system pressure reaches equilibration, at the next mandatory breath interval or after six seconds—whichever comes first.

Range: 0 to 50 cmH_2O

Default: 0 cmH_2O above the applied PEEP

NOTE: This maneuver requires a passive patient and a cuffed endotracheal (ET) tube.

Controls

Sensitivity: This control establishes the level that the airway pressure must drop below PEEP to terminate the AutoPEEPaw maneuver. Maneuver sensitivity has no effect on ventilator trigger sensitivity.

Range: 0.1 to 5 cmH_2O

Default: 3 cmH_2O

Start/Stop: The maneuver begins when Start is pressed and the ventilator is in exhalation. The maneuver stops immediately when Stop is pressed, the maneuver completes or a patient effort is detected. Once the maneuver stops, normal ventilation resumes.

> **NOTE:** If a patient effort is detected, the maneuver terminates and the message bar indicates patient effort was detected.

Delta AutoPEEPaw (dAutoPEEPaw): This tool calculates the difference between airway pressure at the end of an expiratory hold maneuver and the airway pressure at the start of the next mandatory breath, after the expiratory hold maneuver.

Delta AutoPEEPaw = Intrinsic PEEP – Applied PEEP

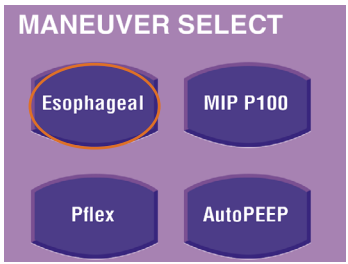
Range: 0 to 50 cmH_2O

> **NOTE:** This measurement requires a passive patient and a cuffed ET tube.

Esophageal maneuver screen

Testing

1. A balloon test must be performed prior to placing the esophageal balloon. Connect the extension tubing and esophageal balloon to the ventilator, and select Esophageal Maneuver from the Maneuver Select menu.
2. Confirm the balloon is not yet placed in the patient.



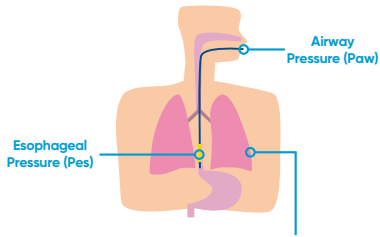
Testing *(continued)*

3. Press the Balloon Test soft key. The balloon fills and empties twice to confirm its integrity. Once this process completes, a **Balloon Test Passed** message appears in the message bar.
4. Insert the catheter.

Placement

Once the balloon leak test is passed, the balloon is ready for placement. Proper placement is imperative for accurate measurements. An approximate level of placement can be made by measuring the distance from the tip of the nose to the bottom of the earlobe and from the earlobe to the distal tip of the xiphoid process.

WARNING: Esophageal balloon placement should only be conducted under direction of a physician who has assessed the patient for contraindications to esophageal balloon use.



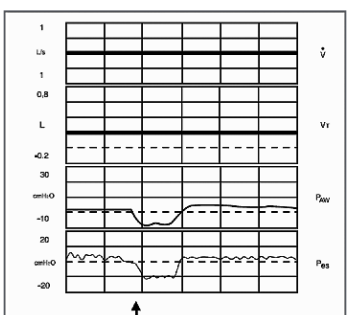
Transpulmonary pressure (Ptp) Ptp = Paw - Pes [4]

Illustration is provided for educational purposes only.

Placement *(continued)*

After the catheter is inserted, touch Pes Off. The key changes color and reads Pes On. The ventilator fills the balloon to the appropriate level and begins monitoring data.

Confirming proper placement: Once the balloon is placed, the appropriate balloon location can be confirmed by performing an occlusion technique. This requires that the airway be occluded and the esophageal and airway pressures be compared for similarity.



The Baydur maneuver *(Am Rev. Resp Dis,* 1982, 126:788). During an expiratory hold *(i.e., inspiratory and expiratory circuit occlusion),* a patient inspiratory effort is initiated *(allow).* With proper placement of the esophageal balloon, simultaneous negative deflections in airway and Pes should be observed.

Additional information

The waveform produced can further confirm proper placement. Pes waveforms correlate to airway pressure in that they become positive during a positive pressure breath and negative during a spontaneous breath. Esophageal tracings may also show small cardiac oscillations reflective of cardiac activity.

A. Airway pressure

B. Pes

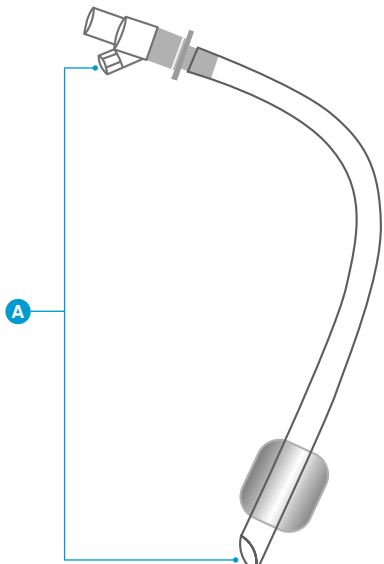
NOTE: Airway pressure and Pes waveforms both have a positive deflection, indicating proper balloon placement.

