NAVA and NIV NAVA

Neonatal pocket guide

GETINGE

Contents

Introduction and background facts

Introduction

This guide aims to present Neurally Adjusted Ventilatory Assist (NAVA) in both its invasive and non invasive forms to users working with neonatal intensive care. This guide cannot replace the User´s manual of the ventilator. NAVA can be used on Servo-n, Servo-u and Servo-i ventilators. The NAVA software, Edi module and the Edi catheter are needed. In this guide the screenshots are from Servo-n with system software version 4.4.

The following is described:

- The physiological background to NAVA
- Important central concepts, such as Edi signal and NAVA level
- Workflow
- Edi catheter
- Invasive NAVA
- Non invasive NAVA
- Unique features of NAVA and NIV NAVA along with useful management tips relevant to neonatal care

NAVA Terminology

Edi is the electrical activity of the diaphragm and can be thought of as a respiratory vital sign. Edi_{peak} is the highest value of the Edi signal during a single breath. Edi_{min} represents the spontaneous tonic activity of the diaphragm, which prevents derecruitment of alveoli during expiration. NAVA level is a gain factor that converts the Edi signal into a proportional pressure.

NAVA in both its invasive and non invasive forms, can be used on all patients requiring ventilatory assistance (neonatal, pediatric and adult patients), provided that the electrical signal from the brain to the diaphragm is intact and that there is no contraindication for insertion/exchange of a nasogastric tube.

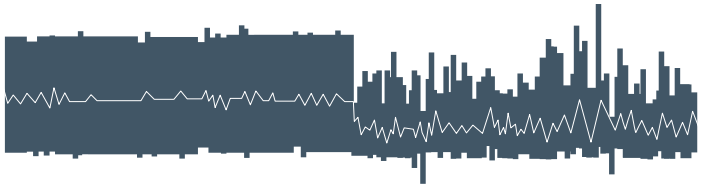
NAVA delivers assist in proportion to and in synchrony with the patient's respiratory efforts. These efforts are reflected by the Edi signal, which represents the electrical activity of the diaphragm, the body's principal breathing muscle. Understanding the Edi signal and its use in invasive NAVA and NIV NAVA is essential to successful ventilation using these modes.

Physiology of the Edi signal

During normal respiration, a spontaneous breath starts with an impulse generated by the respiratory center in the brain. This impulse is then transmitted via the phrenic nerves and electrically activates the diaphragm (excitation), leading to a muscle contraction. The diaphragm contracts into the abdominal cavity, which leads to a descending movement, creating a negative alveolar pressure and an inflow of air.

Muscular contraction of the diaphragm is always preceded by an electrical impulse and this electrical activation is controlled by nerve stimuli, and ultimately by the respiratory center in the brain. The signal that excites the diaphragm is proportional to the integrated output of the respiratory center in the brain and controls the depth and cycling of the breath.

Since the Edi signal varies with each breath, the assist pressures will vary accordingly. In summary, inspiration will start when the patient triggers a breath and gas flows into the lungs at varying pressures in proportion to the patients Edi signal.



Swtich from SIMV to NAVA, pressure trend illustration.

Using the Edi signal in NAVA

The electrical activity of the diaphragm, the Edi signal, is captured by a special catheter (the Edi catheter), which is fitted with an array of electrodes. Like an ordinary feeding tube, the Edi catheter is placed in esofhagus into the stomach.

The Edi signal that is picked up by the electrodes on the Edi catheter is filtered and processed by the Edi Module. The processed Edi signal is relayed to the ventilator which will, depending on the NAVA level chosen, then deliver assist to the patient in proportion to and in synchrony with this signal.

Basically, NAVA uses the Edi signal to control the ventilator and assist the patient's breathing in proportion to and synchrony with the babies respiratory drive.

