Modes of ventilation

Invasive and non-invasive
Servo-i 8.0

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Contents

Introduction

Mechanical ventilation is required when a patient is unable to achieve adequate ventilation and gas exchange. The ventilation pattern must be adapted to suit the patient's need for oxygenation and CO_2 elimination. The Servo-i ventilator system provides ventilation modes which clinicians can tailor to the patients' needs.

This pocket guide only covers selected topics and cannot replace the user's manual.

Summary of ventilation modes

Invasive modes

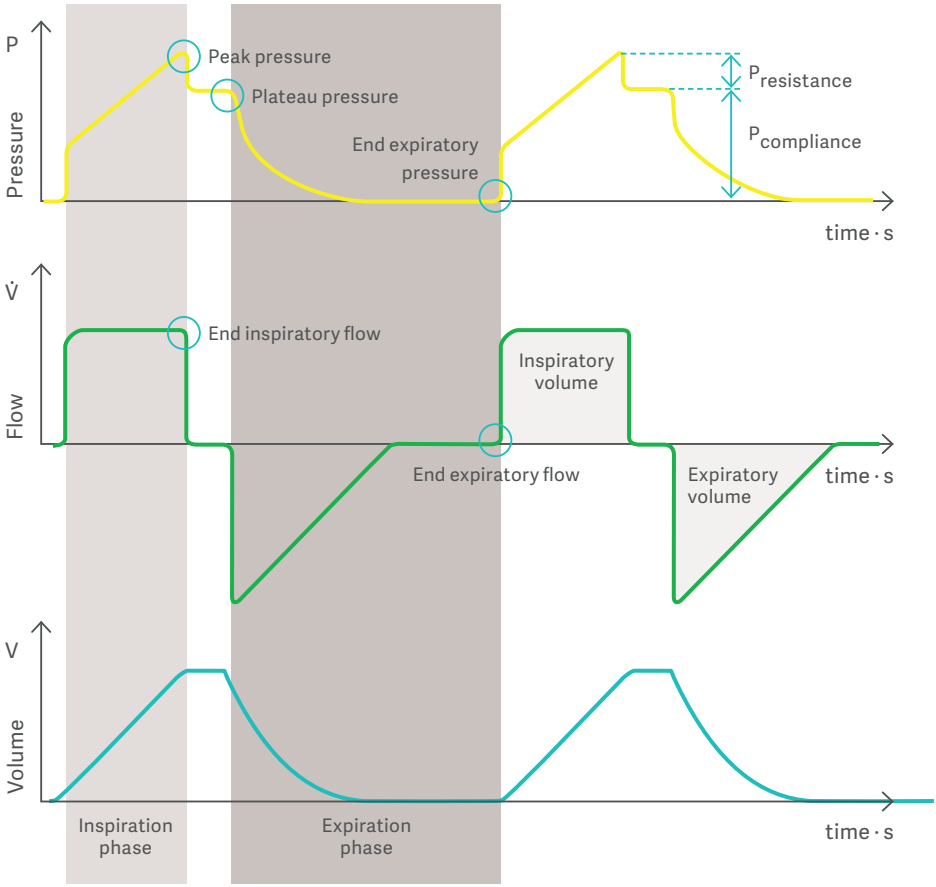
Controlled modes	Supported modes	Combined modes
VC	PS	Automode: VC-VS PC-PS PRVC-VS SIMV: VS-PS VC-PS PRVC-PS Bi-Vent/APRV
PC	VS	
PRVC	NAVA	

Non invasive modes

Supported modes	Controlled modes
NIV PS/CPAP	NIV-PC
NIV NAVA	
Nasal CPAP	

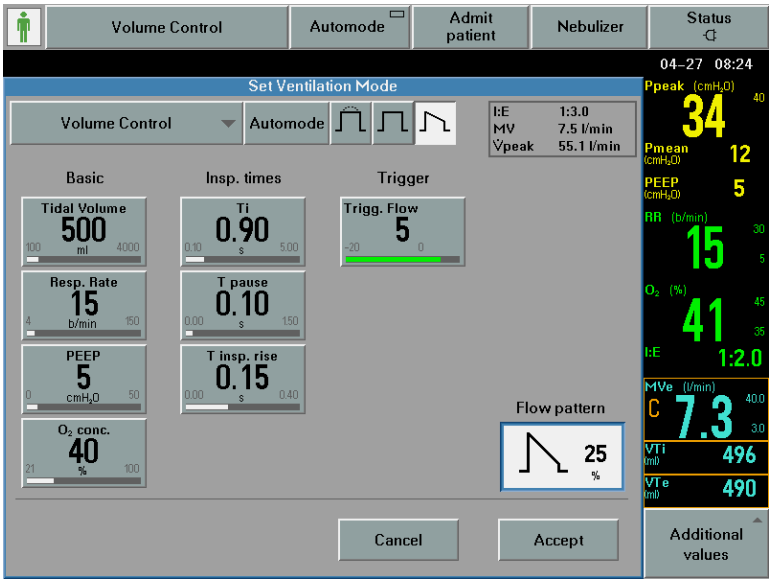
Flow pattern – Volume Control ventilation

The flow pattern in Volume Control and SIMV (VC) is constant during inspiration. During the pause time the flow is zero. At the beginning of expiration, flow is large. It gets smaller and smaller and reaches zero by the end of expiration.



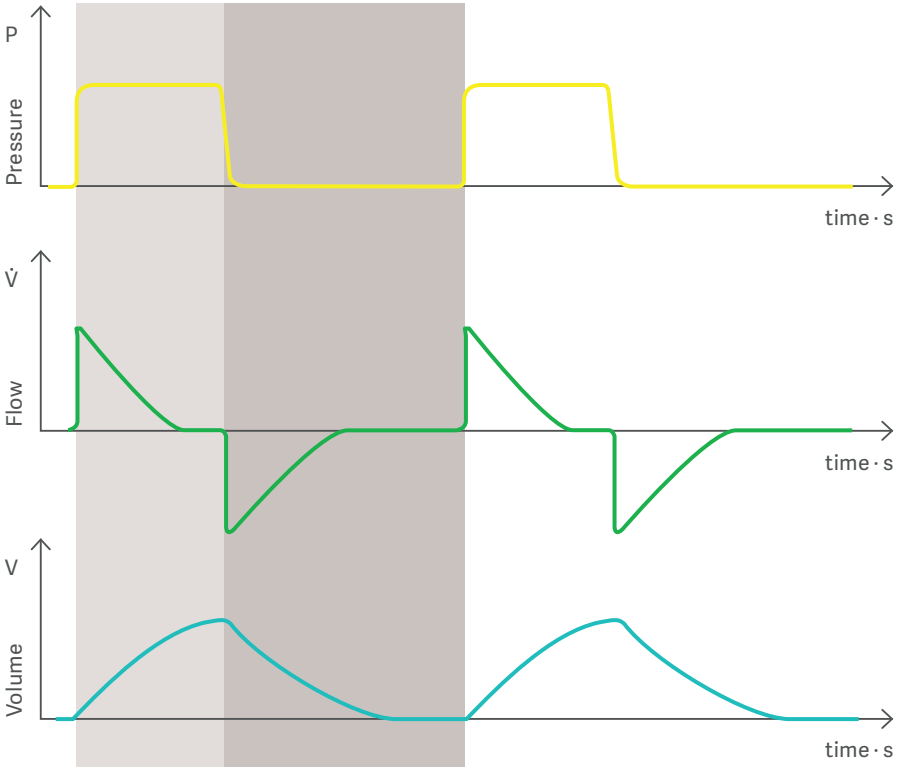
Introduction

It is possible to choose decelerating flow in Volume Control. The Volume Control with alternative flow patterns is enabled in the start-up configuration.



Flow pattern – Pressure Control ventilation

In Pressure Control, Pressure Regulated Volume Control (PRVC), Pressure Support, Volume Support, SIMV (PRVC) with Pressure Support and SIMV (PC) with Pressure Support, the flow is decelerating and the pressure is constant.

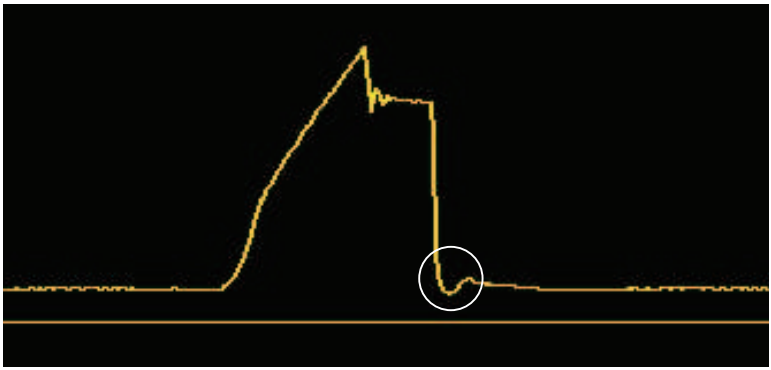


Fast PEEP/expiration valve

The PEEP/expiration valve of the Servo ventilators is extremely fast and allows rapid and accurate control.

In order to facilitate a fast expiration, the expiratory valve is opened fully for a very short time during the start of the expiration.

The pressure in the breathing system then transiently drops below the set PEEP value, but still the intrapulmonary pressure is kept above PEEP.



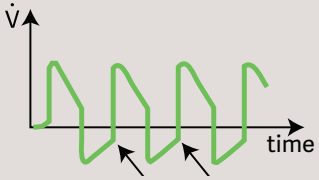
Important ventilatory settings – Invasive ventilation

PEEP

Positive End Expiratory Pressure (PEEP) can be set in the range of 0–50 cmH_2O. A Positive End Expiratory Pressure is maintained in the alveoli and may prevent collapse of the airways.

Auto-PEEP

If the respiratory rate is set high or the expiratory time is not long enough there is a risk for auto-PEEP. The patient does not have enough time to exhale and it is evident on the flow curve that flow will not return to zero before the next breath starts.



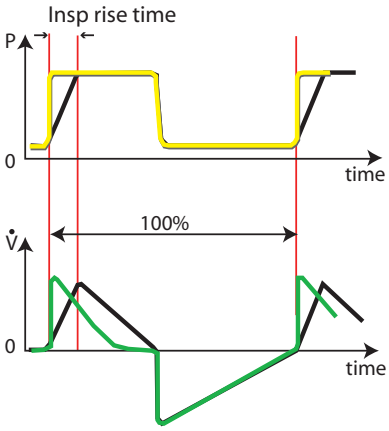
There are different ways to check on the Servo-i if the patient has an auto-PEEP:

- The Exp. flow will not go back to zero before the next inspiration starts.
- V̇ee is not zero, see 2nd page of Additional values on the User Interface.
- V̇ee (End expiratory flow)
- Total PEEP = set PEEP + Auto-PEEP. Press "Exp. Hold" for a few seconds to see total PEEP on 3rd page of Additional values on the User Interface.

Inspiratory rise time

Inspiratory rise time is the time taken to reach peak inspiratory flow or pressure at the start of each breath, expressed either as a percentage of the respiratory cycle time or in seconds. The flow and pressure rise time can be adapted to suit the patient.

The Inspiratory rise time has to be set to a comfortable value for the patient and can be evaluated by the shape of the flow and pressure curves.



NOTES:

The Inspiratory rise time is shown in seconds if:

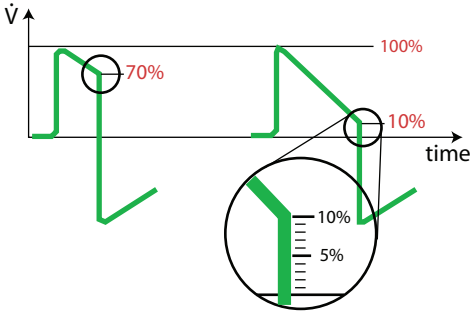
- the ventilator is configured for Insp. time in seconds.
- if ventilating in Pressure Support/CPAP or Volume Support.

The Inspiratory rise time is shown in %:

- in all controlled modes of ventilation if the ventilator is configured for the I:E ratio.

End inspiration

End inspiration is the point at which inspiration changes to expiration in spontaneous and supported modes of ventilation. A decrease of the inspiratory flow to a preset level causes the ventilator to switch to expiration. This preset level is measured as a percentage of the maximum flow during inspiration.



IMPORTANT: Set the End inspiration settings correctly to avoid hyperinflation of the lungs and increased work of breathing. It is possible to set the End inspiration from 1 to 70 % of the inspiratory peak flow for both adults and infants (default values are 30 % for adults and infants).

If the inspiration is ended too early, the patient will not get enough tidal volume.

If the pressure increases 3 cmH_2O above the set Pressure Support level above PEEP, the ventilator changes from inspiration to expiration.

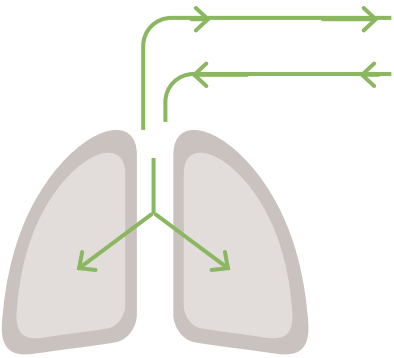
Trigger sensitivity

Trigger sensitivity determines the level of patient effort needed to trigger the ventilator to inspiration.

Trigger sensitivity can be set as either flow triggering ("Trigg. Flow") or pressure triggering ("Trigg. Pressure").