Tracheal catheter

Placement

Some advanced mechanics measurements on the Avea ventilator require a tracheal catheter. To ensure the accuracy of measurements and minimize risk, place the tracheal catheter in the ET tube, and should not extend beyond the tip of the tube.

A. The length of the tracheal catheter should not exceed the length of the ET tube plus the adapter.



Placement *(continued)*

To ensure proper placement, measure the length of the ET tube and its associated adapters. Insert the tracheal catheter into the ET tube, and ensure the catheter does not extend beyond the tip of the tube. Next, assess the patient for signs of adverse response indicating the catheter may have been advanced beyond the tip of the ET tube. Final confirmation of placement should be obtained by assessment of a chest x-ray.

WARNING: Inserting the tracheal catheter beyond the tip of the ET tube may irritate and inflame the trachea and airways or produce vagal responses in some patients.

Advanced pressure monitoring of the respiratory system

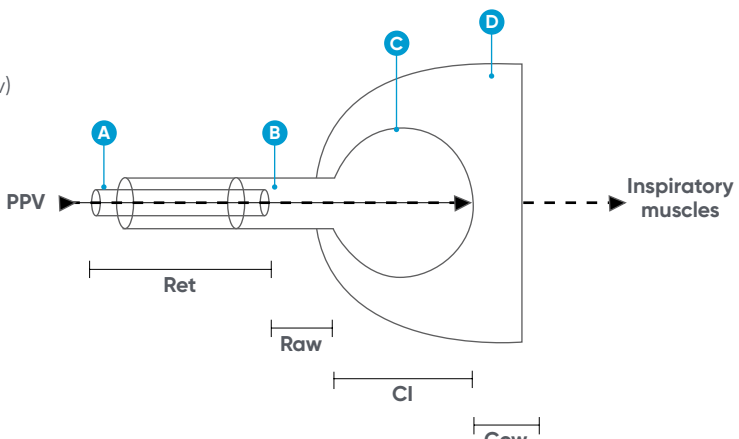
The respiratory system behaves as four mechanical elements in series: endotracheal tube resistance (Ret), airway resistance (Raw), lung compliance (Cl) and chest wall compliance (Ccw). Pressure monitoring at various sites depends on these elements because they interact with delivered flow/volume and the source of the driving pressure.

A. Pairway (Paw)

B. Ptrachea (Ptr)

C. Palveolus (Palv)

D. Ppleura (Pes)



Advanced mechanics

Compliance

Rapid shallow breathing index (f/Vt): This index indicates the spontaneous breath rate per tidal volume, based on the formula:

$f/Vt = f^2/Ve$

f = spontaneous breath rate (BPM)

Ve = spontaneous minute ventilation in L/min

Range: 0 to 500 b^2 /min/L

Normal: ≤ 105

> **NOTE:** This information should be considered with other weaning criteria and thorough patient assessment while deciding on extubation potential.

Chest wall compliance (Ccw): This measurement is a ratio of exhaled tidal volume to delta esophageal pressure (dPes). Ccw depends on extra-pulmonary processes. For example, Ccw reduces with restrictive conditions, such as kyphoscoliosis, ankylosing spondylitis, ascites, proning and obesity.

Compliance *(continued)*

$$\text{Ccw} = \frac{\text{Vte}}{\text{dPes}}$$

Range: 0 to 300 mL/cmH_2O

Normal: 175 to 200 mL/cmH_2O *(adults)*

50 to 190 mL/cmH_2O *(pediatrics)*

NOTE: Requires placement of an esophageal balloon catheter.

Dynamic lung compliance (Clung): The ratio of the tidal volume *(exhaled)* to the delta transpulmonary pressure. The delta transpulmonary pressure is the difference between the airway plateau pressure during an inspiratory pause and Pes at the time the airway plateau pressure is measured, minus the difference between the airway and esophageal baseline pressures. Clung decreases in conditions, such as acute respiratory distress syndrome (ARDS), pneumonia and fibrotic lung disease.

$$\text{Clung} = \frac{\text{Vte}}{\text{dPplat tp}}$$

Compliance *(continued)*

Where: dPplat tp = (Pplat aw – Pes) – (PEEPaw – PEEPes)

Range: 0 to 300 mL /cmH_2O

Normal: 175 to 200 mL /cmH_2O *(adults)*

50 to 190 mL /cmH_2O *(pediatrics)*

NOTE: This measurement requires an inspiratory hold maneuver esophageal balloon catheter.