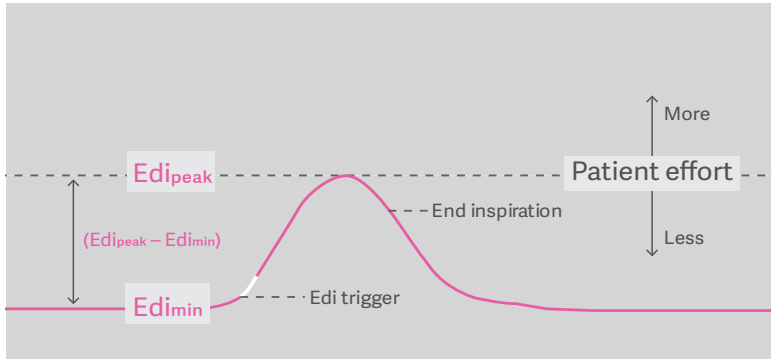
The Edi signal serves as a respiratory vital sign in that it provides:

- Continuous monitoring of the respiratory drive
- Decision support for adjusting assist to unload the patient
- Objective criteria for intubation and extubation decisions.

The Edi signal is displayed on the ventilator screen, enabling the user to monitor this vital sign and to observe and follow the synchrony between patient and ventilator.

Edi trigger

When the preset Edi trigger level is reached, the ventilator will start to deliver assist in proportion to the Edi signal, using the preset NAVA level as the factor by which the signal is multiplied to ensure continuous proportionality. Both NAVA modes, invasive and non invasive, are triggered by an increase in the Edi signal from its lowest value during expiration, the Edi_{min}, rather than a specific Edi level.



1. Edi trigger is set to 0.5 µV above Edi_{min}
2. Expiratory phase starts at 70 % of Edi_{peak}

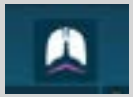
NAVA and NIV NAVA also employ a pneumatic trigger, based on flow or pressure, as a secondary trigger source. In combination with the Edi trigger, this operates on a first-come-first-served basis.

The breath may be triggered either by the Edi or pneumatically, by flow or pressure. The assist to the patient will remain proportional to the patient's Edi signal. The maximum time for inspiration is 1.5 seconds for neonates.

The pressure curve in both NAVA and NIV NAVA follows the Edi signal pattern. Expiration starts when the Edi decreases below 70 % of the peak value (during the ongoing inspiration).

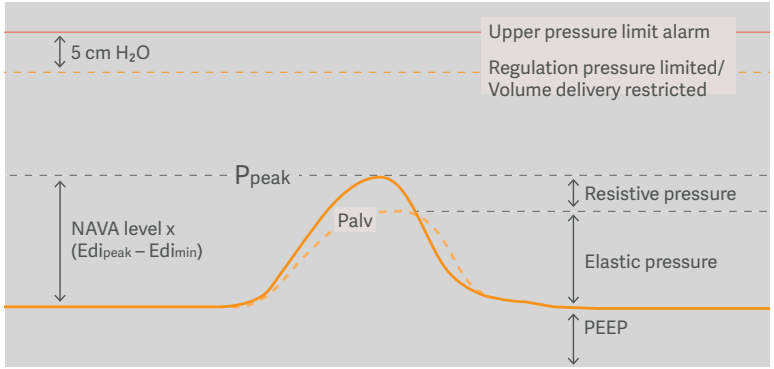
Trigger colors

When the Edi trigger is active, a symbol will be visible in the status bar and the Edi waveform will also be highlighted in white.



If it is a pneumatic triggered breath (flow or pressure) the white indication is displayed in the pressure or flow waveform and there is no purple diaphragm symbol.

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 (P_{peak} alarm limit).



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, including values for both Edi_{peak} and Edi_{min}.

High Flow therapy and Edi monitoring

NAVA

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

Since the Edi signal varies with each breath, the assist inspiratory pressure will vary accordingly. In summary, inspiration will start when the patient triggers a breath and gas flows into the lungs at a varying pressure proportional to the patient's Edi signal.