Auto-triggering of the ventilator is a false triggering of the ventilation when the patient is not attempting to initiate a breath.

IMPORTANT: The trigger level should be set as sensitively as possible without activating auto-triggering.



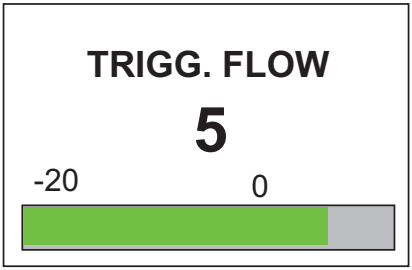
$\dot{V}$ Exp	<2 l/min (adult) < 0.5 l/min (infant)
$\dot{V}$ Exp	2 l/min (adult) 0.5 l/min (infant)

The ventilator continuously delivers a flow during expiration, which is measured in the expiratory channel.

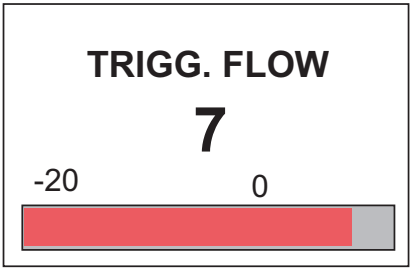
- Adult flow: 2 l/min (~33 ml/s)
- Infant flow: 0.5 l/min (~8 ml/s)

When the difference between the inspiratory and the expiratory flow equals the preset flow trigger level, the Servo-i will start a new inspiration.
Auto-triggering of the ventilator is a false triggering of the ventilation when the patient is not attempting to initiate a breath.

The flow trigger sensitivity setting is divided into steps of 10 %, with each step increasing the trigger sensitivity.

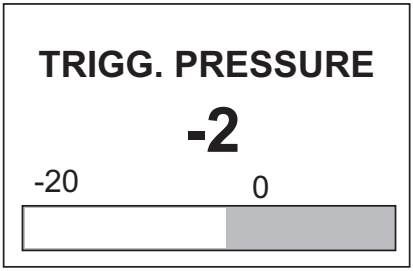


For example if the trigger is set in the red area the patient only has to inhale a very small part of the trigger flow to trigger a breath -there is a risk for auto-triggering.



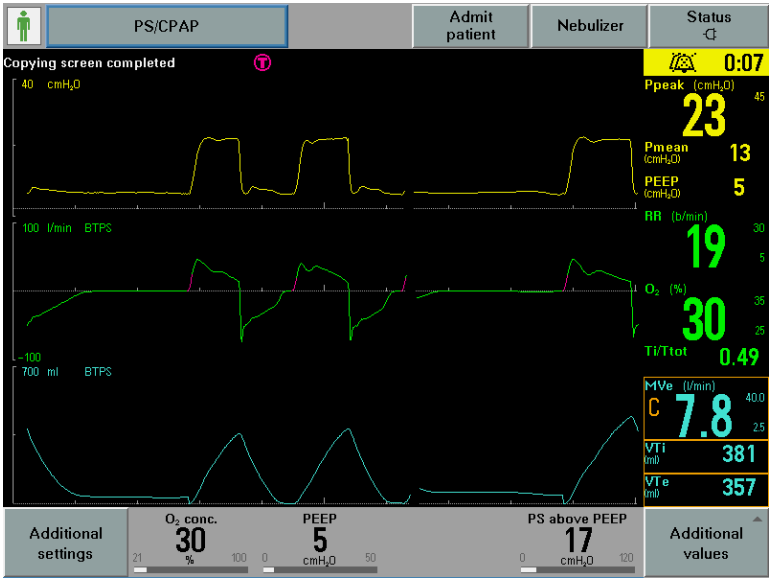
The pressure trigger sensitivity can be set within the range 0–(-20) cmH_2O. To initiate a breath the patient has to create the negative pressure that is set as trigger sensitivity.

The higher the negative trigger pressure is set on the ventilator, the more work of breathing the patient must perform.



Important ventilatory settings – Invasive ventilation

When the patient triggers a breath a purple "T" appears between the text message and the alarm message areas. The initial part of the pressure or flow curves changes to purple to indicate that the patient is triggering the breath.



NOTES:

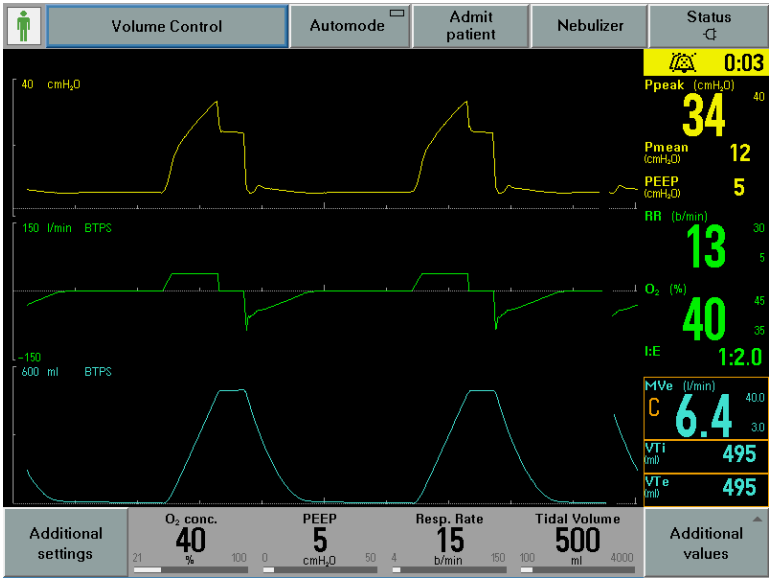
1. If the breath is flow-triggered, then the purple color indication appears on the flow curve.
2. If the breath is pressure-triggered, then the purple color indication appears on the pressure curve.

Volume Control

In this controlled mode of ventilation the ventilator delivers the preset tidal volume with a constant flow during the preset inspiratory time with the preset pause time and at the preset respiratory rate.

The peak pressure can vary from breath to breath if the patient's compliance and resistance change.

In a system without leakage, the inspired tidal volume should be the same as the expired tidal volume. The time for inspiration and expiration can be configured so that it is set as the I:E ratio or as inspiration time in seconds.



Volume Control (VC)

Example

When using Servo-i, you can select if you want to set the tidal volume or the minute volume. The flow during Volume Control ventilation is constant. The Insp. rise time in % is seen in the information area in the "Set ventilation mode" menu. Inspiratory rise time: time to peak inspiratory flow at the start of each breath as a percentage of the respiratory cycle time.

How to calculate the flow

Example:

Preset Insp. Min. Volume = 6 l/min
Insp.time = 25 %

Gives inspiratory flow:

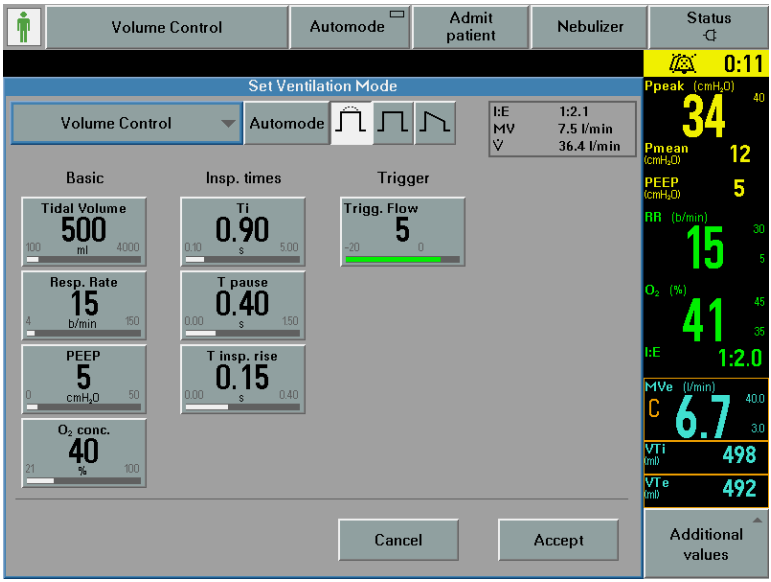
$$\frac{6 \times 100}{25} = 24 \text{ l/min}$$

Volume Control with decelerating flow

The flow pattern can be set so that the end-inspiratory flow is 75 %, 50 % (default), 25 % or 0 % of the peak flow. A flow pattern setting of 100 % provides constant flow.

Volume Control without flow adaptation

With flow adaptation active the ventilator allows the patient to receive higher flow than set. The ventilator delivers volume strictly according to the settings.



 With flow adaptation

 Without flow adaptation

The ventilator delivers volume strictly according to the settings.

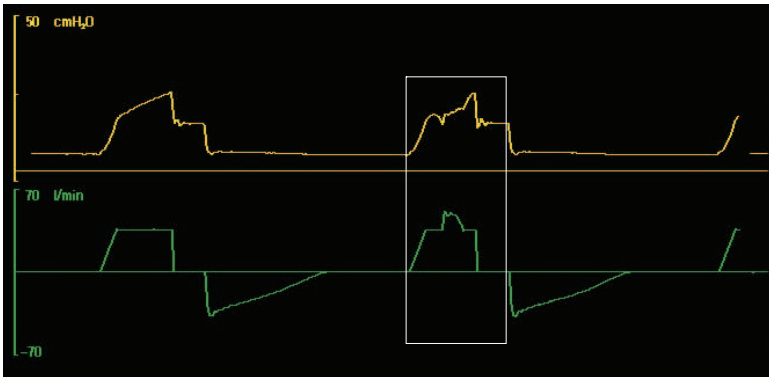
The ventilator interacts with the patient and delivers the extra volume requested regardless of the settings.

With flow adaptation active the ventilator allows the patient to receive higher flow than set. Flow adaptation is not available if the flow pattern is set to a decelerating flow.

Volume Control (VC)

It is very important to set a sensitive triggering level so as to allow the patient to breathe spontaneously as soon as possible. If the patient is making an inspiratory effort during the expiratory phase, an assisted breath is delivered with the same tidal volume as set on the ventilator. Immediate sensing of inspiratory effort from the patient is mandatory in achieving synchrony.

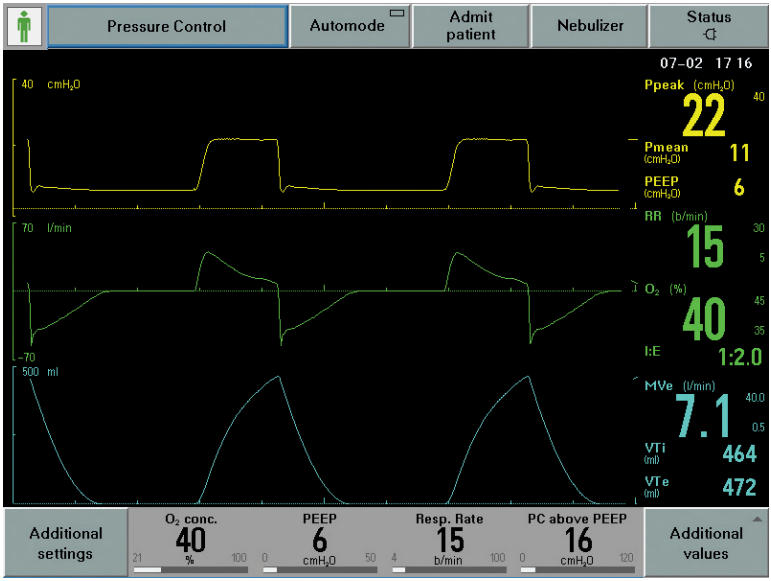
Sometimes the patient may demand a higher tidal volume/flow than that set on the ventilator. For example, this may be the case if the patient is in pain or has an increased temperature, or if the respiratory drive changes.



IMPORTANT: Always set the alarm limits for Pressure (Ppeak) to adequate levels.

Pressure Control

In this controlled mode of ventilation the ventilator delivers a flow that maintains the preset pressure at a preset respiratory rate during a preset inspiratory time.



During inspiratory time the pressure is constant and the flow is decelerating. If for any reason pressure decreases during inspiration, the flow from the ventilator will immediately increase to maintain the set inspiratory pressure. The maximum available flow is 200 l/min (3.3 l/s) for an adult and 33 l/min (0.55 l/s) for an infant. The volume can vary from breath to breath if the patient's compliance and resistance change.

IMPORTANT: Always set the alarm limits for Exp. Minute Volume to adequate levels.

Pressure Control (PC)

Inspiratory rise time in PC is the time taken to reach the peak inspiratory pressure of each breath. Settings can be in the range 0–20 % of the respiratory cycle time.

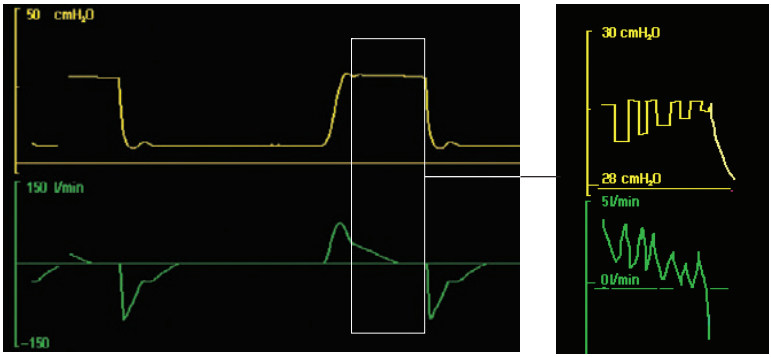
Example:

Respiratory rate 15, the time for 1 breath cycle is 60/15 = 4 sec

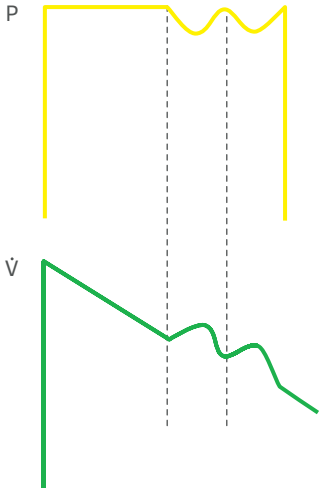
Inspiratory rise time 10 %:

$$\frac{4 \times 10}{100} = 0.4 \text{ sec}$$

The Servo-i immediately senses the smallest deviations in pressure during inspiration,and compensates with an increase in flow during the breath.