Compliance ratio (C_{20}/C): This ratio measures dynamic compliance during the last 20% of inspiration to total dynamic compliance.

Range: 0 to 5

NOTE: A ratio less than 1 would be considered overdistention.

Resistance

Respiratory system resistance (Rrs): Rrs is the airway pressure differential *(peak minus plateau)* to the inspiratory flow 12 ms prior to end inspiration. Rrs is a combination of artificial airway resistance (Rimp) and lung airway resistance (Rlung). Rrs increases with small artificial airways and asthma.

Range: 0 to 100 $cmH_2O/L/sec$

Normal: 2 to 5 $cmH_2O/L/sec$ *(adults)*

2 to 20 $cmH_2O/L/sec$ *(pediatrics)*

NOTE: Rrs measures volume breaths only and requires an inspiratory hold maneuver.

Peak expiratory resistance (Rpeak): This ratio is the resistance at the time of the peak expiratory flow (PEFR).

$$\text{Rpeak} = \frac{\text{PPEFR}}{\text{PEFR}}$$

Range: 0 to 100 $cmH_2O/L/sec$

Normal: 3 to 10 $cmH_2O/L/sec$ *(adults)*

2 to 8 $cmH_2O/L/sec$ *(pediatrics)*

Resistance *(continued)*

Imposed resistance (Rimp): The measurement between the circuit wye and tracheal sensor during the inspiratory hold. Small artificial airways and high flow rates increase Rimp.

Range: 0 to 100 $cmH_2O/L/sec$

Normal: 4 to 12 $cmH_2O/L/sec$ *(adults)*

6 to 15 $cmH_2O/L/sec$ *(pediatrics)*

NOTE: The measurement requires a tracheal catheter and an inspiratory hold maneuver.

Lung resistance (Rlung): The ratio of the tracheal pressure differential *(peak minus plateau)* to the inspiratory flow 12 ms prior to end of inspiration. This value increases in the presence of conditions, such as COPD and obesity.

Range: 0 to 100 $cmH_2O/L/sec$

Normal: 1.2 to 4.5 $cmH_2O/L/sec$ *(adults)*

1.2 to 3.4 $cmH_2O/L/sec$ *(pediatrics)*

NOTE: This ratio requires an inspiratory hold maneuver and placement of a tracheal catheter.

Flow

Peak inspiratory flow rate (PIFR): This rate is the actual peak inspiratory flow rate for the inspiratory phase of a breath.

Range: 0 to 300 L/min *(all patients)*

Normal: 50 to 60 L/min *(adults)*

10 to 50 L/min *(pediatrics)*

Peak expiratory flow rate (PEFR): This rate is the actual peak expiratory flow rate for the expiratory phase of a breath.

Range: 0 to 300 L/min *(all patients)*

Normal: 30 to 40 L/min *(adults)*

10 to 35 L/min *(pediatrics)*

Pressure

Delta airway pressure (dPaw): This pressure reflects the difference between peak airway pressure (Ppeak aw) and baseline airway pressure (PEEPaw).

dPaw = Ppeak aw – PEEPaw

Range: -120 to 120 cmH_2O

Normal: 20 to 30 cmH_2O *(adults)*

12 to 24 cmH_2O *(pediatrics)*

Delta esophageal pressure (dPes): This pressure reflects the difference between peak esophageal pressure (Ppeak es) and baseline esophageal pressure (PEEPes).

dPes = Ppeak es – PEEPes

Range: -120 to 120 cmH_2O

Normal: 15 to 25 cmH_2O *(adults)*

7 to 19 cmH_2O *(pediatrics)*

Pressure *(continued)*

Transpulmonary pressure plateau (PtpPlat): This pressure reflects the difference between airway plateau pressure (Pplat aw) and the corresponding Pes during an inspiratory hold.

PtpPlat = Pplat aw – Pes

Range: -60 to 120 cmH_2O

Normal: 13 to 18 cmH_2O *(adults)*

8 to 15 cmH_2O *(pediatrics)*

NOTE: This measurement requires an inspiratory hold maneuver and esophageal balloon catheter placement.

AutoPEEP

AutoPEEPes: AutoPEEPes measures the difference between the Pes measured at the end of exhalation (PEEPes), minus the Pes measured at the start of a patient-initiated breath (Pes start) and the sensitivity of the ventilator's demand system.

The sensitivity of the ventilator's demand system is the difference between baseline airway pressure (PEEPaw) and the airway pressure when the patient initiates a breath (Paw start). The difference between PEEPes and Pes start reflects the muscle pressure that must be generated to overcome AutoPEEP before changes in circuit pressure or flow.

A proper sensitivity setting is crucial. An improper setting can mean the patient must expend muscle energy that may not result in successfully triggering the ventilator. This leads to a value that does NOT truly reflect AutoPEEP.