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. It may also need adjusting over time in the same patient.

- The NAVA level is typically set to between 1.0 and 3 $cmH_20/\mu V$. In NIV NAVA the NAVA level is generally lower than that set for invasive NAVA.
- Titrate NAVA level comfort and Edi_{peak} 10–15 µV.
- If the patient is comfortable and the Edi_{peaks} are < 5µV, decrease the NAVA level in steps of 0.2–0.3 until the Edi_{peak} values are > 5 µV.
- If there is an increased WOB and Edi_{peak} > 20µV, increase the NAVA level in steps of 0.2–0.3 increments until the patient is comfortable and the Edi_{peaks} are < 15 µV.

Protocol contributed by Howard Stein MD (Russell J. Ebeid Children's Hospital, Toledo, OH, USA) and Kimberly Firestone MSc, RRT (Akron Children's Hospital, Akron, OH, USA).

Starting and running NAVA

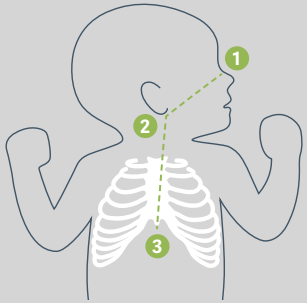
The following equipment is required:

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

Edi catheter package

Edi module and Edi cable

NAVA workflow



Edi catheter insertion and positioning

1. Connect the Edi module and cable.
2. Perform the Edi module function check.
3. Measure NEX (nose-ear and xiphold) distance in cm (1 2 3). If you are using the measuring tape included in the package the insertion distance is displayed. Note there are one side for oral insertion and one for nasal insertion. If you are using an ordinary measuring tape the calculation tool on the user interface can be used.
4. Determine the insertion distance.
5. Dip the Edi catheter in water for a few seconds and insert. Do not apply any other substance than water to the Edi catheter. Lubricants, gels or solvents may destroy the coating and the contact with the electrodes.
6. Connect the Edi cable to catheter.
7. Verify the position in the catheter positioning window.
8. Check the position of the Edi catheter as a feeding tube according to hospital routines.
9. Secure it to the patient, and make a note of the insertion distance in the Edi catheter positioning window.
10. Verify the position regularly.

Insertion and positioning of the Edi catheter

Select the appropriate Edi catheter for the patient. You need to know the patient's height and weight. The table below provides more details.

The different catheter sizes are shown on the packages labelling and also on the Edi catheter insertion window tool on the user interface.

Note: For neonates below 1000 g use Edi catheter 6Fr / 49 cm.

Patient height	Patient weight	Edi catheter size
< 55 cm	0.5 - 1.5 kg	6 Fr 49 cm
< 55 cm	1.0 - 2.0 kg	6 Fr 50 cm
< 55cm	1.0 - 2.0 kg	8 Fr 50 cm
45 – 85 cm		8 Fr 100 cm

Note: Yellow prompt when the Edi catheter does not match the patients weight.

Insert the Edi Module into the Servo-u/n or i ventilator and connect the Edi Cable. Perform the Edi Module function check.

Edi catheter positioning

Open the Edi catheter positioning window.

Check the position of the Edi catheter by means of the ECG waveforms:

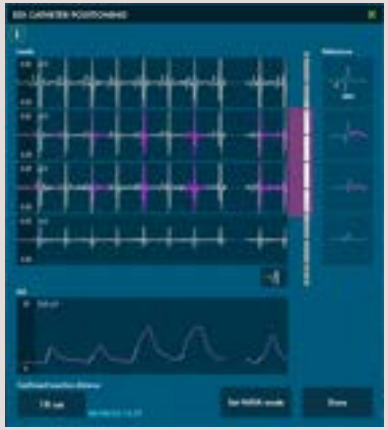
- Verify that P and QRS waves are visible in the top leads and decrease in the lower leads and that the P waves disappear in the lowest lead.
- Finetune the Edi catheter postion if necessary. When the purple diaphragm activity zone is aligned with the mid ECG leads, and they indicate Edi activity highlighted in purple during an inspiration, the Edi catheter is ready to be secured.