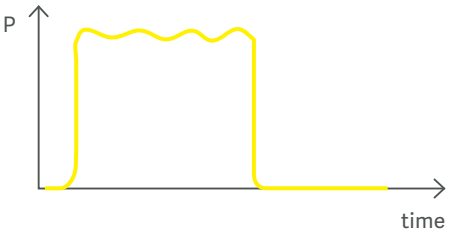


A decrease in pressure will occur when there is a leakage in the breathing system, at the endotracheal tube, or in the lungs, e.g. pneumothorax or fistula. When previously collapsed airways are starting to open the pressure decreases and the alveoli are opened by a precise increase in flow.



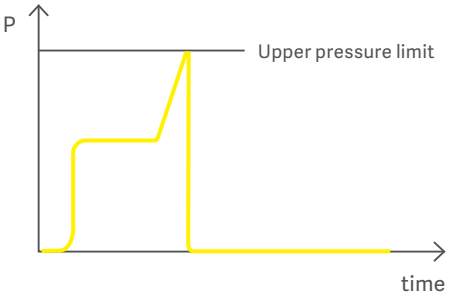
Active expiratory valve

If a patient tries to exhale during inspiration then pressure increases. When the pressure increases to 3 cmH_2O above the set inspiratory pressure level, then the expiratory valve opens and regulates the pressure down to the set inspiratory pressure level.



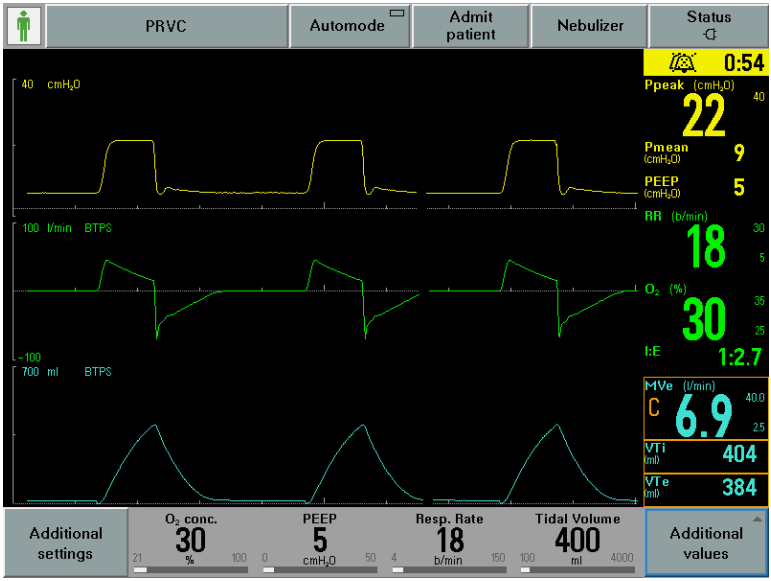
Upper pressure limit

If the pressure increases to the set Upper pressure limit e.g. the patient is coughing, then the expiratory valve opens and the ventilator switches to expiration.



Pressure Regulated Volume Control

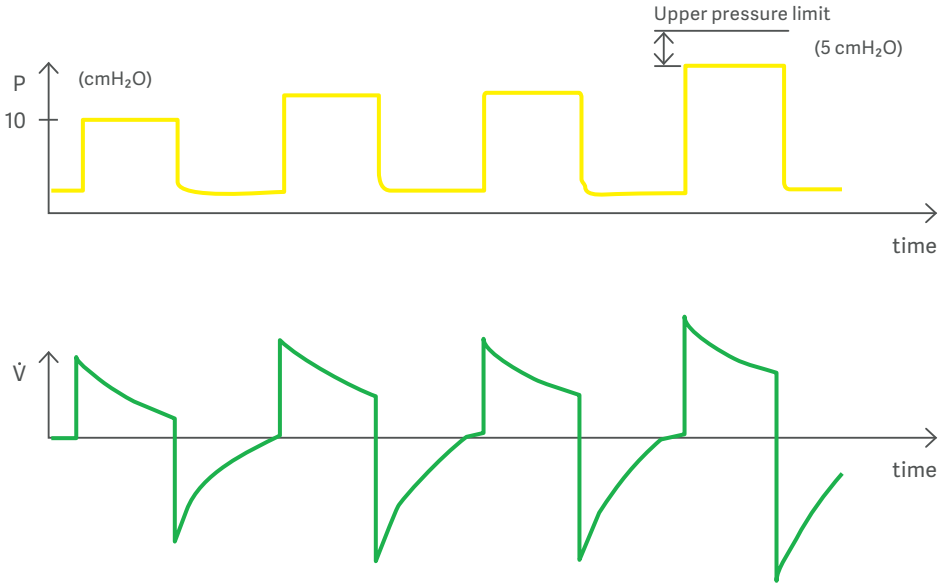
PRVC is a controlled mode of ventilation which combines the advantages of volume controlled and pressure controlled ventilation. The Servo-i delivers the preset tidal volume with the lowest possible pressure.



IMPORTANT: PRVC is not recommended when there is a leakage in the patient´s breathing circuit.

Pressure Regulated Volume Control (PRVC)

The first breath delivered to the patient is a volume controlled breath. The measured plateau pressure is used as the pressure level for the next breath. For the following breath, this pressure is constant during the set inspiratory time and the flow is decelerating.



The set tidal volume is achieved by automatic, breath-by-breath regulation.

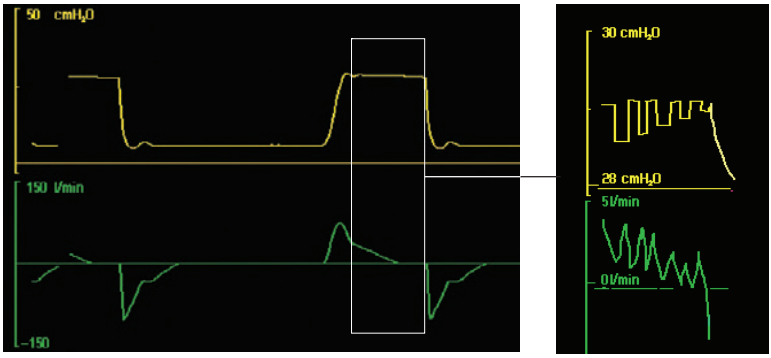
The ventilator adjusts the inspiratory pressure level to the lowest possible level to guarantee the preset tidal volume, in accordance with the mechanical properties of the airways/lungs/thorax.

If the measured tidal volume increases/decreases above/below the preset tidal volume, then the pressure level decreases/increases between consecutive breaths (in steps of a maximum 3 cmH_2O) until the preset tidal volume is delivered.

The maximum inspiratory pressure available is 5 cmH_2O below the preset upper pressure limit. If the pressure reaches 5 cmH_2O below the preset upper pressure limit, the ventilator will deliver as much volume as possible with this pressure. At the same time, the alarm message "Regulation Pressure Limited" will be displayed in the alarm message area to inform the user that the set volume cannot be delivered. The alarm limit for expired minute volume will also alert the user if properly set.

Pressure Regulated Volume Control (PRVC)

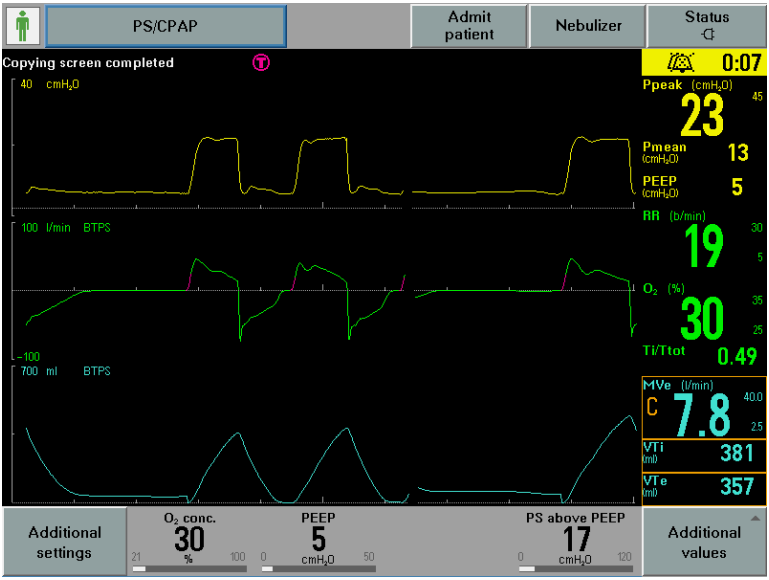
The Servo-i will sense the smallest deviations in pressure. If it appears that previously collapsed units of the lung are starting to open in the late phase of inspiration then the pressure tends to decrease. This is compensated by a precise increase in flow.



Terminal airway resistance decreases in discrete steps as pressure is applied. By immediately sensing the pressure drop that could be induced by an opening avalanche, Servo-i provides adequate flow to balance and further enhance the opening process.

Pressure Support

Pressure Support is a spontaneous mode of ventilation. The patient initiates the breath and the ventilator delivers support with the preset pressure level. With support from the ventilator, the patient determines frequency and duration of the breaths.



In Pressure Support the patient triggers all breaths, the preset inspiratory Pressure Support level is kept constant and there is a decelerating flow. Set PEEP and set Pressure Support above PEEP result result in the constant inspiratory pressure.

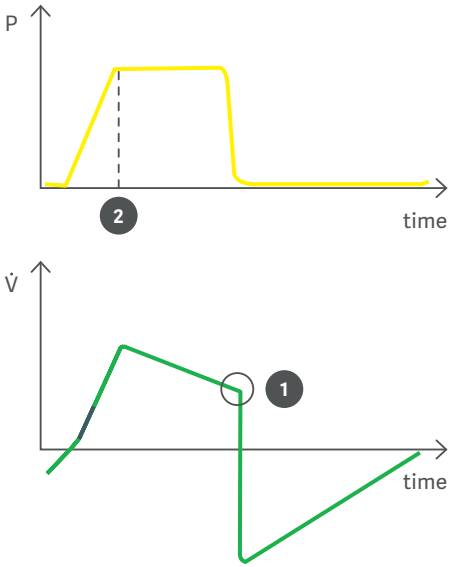
Pressure Support (PS)

If the mechanical properties of the lung/thorax and patient effort change, then delivered tidal volume will be affected. In this case the Pressure Support level must be adjusted to obtain the desired ventilation.

The higher the preset inspiratory pressure level from the ventilator, the more gas flows into the patient. As the patient becomes more active, the Pressure Support level may be gradually reduced.

Pressure and flow curves

Inspiration is supported by a constant preset pressure when activated by patient effort. Since the pressure provided by the ventilator is constant, the flow will decrease until the inspiratory cycle off (1) is reached and then the expiration starts. Depending on how the Inspiratory rise time (2) is set, the pressure will either rise very quickly or slowly at the beginning of the breath.



Expiration starts:

- when the inspiratory flow decreases to the preset End inspiration level.
- if the pressure increases 3 cmH_2O or 10 % above the Pressure Support level (highest value applicable).
- if the upper pressure limit is exceeded.
- if the inspiration exceeds 2.5 s in Adult range and 1.5 s in Infant.
- if the flow drops to a flow range between 25 % of the peak flow and lower limit for inspiratory cycle off fraction level and the time spent within this range exceeds 50 % of the time spent in between the start of the inspiration and the entering this range.

Important:

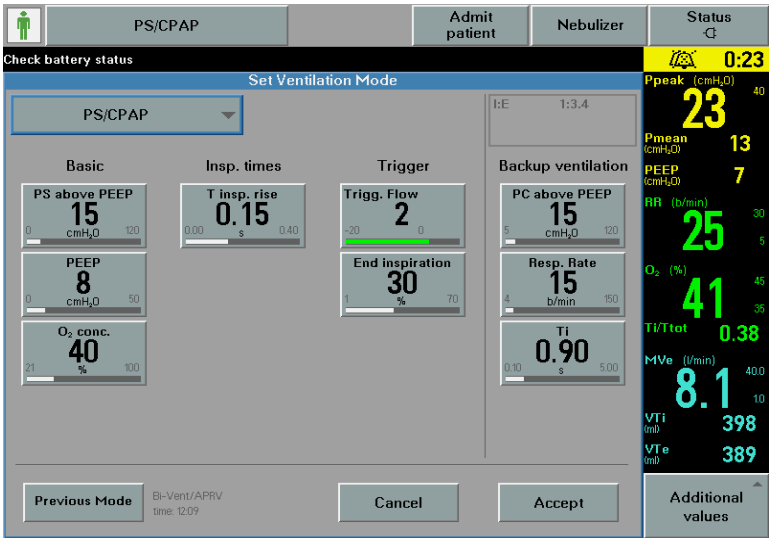
1. The trigger sensitivity should be set optimally for the patient without increasing the work of breathing.
2. The Inspiratory rise time should be increased or decreased from the default settings to a value comfortable for the patient.
3. As the patient becomes more active the pressure support level may be gradually reduced.
4. It is important to monitor the Tidal Volume levels and the Respiratory Rate.
5. The apnea alarm should always be set to suit the situation of the individual patient.
6. Ensure that the alarm limits for the expiratory Minute Volume alarm and for the Respiratory Rate are appropriately set.