AutoPEEPes will be elevated in conditions of incomplete emptying on exhalation, leading to the presence of AutoPEEP. AutoPEEP is a significant inspiratory load for the patient.

AutoPEEPes = (PEEPes – Pes start) – (PEEPaw – Paw start)

Range: 0 to 50 cmH_2O

Normal: 0

NOTE: This measurement requires esophageal balloon catheter placement.

AutoPEEP *(continued)*

Transpulmonary pressure, AutoPEEP (PtpPEEP): The difference between the corresponding airway and Pes at the end of an expiratory hold during an AutoPEEP maneuver.

PtpPEEP = Paw – Pes *(at the end of an expiratory hold)*

Range: -60 to 120 cmH_2O

Normal: 0

> **NOTE:** This measurement requires an expiratory hold and esophageal catheter placement.

Work of breathing

Ventilator work of breathing (WOBv): This equation calculates the summation of Paw minus baseline airway pressure (PEEPaw) multiplied by the change in tidal volume to patient (ΔV) during inspiration and normalized to total inspiratory tidal volume (Vti).

If Paw = PEEPaw,

$$\textbf{WOBv} = \frac{\sum(\textbf{Paw} - \textbf{PEEPaw})\,\Delta V}{\textbf{Vti}}$$

Range: 0 to 20 Joules/L

Normal: 0.1 to 0.8 Joules/L *(adults)*

0.05 to 0.6 Joules/L *(pediatrics)*

Work of breathing *(continued)*

Patient work of breathing (WOBp): This equation calculates the summation of two work components: work of the lung and work of the chest wall, normalized to the delivered tidal volume.

$$WOBp = WOBlung + WOBcw$$

$$\textit{where}\quad WOBlung = \sum_{Testart}^{Tiend} (PEEPes - Pes)\,\Delta V \qquad \textit{(if PEEPes > Pes and V > 0)}$$

$$\textit{And}\quad WOBcw = \frac{Vp^2}{2Ccw} \qquad \textit{(if PEEPes > Pes)}$$

Normal: 0.4 to 0.6 Joules/L *(adults)*

0.2 to 0.5 Joules/L *(pediatrics)*

NOTE: For weaning from mechanical ventilation: < 0.98 Joules/L *(adults)*, < 0.50 Joules/L *(pediatrics)*

Work of breathing *(continued)*

Work of the lung (WOBlung): The calculation using Pes when PEEPes is greater than Pes, indicating patient effort. Work of the chest wall (WOBcw) for a spontaneously breathing patient is calculated using only the portion of the total tidal volume delivered due to patient effort (Vp) and Ccw.

Range: 0 to 20 Joules/L

Normal: 0.4 to 0.6 Joules/L *(adults)*

0.2 to 0.5 Joules/L *(pediatrics)*

Readiness to wean: < 0.98 Joules/L *(adults)*

< 0.50 Joules/L *(pediatrics)*

NOTE: This measurement requires esophageal balloon catheter placement.

Work of breathing *(continued)*

Imposed work of breathing (WOBi): WOBi reflects the work performed by the patient to breathe spontaneously through the breathing apparatus *(e.g., the ET tube, breathing circuit, demand flow system).* Imposed work is assessed by integrating the change in tracheal pressure and tidal volume, and normalizing the integrated value to the total inspiratory tidal volume (Vti) based on the following formula:

$$\mathbf{WOBi} = \int_{0}^{Vti} \mathbf{(PEEPaw - PTR)} * \frac{dV}{dt}$$

PEEPaw = Airway baseline pressure

Ptr = Tracheal pressure

Vti = Inspired tidal volume

Range: 0 to 20 Joules/L

Normal: 0.15 to 0.3 Joules/L *(adults)*

0.1 to 0.2 Joules/L *(pediatrics)*

NOTE: This measurement requires tracheal catheter placement.

Avea ventilator screens

A mandatory, patient-triggered breath. Note a low WOBp and WOBi with high WOBv.

A. Low WOBp

B. WOBi

C. WOBv

A patient-triggered, pressure-supported breath. Note a higher WOBp and WOBi with lower WOBv and small amounts of AutoPEEP present.

A. AutoPEEP

Notes

Notes

Notes

vyaire™
MEDICAL

⚠ **WARNING**—U.S. Federal Law restricts this device to sale by or on the order of a physician.

GLOBAL HEADQUARTERS

Vyaire Medical, Inc.
26125 North Riverwoods Blvd
Mettawa, IL 60045, USA

Vyaire Medical, Inc.
22745 Savi Ranch Parkway
Yorba Linda, CA 92887, USA

vyaire.com

©2018 Vyaire. Vyaire, the Vyaire Logo and Avea are trademarks of Vyaire Medical, Inc. | 32114-001 Version A (0218)