Diaphragm activity zone indication.

Reference graphics, static ECG complex.

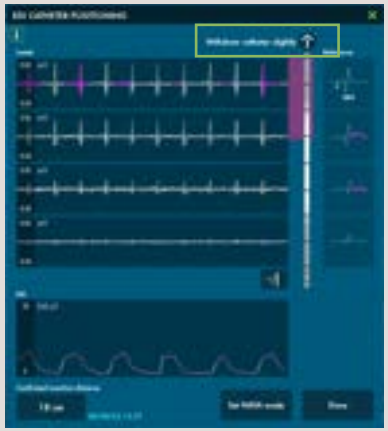
- If it is not already aligned correctly carefully adjust the Edi catheter position: If the top leads are highlighted in purple, the strongest signal is picked up by the upper electrodes due to the catheter being too deeply inserted. Carefully withdraw the Edi catheter in small steps of between 0.5-1.5 cm each depending on catheter size, until the purple highlights appear in themiddle leads. Do not exceed four such steps. A positioning arrow pointing upwards will also be visible above the catheter representation in the window. This indicates that the catheter should be carefully withdrawn.

Positioning Window

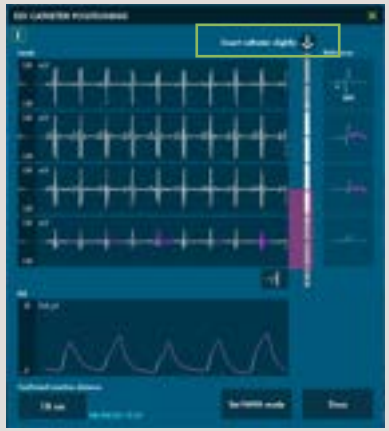


Correct position
Look for a diminishing ECG waveform progressing from the 1st to the 4th waveform and the presence of a purple color in the 2nd and 3rd waveforms (this may fluctuate to the 1st and 4th waveforms at times).

Re-Positioning



Too deep
Pull out slightly. QRS gets smaller from the top to bottom leads.



Too shallow
Insert further slightly. QRS gets bigger from the top to bottom leads.

Edi catheter positioning

Both the symbols on the representation of the Edi catheter and the color highlights on the leads show where the Edi signal is strongest.

If no Edi signal is detected, there will be no such indications. Note that the color highlights on the leads change more rapidly than the symbols on the Edi catheter.

Arrow indication

A positioning arrow pointing upwards will also be visible. This indicates that the catheter should be carefully moved upwards. If the bottom leads are highlighted in purple, insert the Edi catheter further in similar steps until the purple highlights appear in the center. Do not exceed four steps.

A positioning arrow pointing downwards will also be visible. This indicates that the catheter should be carefully moved downwards.

Edi catheter positioning guide -arrows (not visible when catheterposition is in an appropriate position).

IMPORTANT:
The positioning arrows can only be used to fine tune the catheter position when there is a reliable Edi signal. If the Edi signal is low or absent, the arrows should not be used to adjust the catheter position.

Always follow hospital routines to check the position of the Edi Catheter when it is used as a gastric feeding tube.

Make a note in the patient's file of the actual length inserted and mark this on the Edi catheter and/or enter it on the screen as the final distance.

- Secure the Edi catheter, being careful not to manipulate or move it in order to avoid interference with Edi monitoring.

PEdi - Pressure estimation

It's possible to monitor the Edi signal in any mode. In the uppermost waveform, two curves are presented simultaneously. The gray curve shows the estimated pressure based on Edi (PEdi) and the set NAVA level and the yellow curve is the current patient airway pressure in the selected conventional mode. This may be used to evaluate the synchrony of the breaths.