Continuous Positive Airway Pressure (CPAP)

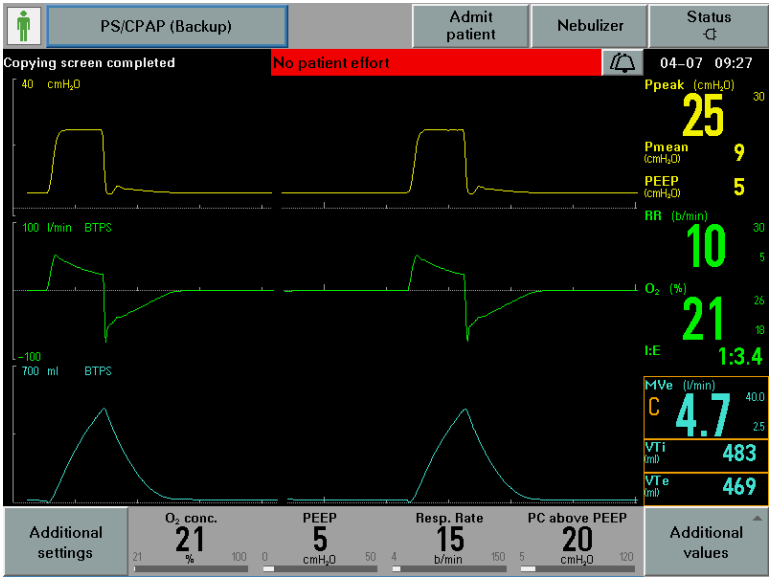
CPAP works in exactly the same way as Pressure Support, except the Pressure Support level is set to zero. Continuous positive pressure is maintained in the airways, and if properly set, airway collapse can be prevented. Inspiration starts upon patient effort, and expiration starts as for Pressure Support.

Backup Pressure Support

If the apnea alarm limit is reached, the ventilator automatically switches to backup mode for Pressure Support, which is Pressure Control.



If there is no patient effort when the apnea time has been reached, the ventilator will switch automatically to PS/CPAP (Backup), which is Pressure Control. The third and fourth direct access knobs then adjust the respiratory rate and PC above PEEP. The ventilator will switch back to PS/CPAP if the patient starts to trigger the Servo-i again.



Volume Support

Volume Support is a spontaneous breathing mode. The resulting volume is continuously monitored and the constant inspiratory pressure automatically adjusts to the required level. The patient determines frequency and duration of the breaths which show a decelerating flow pattern.

If the patient's activity increases, the inspiratory Pressure Support will decrease, provided that the set tidal volume is maintained. However, if the patient breathes below the set tidal volume, then the inspiratory Pressure Support will increase.

Important:

1. The trigger sensitivity should be set optimally for the patient without increasing the work of breathing.
2. The Inspiratory rise time should be increased or decreased from the default settings to a value comfortable for the patient.
3. It is important to monitor the Pressure levels and the Respiratory Rate.The apnea alarm should always be set to suit the situation of the individual patient.
4. Ensure that the alarm limits for the expiratory Minute Volume alarm and for the Respiratory Rate are appropriately set.

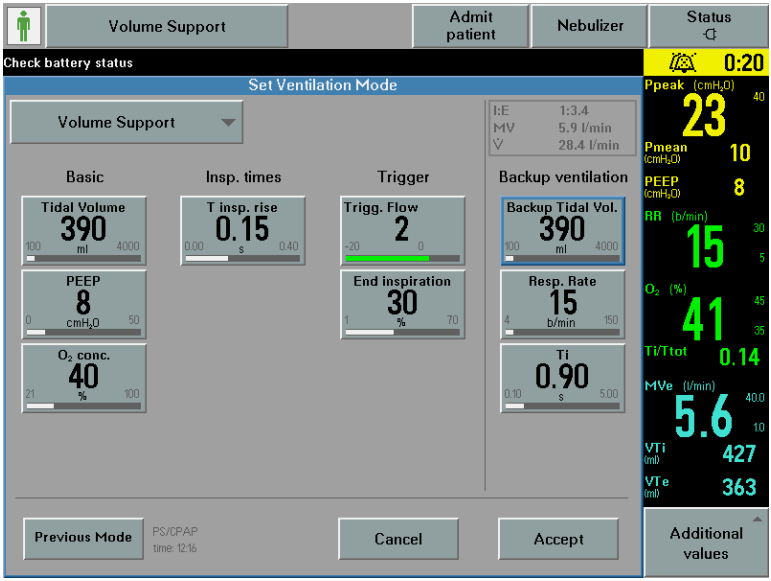
The start breath is given with 10 cmH_2O support. From that breath the ventilator calculates and continuously regulates the pressure needed to deliver the pre-set Tidal Volume.

During the next 3 breaths of the start up sequence the maximum pressure increase is 20 cmH_2O for each breath. After the start up sequence the pressure increases or decreases in steps of maximum 3 cmH_2O. If the delivered Tidal Volume decreases below the set Tidal Volume the pressure support level is increased in steps of maximum 3 cmH_2O until preset Tidal Volume is delivered.

If the pressure support level causes a larger Tidal Volume than preset, the support pressure is lowered in steps of maximum 3 cmH_2O until the preset Tidal Volume is delivered.

Volume Support (Backup)

In this mode it is also important to set the apnea time appropriate to the individual patient situation. :

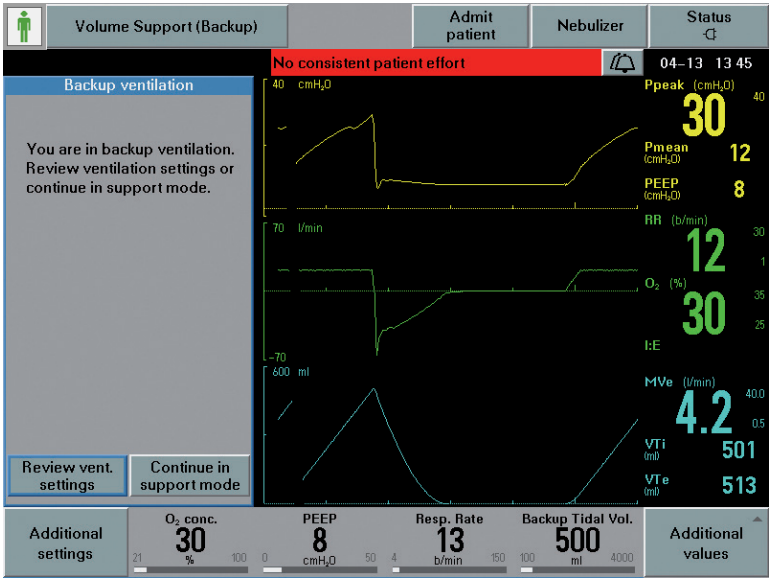


If there is no patient effort when the apnea time has been reached, the ventilator will switch automatically to Volume Support (Backup), which is Volume Control.

Volume Support (VS)

The third and fourth direct access knobs then control the respiratory rate and the backup tidal volume.

The ventilator will switch back to Volume Support if the patient starts to trigger again.



Neurally adjusted ventilatory assist (NAVA)

NAVA and NIV NAVA are patient initiated ventilation modes in which the ventilatory support is triggered by the electrical activity of the diaphragm (Edi). NAVA and NIV NAVA can be used on all patients who require ventilatory support (neonatal, pediatric and adult patients).

The Edi signal is captured by a special nasogastic feeding tube (the Edi catheter), which is fitted with an array of electrodes. Like an ordinary feeding tube, the Edi catheter is placed in the esophagus. It is positioned in the esophagus so that the set of measuring electrodes spans the path of movement of the diaphragm.

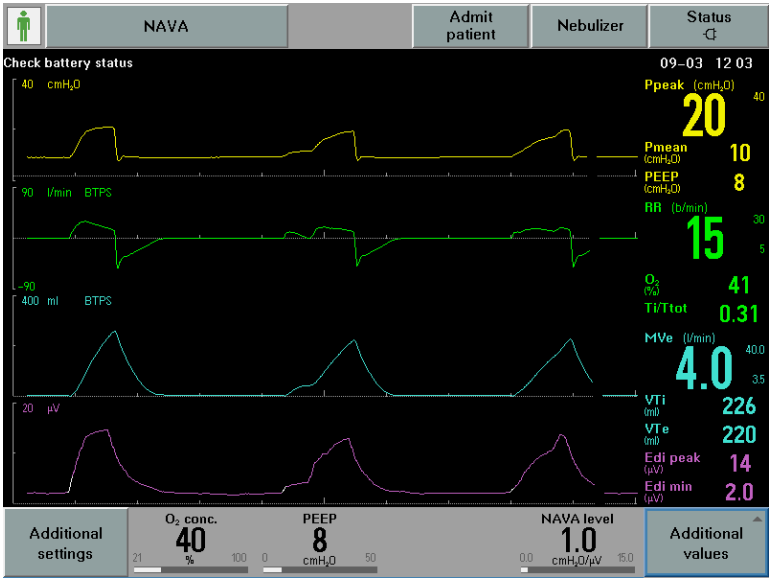
The Edi catheter must be removed from the patient before an MR examination.

The following equipment are required:

- Edi catheter (different sizes depending on patient size)
- Edi module
- Edi cable

NAVA and NIV NAVA

During NAVA ventilation the patient controls the respiratory rate and the tidal volume with the support from the ventilator.



During the expiratory phase, the Edi does not influence the ventilation, therefore the operator should set an appropriate PEEP value.

The set pressure varies during the entire inspiration due to the Edi variation, but is limited to 5 cmH_2O below the set upper pressure limit.

NAVA

The Edi signal that is picked up by the electrodes on the Edi catheter and is filtered and processed by the Edi module.

NAVA and NIV NAVA also employ a pneumatic trigger, based on flow or pressure, as a secondary trigger source. In combination with the Edi trigger, this operates on a first-come-first-served basis.

The pressure curve in both NAVA and NIV NAVA follows the Edi signal pattern. Expiration phase starts when the Edi decreases below 70 % of the peak value (during the ongoing inspiration). Or if the pressure increases 3 cmH_2O above the inspiratory target pressure. Expiration also start if the upper pressure limit is exceeded.

As long as the patient has an Edi catheter in position, the Edi signal can in addition be monitored in all modes of ventilation, invasive and non invasive, as well as in Standby.

Edi catheter positioning

Check the position of the Edi catheter by means of the ECG waveforms: Verify that the P and QRS waves are visible on the top leads, and that the P waves disappear and the QRS wave amplitude decreases on the lower leads.

If the Edi deflections are present, observe which leads are highlighted in pink. If the leads highlighted in pink are in the center during an inspiration, i.e. second and third leads, then the Edi catheter is aligned correctly and ready to be secured.

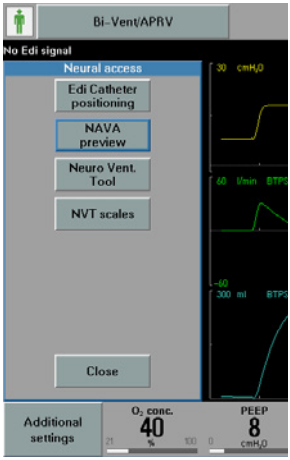
If the top leads are highlighted in pink, pull out the Edi catheter slightly, until the pink highlight appears in the two central leads.

If bottom leads are highlighted in pink, insert the Edi catheter further in slightly, until the pink highlight appears in the center.

NOTE: The pink indication can only be used if there is a stable Edi signal. If the Edi signal is very low or absent, there will be no pink highlights.

NAVA preview

Select NAVA preview. The grey curve then displayed on the user interface below shows the estimated pressure based on the Edi and the set NAVA level.



The Edi signal

Evaluate the Edi signal. Please note that sedation, muscle relaxants, hyper-ventilation, and neural disorders can all result in a low or absent Edi signal, even if the Edi catheter has been perfectly positioned.

PEEP

Edi-guided PEEP titration may be performed by small incremental or decremental steps. Average Edi peak can then be assessed when the respiratory drive has stabilized at the new PEEP level.

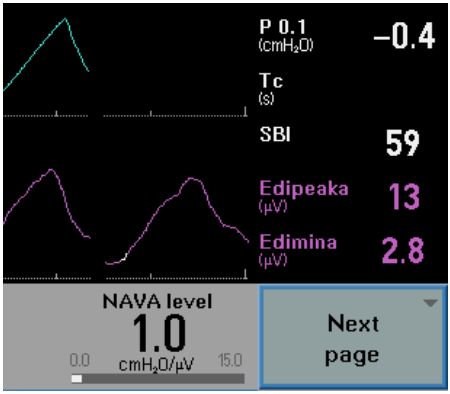
Edi peak:
Reflects the work the diaphragm has to perform for each breath.

Edi min:
Shows the baseline level of the resting diaphragm between contractions. The higher Edi min, the more tonic the diaphragm is.

Never switch to NAVA ventilation if no Edi activity is observed.

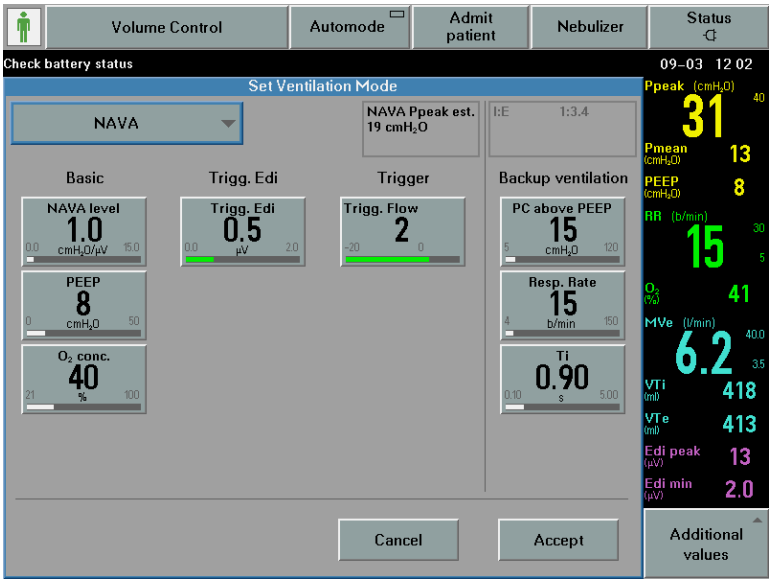
The Edi signal is measured in µV.

Edi mina average and **Edi peaka** average can be found under Additional values.



NAVA mode

1. NAVA level: The relation between measured Edi signal and pressure assist provided. ($cmH_2O/\mu V$)
2. PEEP (cmH_2O)
3. Oxygen concentration (%)
4. Trigg. Edi: The predefined level that the Edi signal has to reach to start a new inspiration.
5. Pneumatic trigger (flow or pressure)
6. PC (Pressure Control level) above PEEP (cmH_2O) in backup ventilation
7. Resp. Rate in backup ventilation
8. I:E / Ti in backup ventilation (depending on configuration)



The NAVA level

The NAVA level is the factor by which the Edi signal is multiplied to adjust the amount of assist delivered to the patient. This assist is thus proportional to the patient's Edi and as such, it follows a physiological pattern.

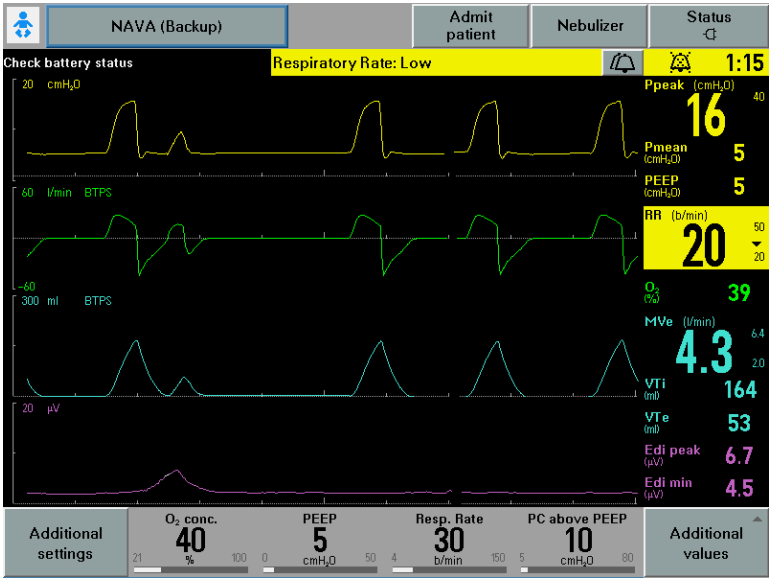
The set NAVA level reflects the amount of work of breathing that the ventilator will take over from the patient. The appropriate NAVA level varies for different patients since they require different assist levels.

Edi trigger

The Edi trigger is the predefined level that the Edi signal has to reach to start a new inspiration. The Edi trigger should be set to a level where random variability in the background noise does not exceed the trigger level. The variability of the background noise is typically less than 0.5 µV which is the default value.

Back up ventilation

The backup settings should be chosen so as to ensure adequate ventilation in case of apnea.



Turning off NAVA apnea alarms

In the infant patient category the apnea alarms *No patient effort* and *No consistent patient effort* can be turned off in NAVA and NIV NAVA. This switch to backup ventilation is always active irrespective of any changes in the alarm configuration.

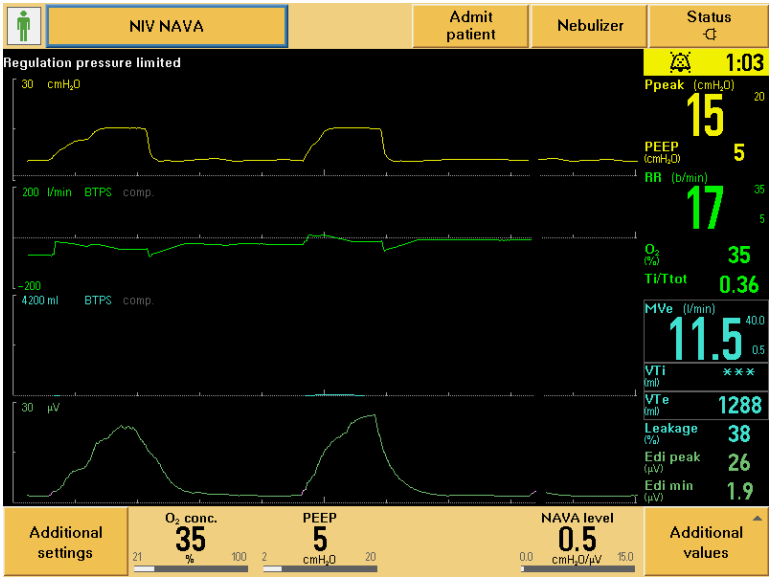
If the *No consistent patient effort* alarm is turned off, the system will not lock in backup ventilation after 3 switches to backup ventilation during 2 minutes. This is only available in NAVA.

Weaning

Follow local weaning policies and protocols. Integrate NAVA level and Edi as decision criteria.

NIV NAVA

NIV NAVA is independent of leakage in patient interfaces. The parameters to be set for NIV NAVA are the same as for invasive NAVA except that the Pneumatic trigger is not set as in all NIV modes.



No or Low Edi signal

- High sedation level?
- Patient overassisted?
- Edi catheter out of position?
- Phrenic nerve injury or other neurological disorder?

Increased Edi signal

- Too low NAVA level? Patient underassisted?
- Too low PEEP? Atelactasis/ Cyclic tidal recruitment?
- Airway obstruction, e.g. secretion?
- Worsened disease condition?
- Too low pH and/or high $PaCO_2$? Patient not ready for a support ventilation mode?

Flow triggering or switch to NAVA(PS) backup

- PS flow trigger set too sensitive?
- Consider change to pressure trigger
- Patient using accessory muscles

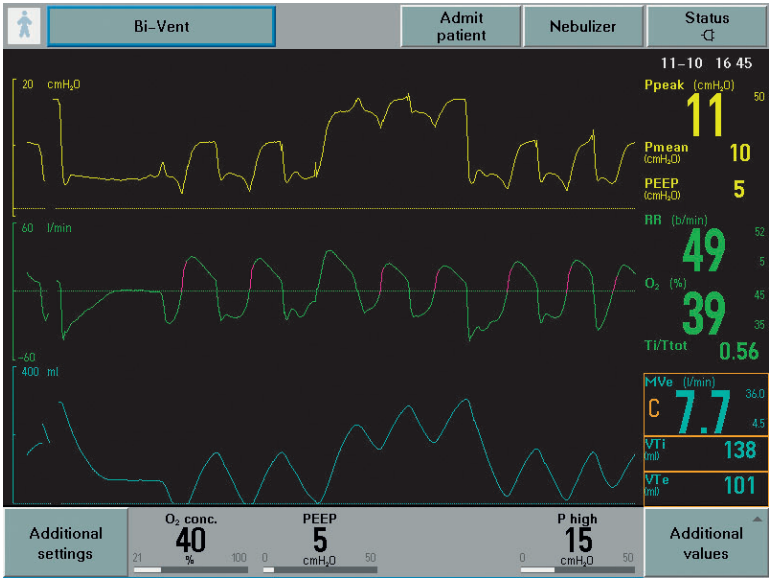
Volume delivery restricted/ Regulation pressure limited

- Upper pressure limit alarm set too low?

Bi-Vent/APRV

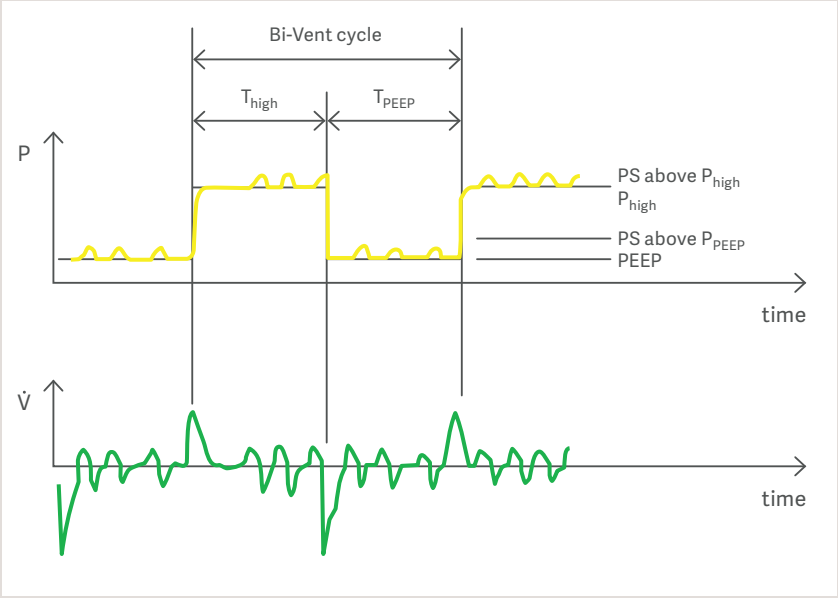
Bi-Vent is a time-cycled, pressure-limited mode of ventilation that allows spontaneous breathing throughout the entire ventilatory cycle.

Bi-Vent has two, time-cycled pressure levels and switches between these levels. In Bi-Vent mode the patient can breathe spontaneously at both these levels, and it is possible to support the patient with Pressure Support at both pressure levels.



Example:
Time for Phigh is set to 2 s and time for PEEP is set to 4 s and this will give you 6 s for the Bi-Vent cycle. The mandatory rate will be 60/6 = 10 breaths per minute. The Bi-Vent cycle may be shifted somewhat depending on the patient and the ventilator settings since the ventilator continuously synchronizes with the patient's breathing. Since Bi-Vent is a controlled mode of ventilation, backup ventilation is not available.

Bi-Vent/APRV



Every Bi-Vent cycle has a time for the P_{high} and for the PEEP level. The time for P_{high} can be set in the range 0.2–10 s and the time for PEEP can be set in the range 0.2–10 s. This means that you can set the mandatory rate from 3–150 breaths per minute.

APRV

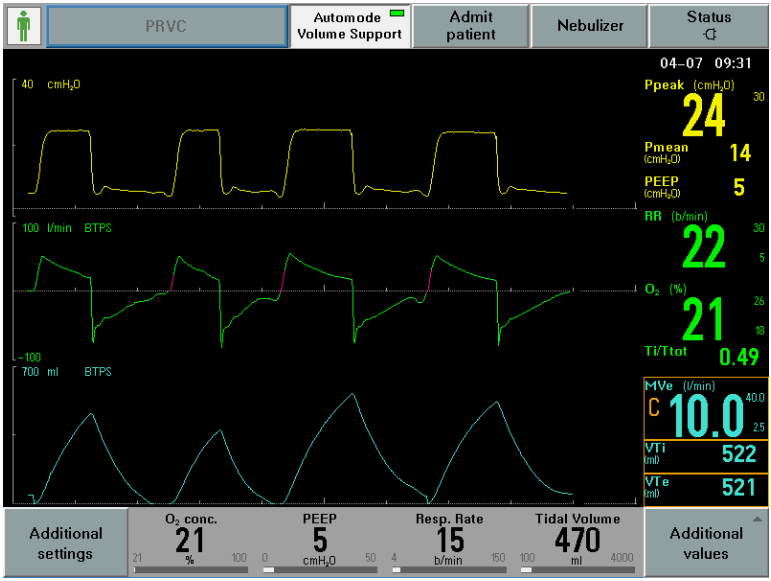
APRV stands for Airway Pressure Release Ventilation and is a time-cycled, pressure-limited mode that allows spontaneous breathing throughout the entire ventilatory cycle. APRV differs from Bi-Vent in that it uses an inverse I:E ratio.

Since Bi-Vent/APRV is basically a controlled mode of ventilation, apnea alarm and backup ventilation are not available. It is also very important to set the lower and upper alarm limit for expired minute volume.

Automode®

Automode is an interactive mode of ventilation. The combined control and support function of the ventilator adapts to the patient's breathing capacity. Automode allows patients to go into a support mode automatically if they trigger the ventilator, thereby better adapting ventilation to patient effort. If the patient is not making any breathing effort the ventilator will deliver controlled breaths.

Automode provides both patient and clinician with the best possible means of starting the weaning period when ventilator therapy is initiated.