Evaluate the Edi signal. A low or absent Edi may be due to any of the following:

- hyperventilation
- sedation
- muscle relaxants
- neural disorders

User interface

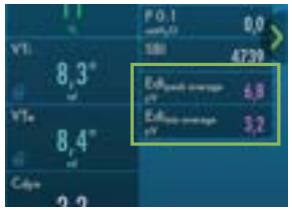
During ventilation, the Edi waveform will be displayed on the screen, and relevant Edi$_{peak}$ and Edi$_{min}$ values will also be displayed in the numerical values.

Shortcut to Edi catheter positioning

Average Edi$_{peak}$ and Edi$_{min}$

Verify that the Edi scale is fixed. The scaling function is accessed by tapping and holding the Edi waveform. The recommended level is 20 µV. Set a sufficiently high upper limit on the scale where the Edi signal is not fully visible.

Tap on the green arrow and the average Edi$_{peak}$ and Edi$_{min}$ is displayed.



Average Edi$_{peak}$
The mean value of the Edi$_{peak}$ for all breaths during the last 60 s.
Average Edi$_{min}$
The mean value of the Edi$_{min}$ for all breaths during the last 60 s.

Invasive ventilation with NAVA

Setting ventilation mode

Backup ventilation for NAVA is Pressure Control.
Apnea management is the same in both NAVA and NIV NAVA.

The following parameters are set in NAVA:

- Oxygen concentration (%)
- PEEP (cmH_2O)
- NAVA level
- Edi trigger
- Trigger

PC backup settings:

- Apnea time (s)
- Backup respiratory rate (b/min)
- Backup PC above PEEP (cmH_2O)
- Backup I:E or Ti (s)

The NAVA level

The NAVA level is typically set to between 1.0 and 3 $cmH_20/\mu V$. In NIV NAVA the NAVA level is generally lower than that set for invasive NAVA.

- Titrate NAVA level comfort and Edi_{peak} 10–15 µV.
- If the patient is comfortable and the Edi_{peaks} are < 5µV, decrease the NAVA level in steps of 0.2–0.3 until the Edi_{peak} values are > 5 µV.
- If there is an increased WOB and Edi_{peak} > 20µV, increase the NAVA level in steps of 0.2–0.3 increments until the patient is comfortable and the Edi_{peaks} are < 15 µV.

Protocol contributed by Howard Stein MD (Russell J. Ebeid Children's Hospital, Toledo, OH, USA) and Kimberly Firestone MSc, RRT (Akron Children's Hospital, Akron, OH, USA).

Setting and optimizing PEEP

Initially, set the same PEEP as in the previous ventilator settings. If Edi_{min} is constantly > 1 µV (as a sign of tonic diaphragmatic activity to maintain FRC), increase PEEP.

Setting apnea time

If breathing is irregular and the patient unstable, apnea time down may be decreased to 2 seconds. This will result in back-up breaths after each 2-second apnea until next spontaneous breath indicated by Edi signal occurs. Adjust as clinically indicated (minimum rate – 2 seconds = 30 bpm, 1 second = 60 bpm).

However, make sure that the back-up ventilation does not hyperventilate the patient preventing spontaneous breathing efforts (which would keep the patient unnecessarily on back-up ventilation).

The trends will show the number of back-up periods and percent time the patient has been on back-up per each minute. If the patient is stable and switching a lot between back-up and NAVA support, you may increase apnea time to decrease back-up ventilation.

Back up settings

Adjust the back-up settings appropriately taking into account the pre-NAVA settings and the recovery process of the patient.

Edi trigger

Avoid "artifact self-triggering" which can happen when trigger is too low (lower number is more sensitive). The Edi trigger default level is 0.5 uV.