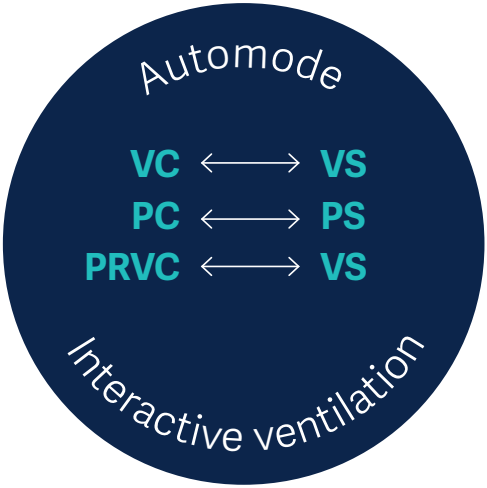
Automode®

Essentially the ventilator works in two modes: control or support.

When the patient makes an inspiratory effort in control mode, then the ventilator reacts by supplying a assisted breath.

The possible combinations are:

- Volume Control – Volume Support
- Pressure Control – Pressure Support
- PRVC – Volume Support



Trigger Timeout is the maximum allowed apnea time in Automode before controlled ventilation is activated.

The trigger timeout settings are within the ranges 7–12 seconds for adults and 3–15 seconds for infants.

The ventilator initially adapts with a dynamic Trigger Timeout limit.
This means that for the spontaneously breathing patient the the apnea time increases increases successively during the first 10 breaths. Patient activity can be seen by looking at the trends.

Early detection and adaptation to patient effort promote spontaneous breathing and early weaning.

Synchronized Intermittent Mandatory Ventilation (SIMV)

SIMV

During SIMV the patient receives mandatory breaths that are controlled or assisted by the ventilator. These mandatory breaths are synchronized with the breathing efforts of the patient who can breathe spontaneously between the mandatory breaths.

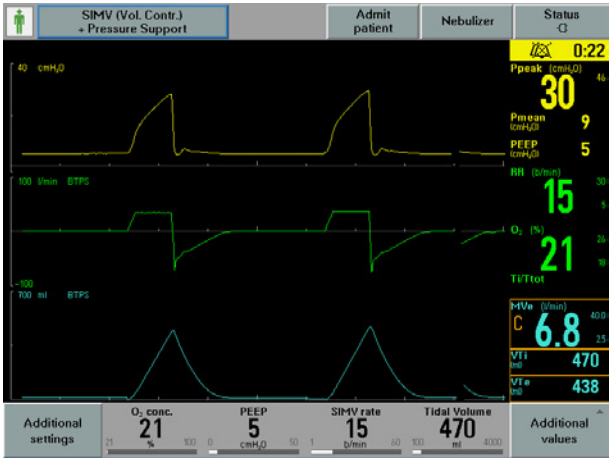
The mandatory breath is defined by the basic settings (mode of ventilation, breath cycle time, respiratory pattern and volumes/pressures). The SIMV rate is the rate of the mandatory breaths per minute.

The spontaneous/pressure-supported breath is defined by setting the Pressure Support level above PEEP and the cycle off %. When the user gradually decreases the SIMV rate, the patient has more and more time for the spontaneous/pressure-supported breaths.

There are three different SIMV modes:

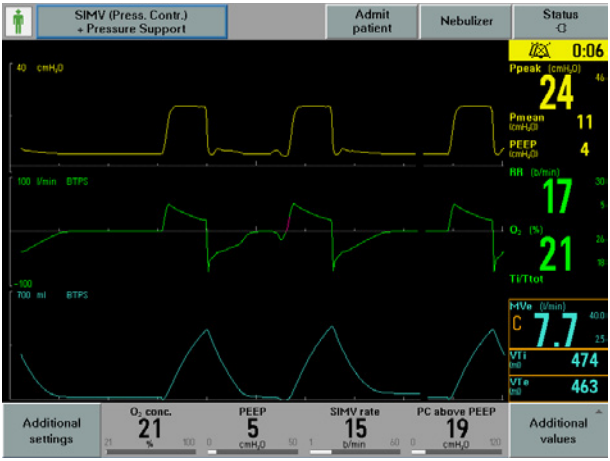
- SIMV (Volume Control) + Pressure Support
- SIMV (Pressure Control) + Pressure Support
- SIMV (PRVC) + Pressure Support

SIMV (Volume Control) + Pressure Support

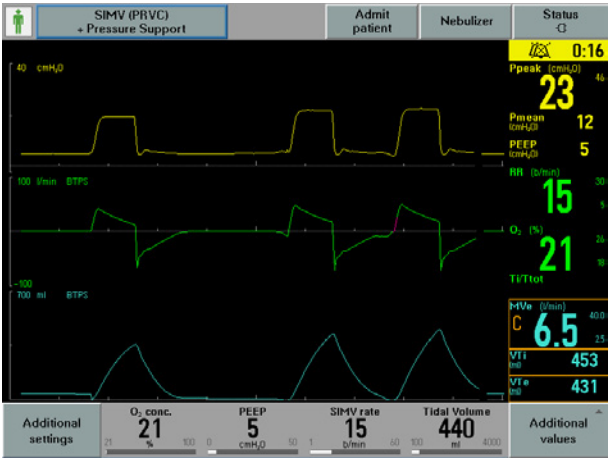


Synchronized Intermittent Mandatory Ventilation (SIMV)

SIMV (Pressure Control)
+ Pressure Support



SIMV (PRVC)
+ Pressure Support

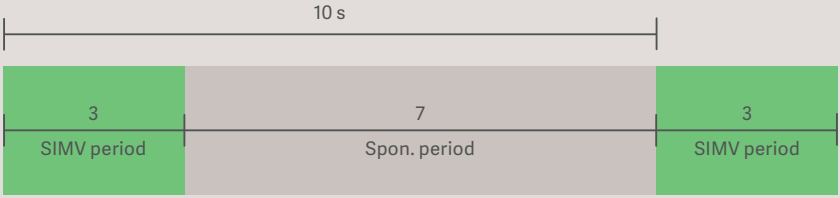


Breath Cycle Time (Breath Cycle T)

This is the length of the total respiratory cycle of the mandatory breath. i.e. the total time for inspiration, pause and expiration.

NOTE: The Breath Cycle Time is only applicable if the Servo-i is configured for setting the inspiratory time by setting the I:E ratio.

SIMV cycle



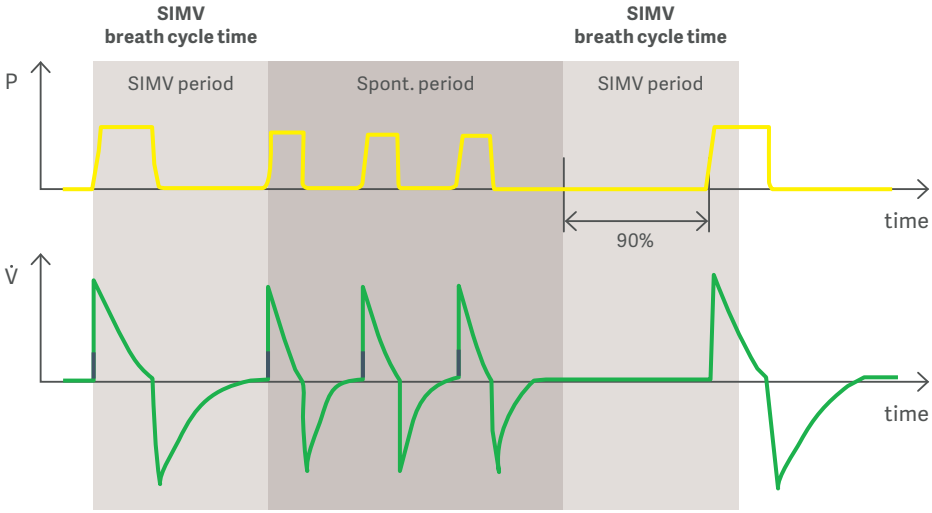
The following settings are made in this example:

1. SIMV rate = 6
2. Breath cycle time = 3 (the time for the mandatory breath)
3. The SIMV cycle in seconds is calculated as follows: 60 seconds divided by the SIMV rate - in this example 60/6 = 10 s.
4. The SIMV cycle is divided into an SIMV period and a spontaneous period.
5. The time for the spontaneous period is 10 s - 3 s = 7 s.

The time for the mandatory breath is:

6. 3 s = SIMV period
7. I:E ratio 1:2 = 1 s for inspiration and 2 s for expiration.

Synchronized Intermittent Mandatory Ventilation (SIMV)



When the patient starts to breathe, then Pressure Support is delivered during the spontaneous period, and if triggering occurs in the SIMV period then the set mandatory breath is delivered. The ventilator will wait during the next SIMV period for the patient to trigger. However, if the patient has not triggered within the first 9^9 % of the breath cycle time (SIMV period), then a mandatory breath is delivered.

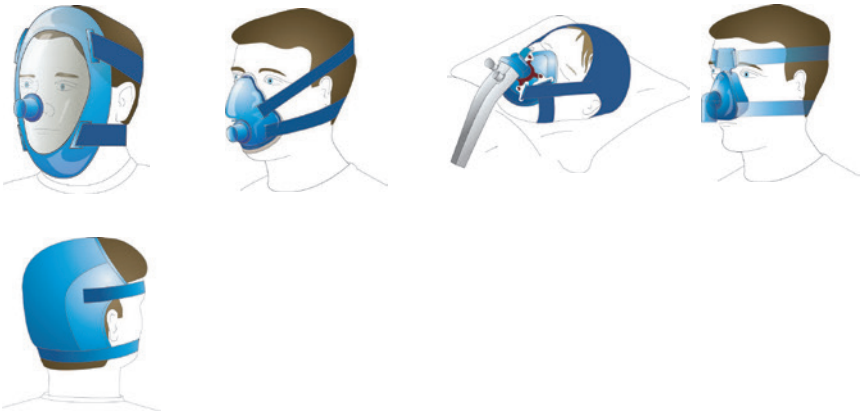
Non Invasive Ventilation - NIV

NIV - General

Non Invasive Ventilation (NIV) refers to the delivery of mechanical ventilation using a face mask or similar device, rather than an endotracheal tube.

Interfaces for the application of NIV

There are several types of patient interfaces on the market:
oronasal or full-face masks, total face mask and nasal masks. The masks are available in different sizes. As patients have different facial contours, it is very important to have a variety of masks to ensure a proper fit, as a poorly fitting mask usually results in failure of NIV.

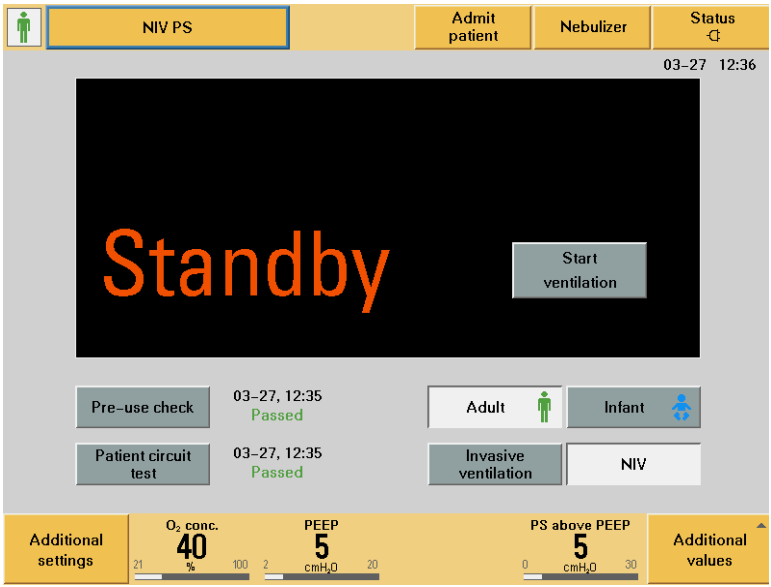


Monitoring patient comfort and tolerance during NIV is very important and must be performed at the bedside while observing the patient.

The NIV application

When NIV is selected in Standby, the user interface changes frame color from grey to yellow. NIV Pressure Support, NIV Pressure Control, Nasal CPAP and NIV NAVA are the ventilation modes available in NIV.

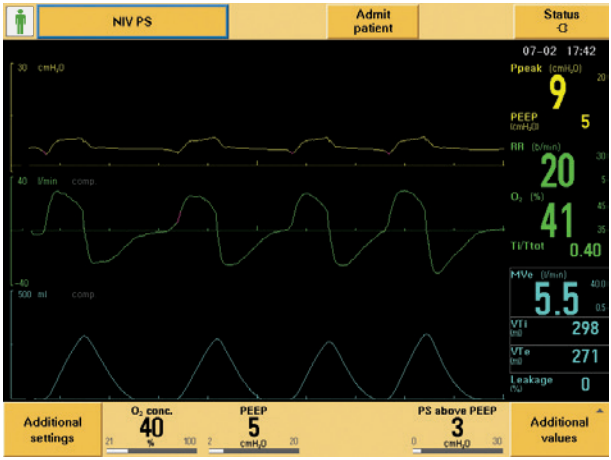
Observe that the default settings are automatically changed when switching between Invasive and Non Invasive modes.



Leakage compensation

During NIV, the ventilator automatically adapts to the variation of leakage in order to maintain the required pressure and PEEP level. The leakage is presented on the Servo-i as the Leakage fraction % and is a measurement of how well the mask fits the patient.

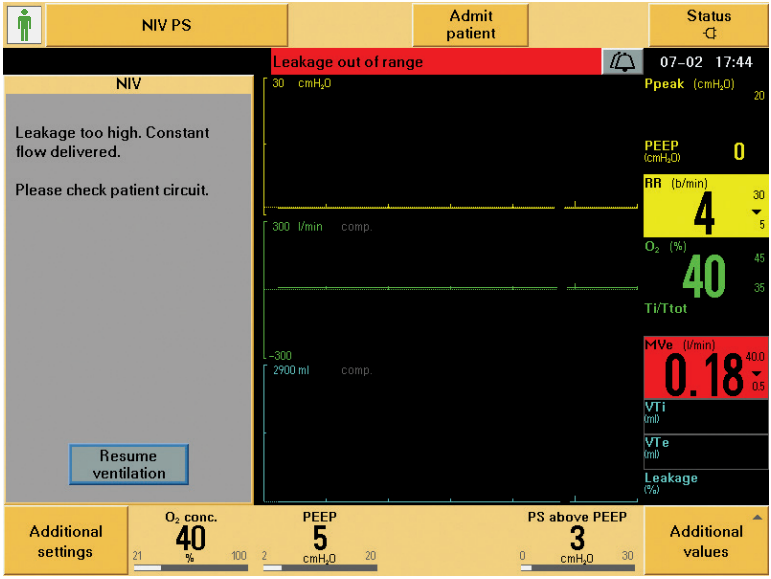
When the patient breathes irregularly the leakage value varies. The leakage value displayed represents leakage during inspiration (an average taken during 2 - 3 breaths). The volumes shown in the measured value box are compensated for leakage, meaning that they correspond to the actual volume the patient breathes in and out.



NOTE: Leakage compensation during expiration is up to 65 l/min for adults and up to 25 l/min for infants and during inspiration compensated up to 200 l/min for adult and 33 l/min on infants.

Disconnect position (ventilation paused)

If the leakage is excessive (>65 l/min for adults and >25 l/min for infants) or if the patient is disconnected, the Servo-i will pause ventilation and issue a high priority alarm. A text message will appear on the screen stating "Leakage too high. Constant flow delivered. Please check patient circuit."



An alarm is activated and an alarm message is displayed on the user interface, “Leakage out of range”. To reduce any disturbance caused by the alarm it is possible to pre-silence patient-related alarms before disconnecting the patient from the ventilator.

The ventilation is paused to minimize patient discomfort. A constant bias flow is delivered to help detect the breathing effort of the patient. Once the leakage has been reduced or the patient reconnected, ventilation is automatically resumed and the screen dialog will disappear after three breaths.

It is also possible to start ventilation manually by pressing the the soft key "Resume ventilation" on the user interface.

In the edit startup configuration window accessed via standby menu – Biomed, it is possible to change the disconnect flow.
The default settings are:

- Low flow – 7.5 l/min for both adults and infants

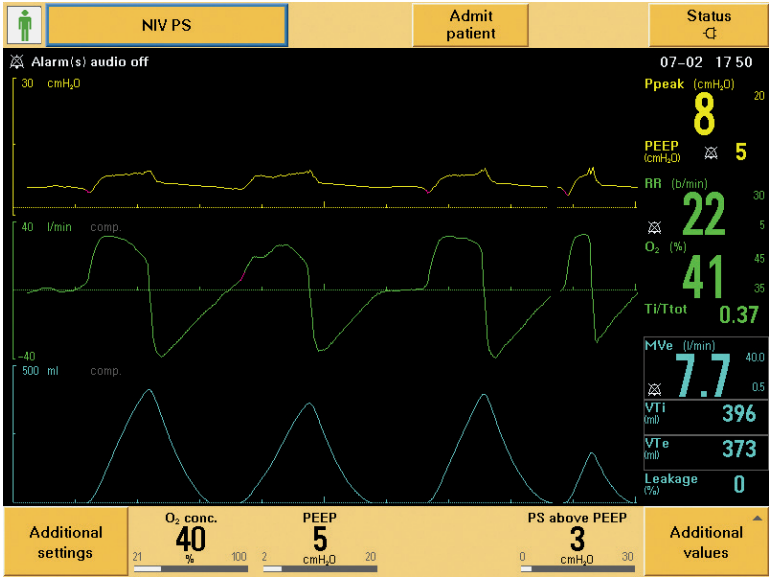
These can be changed to:

- High flow – 40 l/min for adults and 15 l/min for infants
- Disabled – no pause in case of high leakage. The ventilator continues to deliver assist even when leakage is excessive and the Leakage out of range alarm will then be a medium priority alarm.

Trigger Sensitivity

The Trigger sensitivity is fixed in NIV. If the patient lowers the pressure to 1 cmH_2O below PEEP during expiration or causes an expiratory flow decrease of 6 ml during 100 ms, then the Servo-i delivers a breath.

The dynamic pressure and flow compensation will maintain the Trigger sensitivity even in the case of a considerable leakage.



When START VENTILATION is tapped in standby, a waiting position dialog is displayed.

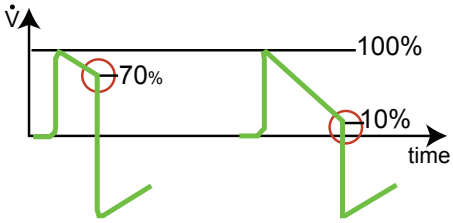
Ventilation starts when one of the following criteria has been met:

- the ventilator detects a patient's attempt to breathe.
- the user presses the soft key "Start ventilation".

During the waiting phase, all audible patient-related alarms are deactivated and no ventilation is delivered.

End inspiration

End inspiration is the point at which inspiration changes to expiration in NIV Pressure Support.



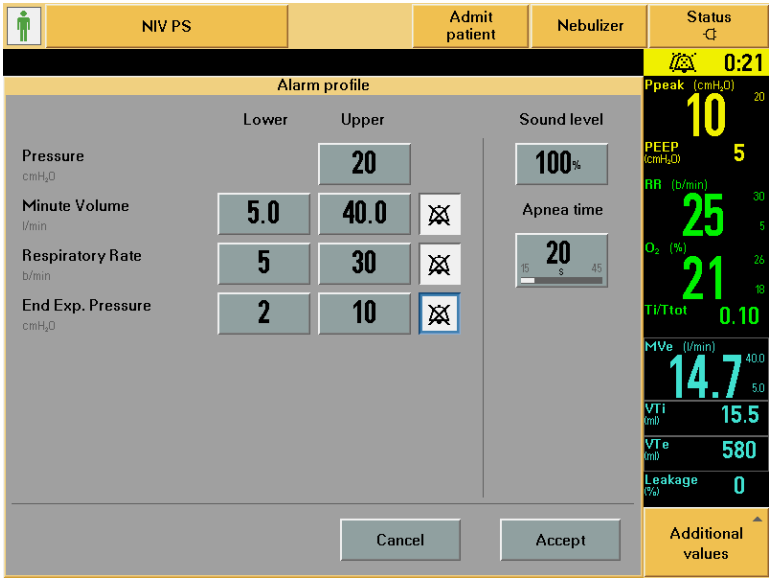
IMPORTANT: The End inspiration setting is important to patient comfort and ventilator synchronization with the patient. If it is set too low, this may lead to hyperinflation of the lungs and increased work of breathing. If it is set too high, it may cut off inspiration too early and the patient will not get enough tidal volume.

It is possible to set the End inspiration from 10 % to 70 % of inspiratory peak flow for both adults and infants (default values are 50 % for adults, and 30 % for infants).

Alarms

Since the leakage often varies during NIV, alarms may be activated more often than necessary. To reduce this disturbance, it is possible to set audible alarms to "Audio Off" for all patient-related alarms, excluding the high-pressure alarm.

To enable the "Audio Off" function, press the soft key with the "Bell" symbol displayed next to the relevant alarm.



NIV Pressure Support

NIV Pressure Support is a spontaneous mode of ventilation. The Servo-i delivers support with the preset pressure level and a decelerating flow. With support from the ventilator.

If the mechanical properties of the lung/thorax and patient effort change, delivered tidal volume will be affected. The Pressure Support level must be regulated to obtain the desired ventilation.

As the patient becomes more active, the Pressure Support level may be gradually reduced. The Inspiratory rise time and the End inspiration must be set to a comfortable value for the patient.

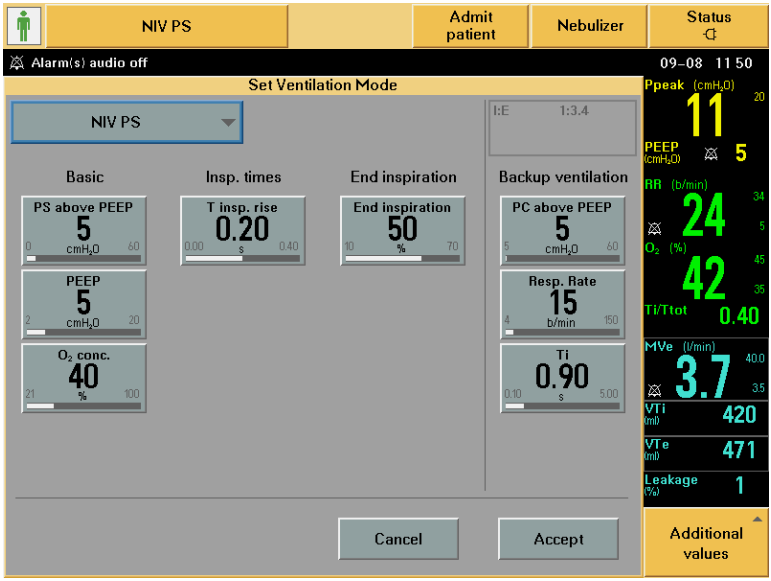
NOTE: Normally in NIV the treatment is started with a low Pressure Support level, 2–3 cmH_2O. The Pressure Support level above PEEP is then slowly titrated to the level that will give a comfortable breathing pattern.

Backup ventilation

Backup ventilation is Presssure Control.

The default settings for backup ventilation are:

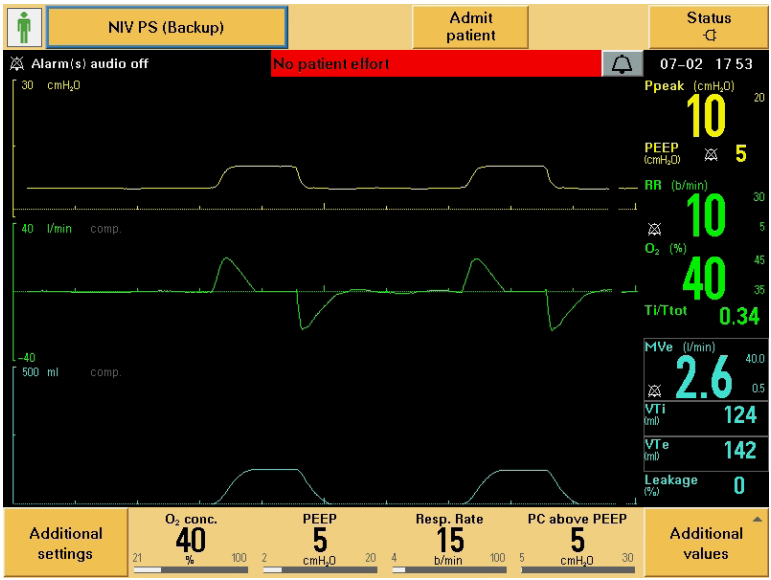
- PC above PEEP – 5 cmH_2O (range 5–30 cmH_2O)
- Resp. Rate – 15 breaths/minute for adults and 30 breaths/minute for infants (range 4–150 breaths/minute)
- I:E – 1:2 for both adults and infants (range 1:10.0–4.0:1) or
- Ti – 0.9 seconds for adults and 0.5 seconds for infants (range 0.1–5 seconds)



NIV Pressure Support

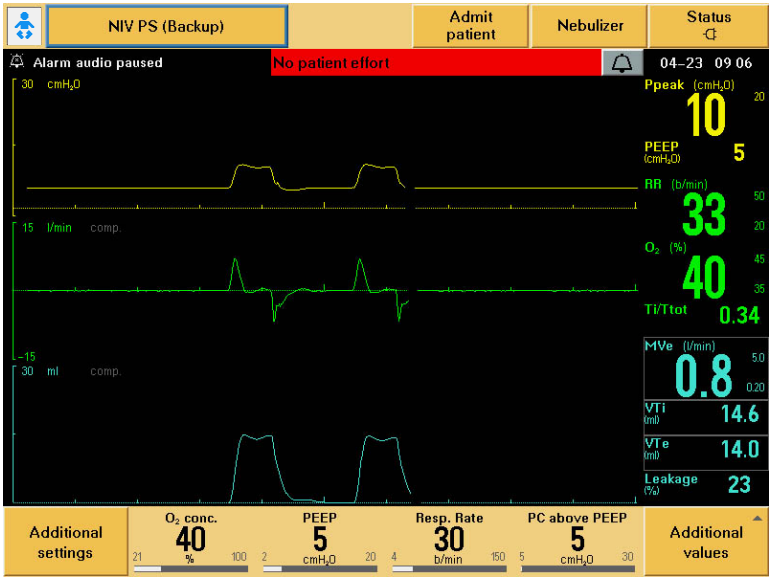
After the set apnea time, the Servo-i has switched here to NIV PS (Backup) and the message "No patient effort" has been displayed. The Servo-i will now start to ventilate in Pressure Control. The third and fourth direct access knobs are used in backup mode to adjust the respiratory rate and PC above PEEP.