Weaning patients from NAVA

Decrease the NAVA level as the patient's pulmonary status improves. Decrease the NAVA level in steps of 0.2-0.3 cm $H_2O/\mu V$. Decrease back up settings if in backup frequently. Once at NAVA level 0.5– 1 cm $H_2O/\mu V$, extubate to NIV NAVA, go from NIV NAVA, CPAP or High Flow. Follow local policy and weaning protocol. Integrate NAVA level and Edi as decision criteria. Monitor the Edi signal in CPAP or High Flow therapy.

Trend curves

The trend curves give information about respiratory variables for the preceding 74 hours and they should be routinely checked together with the baby's clinical condition.

The following trend curves are described:
- Number of switches to Backup/min
- Percent (%) of time in backup ventilation/min
- Respiratory rate trend

Number of switches to backup/min

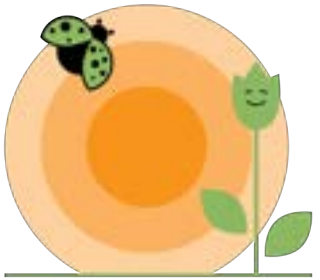
This indicates the number of times the neonate goes into backup every minute. If the number of switches to backup/min is high and the neonate is stable, the current apnea time may be too short and the neonate could tolerate a longer apnea time. If the number of switches to backup/min is high and the neonate is desaturating, the current apnea time (time without any ventilation) may be too long, consider shortening the apnea time. If the number of switches to backup/min is low, and the neonate is having minimal apnea at the set apnea time, consider lengthening the apnea time.

Percent (%) of time in backup ventilation

This indicates the amount of time as a (%) the neonate is in backup/min. If % of time in backup ventilation/min is high and the number of switches to backup/min are low then the neonate may not be ready to be weaned (the neonate is mostly in backup). If % of time in backup ventilation/min is low the neonate may be ready to be weaned by lengthening the apnea time. If both the % time in backup is high and the number of switches to backup/min are high the neonate may be ready to be weaned by lengthening the apnea time.

Respiratory rate trend

The respiratory rate trend can also be used to determine the amount of time the neonate is in NAVA versus backup ventilation. When in NAVA, the measured and spontaneous respiratory rate will be equal. When in backup ventilation, the measured respiratory rate will be higher than the spontaneous respiratory rate.



NIV NAVA

Introduction to NIV NAVA

NIV NAVA does not rely on a pneumatic signal. Both triggering and cycle off of the breath rely on the Edi signal and are therefore independent of leakage.

There are several types of patient interface. For neonates, the most commonly used interfaces are nasal prongs or nasal masks.

Starting NIV NAVA

Setting ventilation mode
Backup ventilation for NIV NAVA is Pressure Control.

Apnea management is the same in both NAVA and NIV NAVA.

The leakage fraction alarm function is only available in the NIV NAVA neonatal category.

IMPORTANT:
In NIV NAVA, small tidal volumes in combination with high leakage reduce the accuracy of expiratory measurements.

The following parameters are set in NIV NAVA:

1. Oxygen concentration (%)
2. PEEP (cmH_2O)
3. NAVA level
4. Edi trigger

PC backup settings:

5. Apnea time (s)
6. Backup respiratory rate (b/min)
7. Backup PC above PEEP (cmH_2O)
8. Backup I:E or Ti (s)

The NAVA level
The NAVA levels in NIV NAVA are usually lower than in invasive NAVA (0.5–1.0 µV/cmH2O/µV).

- If Edi_{peak} is < 5 µV, decrease the NAVA level.
- If Edi_{peak} is > 20 µV, increase the NAVA level.

The changes in NAVA level should be in steps of 0.1–0.2 µV/cmH_2O, with a few breaths between each step.

Protocol contributed by Howard Stein MD (Russell J. Ebeid Children's Hospital, Toledo, OH, USA) and Kimberly Firestone MSc, RRT (Akron Children's Hospital, Akron, OH, USA).

Before starting ventilation it is important to check the alarm profile including the apnea time setting.

It is important to set a suitable upper limit for pressure. The maximum available pressure level is 5 cmH_2O below the preset upper pressure limit. The maximum peak pressure is 70 cmH_2O.