The Servo-i will automatically switch back to NIV PS if a patient effort is detected. There is no limit on the number of times the ventilator may switch back and forth between NIV PS and NIV PS (Backup).



Apnea audio delay

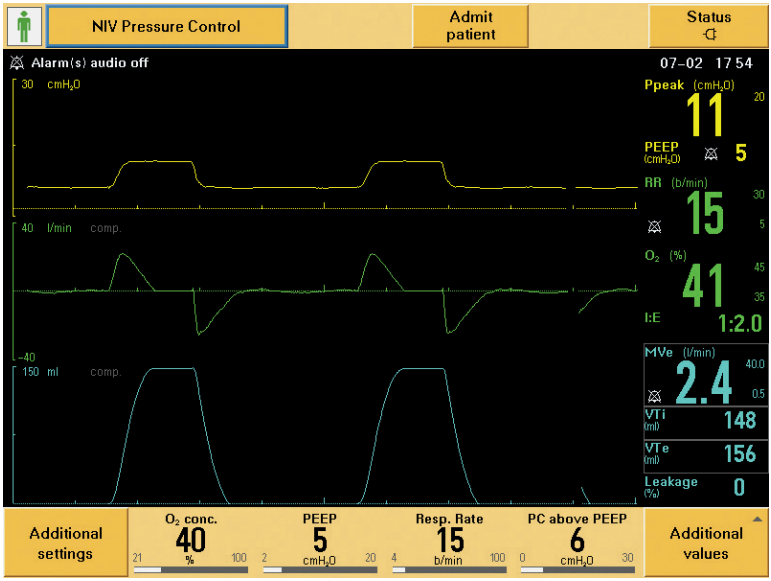
In NIV PS, but only for infants, it is possible to set an apnea audio delay of between 0 and 30 seconds.



The apnea time may be set to 10 seconds and the apnea audio delay may also be set to 10 seconds. If the patient fails to trigger, the message "No patient effort" will appear at the same time as the message "Alarm audio paused" is displayed. The Servo-i will switch to the backup mode.

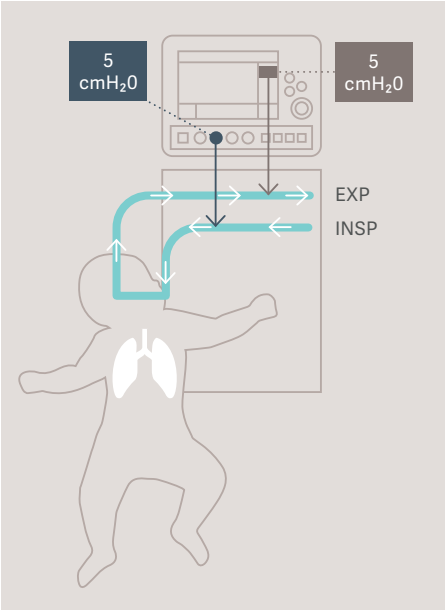
NIV Pressure Control

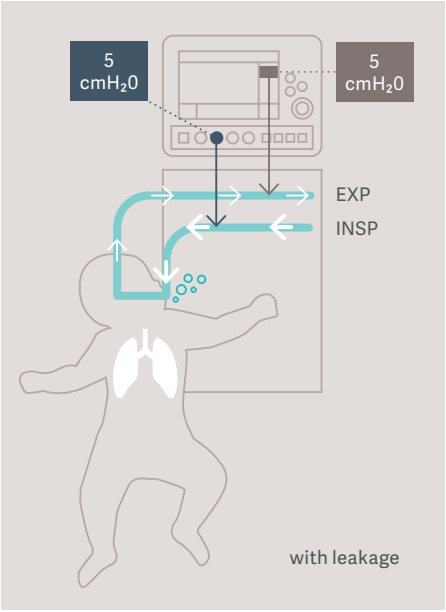
In this controlled mode of ventilation, the ventilator delivers a flow to maintain the preset pressure at a preset respiratory rate and during a preset inspiratory time. The pressure is constant during the inspiratory time and the resulting flow rate is decelerating. If for any reason the pressure decreases during inspiration, the flow from the ventilator will immediately increase to maintain the set inspiratory pressure. The volume may vary from breath to breath if the patient's compliance and resistance change.



Nasal CPAP

The weight range for Nasal CPAP is from 500 g to 10 kg. Nasal CPAP in the Servo-i ventilator delivers the flow necessary to maintain the pressure set by the user.

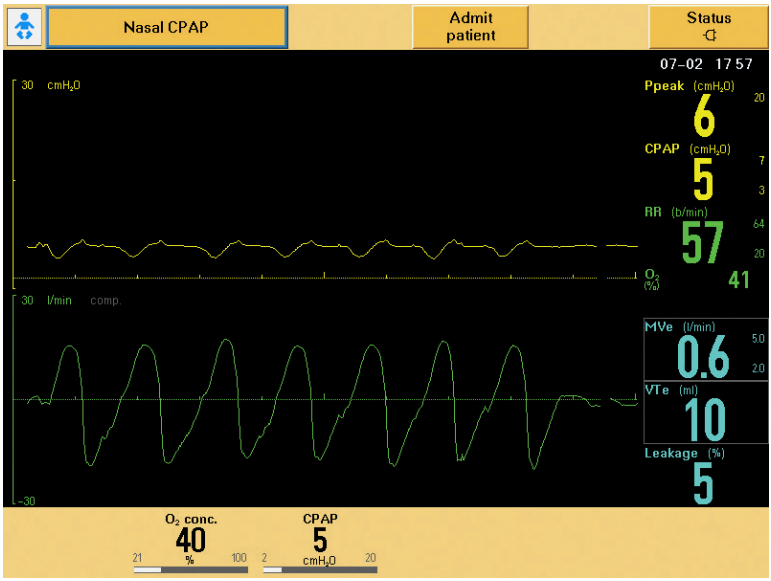




For example, if there is a leakage around the nasal prongs, then the Servo-i will automatically and immediately increase the flow on the inspiratory side in order to maintain the set pressure. The maximum available flow in Nasal CPAP is 33 l/min.

Pressure and flow curves

In Nasal CPAP the pressure level and the oxygen concentration have to be set. The CPAP pressure can be set from 2–20 cmH_2O.



Servo-i regulates the pressure from the set CPAP level in order to minimize the pressure fluctuation, while the flow varies.

In Nasal CPAP, the infants breathe spontaneously from the delivered flow and there is no triggering criteria.

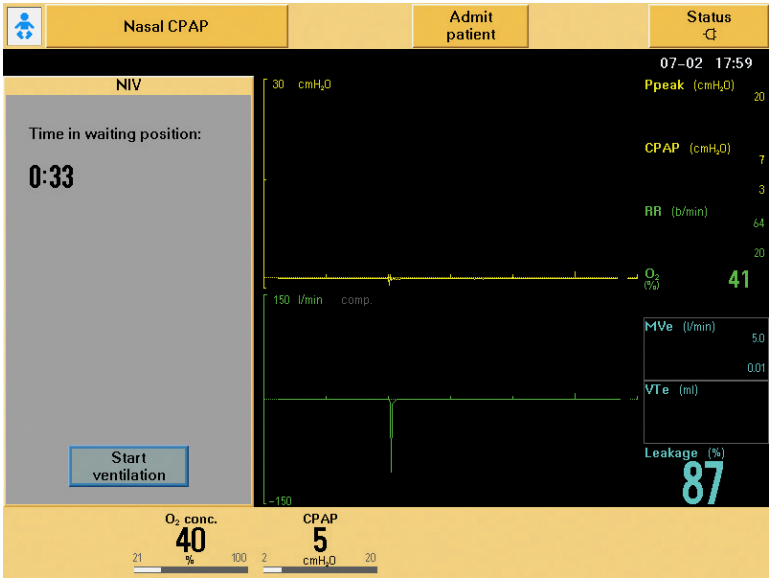
Waiting position

When the Nasal CPAP mode of ventilation starts, a waiting position is initiated. The patient will feel more comfortable, as during this period the ventilator will not deliver a substantial flow until the patient makes an inspiratory effort.

Moreover, all audible, patient-related alarms (except for the O_2 alarm) are inactivated during this phase and no ventilation occurs. The Servo-i has a bias flow of 7.5 l/min while in the Nasal CPAP waiting position.

Ventilation will start when one or both of the following criteria have been met:

- the ventilator detects a patient's attempt to breathe.
- the user presses the soft key "Start ventilation".

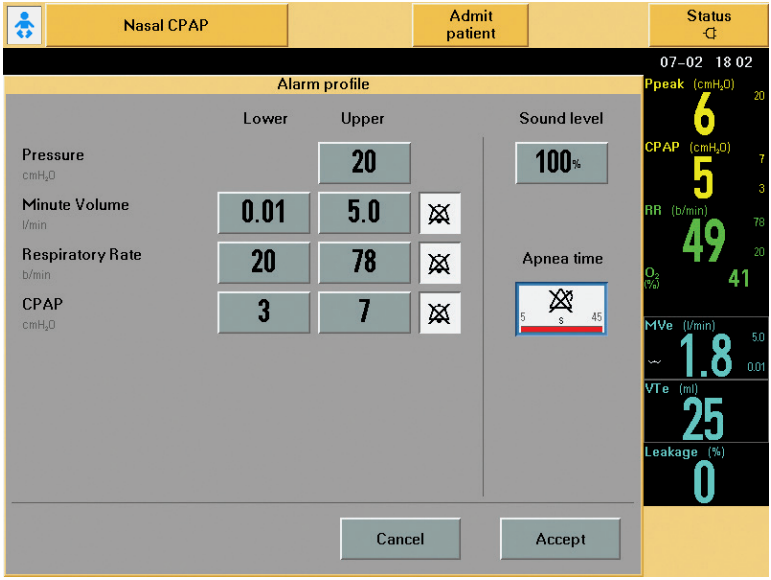


Nasal CPAP – Alarms

Since the leakage often varies in Nasal CPAP, alarms may be activated more often than necessary.

To reduce the frequency of these activations, it is possible to set audible alarms to "Audio Off" for all patient-related alarms except the High Pressure Alarm.

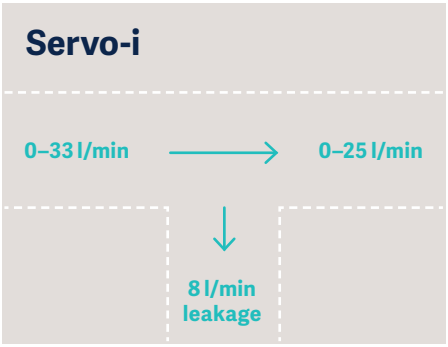
To enable the "Audio Off" function, press the soft key with the "bell" symbol next to the relevant alarm. A crossed-over bell indicates that the "Audio Off" function in both the "Alarm profile" window and the "Measured value" box will be shown. To activate the "Audio Off" function for the apnea alarm, turn the main rotary dial well past the maximum setting of 45 seconds.

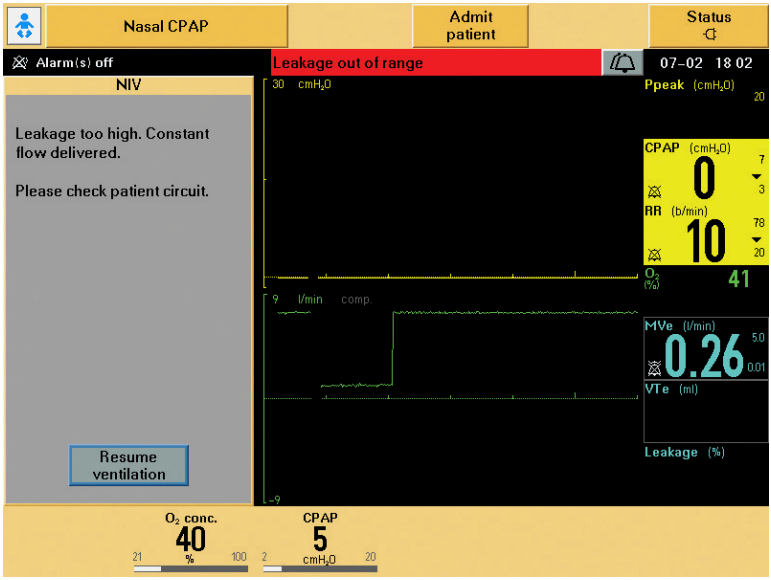


Excessive leakage

The maximum available flow is 33 l/min. If there is a leakage of 8 l/min, then the available flow is 0–25 l/min. If a leakage of 10 l/min has occurred in the patient´s breathing system for a short period of time, or if the patient is disconnected, then the Servo-i informs the user by displaying the message "Leakage too high. Constant flow delivered. Please check patient circuit." in the dialog box.

A high priority alarm is activated and displayed on the User Interface stating "Leakage out of range".





Ventilation is paused to minimize patient discomfort. A constant bias flow is delivered to detect the breathing effort of the patient. It is also possible to start ventilation manually either by pressing the "Start breath" fixed key or the "Start ventilation" soft key on the user interface. However, if the leakage is not remedied then the dialog box will reappear.

The leakage is presented as the leakage fraction (%) on the monitoring section of the user interface. The volumes shown in the Measured value box are "compensated" for leakage. In other words, these volumes correspond to the actual patient volumes.

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This document is intended to provide information to an international audience outside of the US. Servo-i may be pending regulatory approvals to be marketed in your country. Contact your Getinge representative for more information.

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