The maximum available pressure level is thus 5 cmH_2O below the preset upper pressure limit.

Since leakage often varies during non invasive ventilation, alarms may be activated frequently, which may be perceived as disturbing, particularly to the patient. It is therefore possible to set audible alarms to "Audio off" by pressing the bell on the relevant alarm. This applies to all patient related alarms except the high pressure alarm.

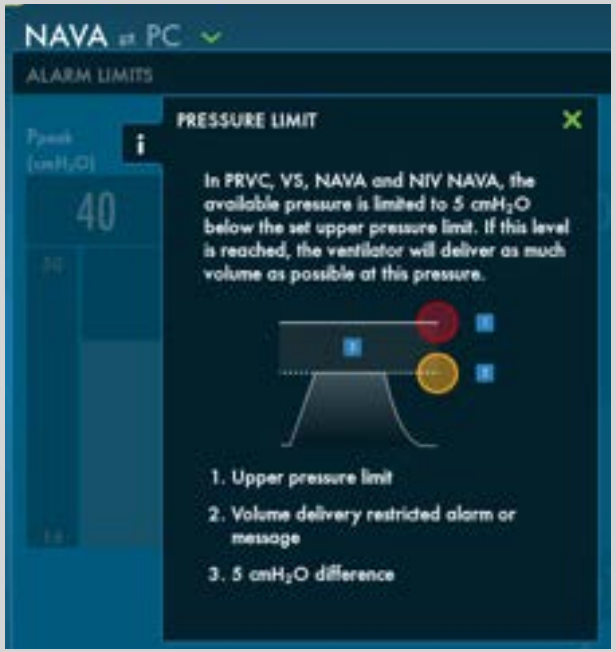
Disconnect flow
Disconnect flow may occur when a patient is disconnected from the interface and the ventilator. Disconnect flow can be configured in the Biomed Configuration menu.

The Disconnect flow can be set in the Edit startup configuration window.
The following settings are possible:
- Low flow – 7.5 l/min
- High flow – 15 l/min
- Disabled – No pause in ventilation in case of high leakage. The ventilator will continue to deliver assist even when leakage is excessive.

Alarms

Volume delivery restricted alarm

Volume delivery is restricted appears as a text message activated during NAVA at a level 5 cmH_20 below the set Upper Pressure Limit. The maximum available pressure level is thus 5 cmH_20 below the preset upper pressure limit.



The following alarms can be turned off:

- Leakage too high
- Expiratory minute volume low
- Expiratory minute volume high
- Inspiratory tidal volume too high

No patient effort alarm

If the Edi signal is low, the ventilator will activate a medium priority alarm after the set apnea time and the message "No patient effort" will appear on the screen. The ventilator will automatically switch to Backup ventilation.

The backup mode for NIV NAVA is Pressure Control.

Once the ventilator detects a valid Edi signal again, it will automatically return from backup ventilation to NIV NAVA. There is no limit on the number of times the ventilator can switch back and forth between NIV NAVA and backup ventilation.

In the neonatal patient category only, the No patient effort alarm can be turned off in NAVA and NIV NAVA.

If the No patient effort alarm is turned off in NAVA, this will automatically turn off the No consistent patient effort alarm as well.

A dialog Backup ventilation active – review ventilation settings or continue in supported mode is displayed on the screen. A choice must be made or this dialog will remain open and the ventilator system will remain in backup ventilation.

Warning: If the Edi is not synchronized with pressure and flow, this may mean that the Edi catheter is displayed and registering the electrical activity on another muscle. This will be indicated by an alarm.

Leakage out of range alarm

The ventilator will compensate for leakage of up to 25 l/min for neonates. If leakage is excessive (>25 l/min for neonates during expiration) or if the patient is disconnected, the ventilator will pause and issue a high priority alarm. A dialog appears, stating that leakage is too high and recommending that the patient circuit should be checked. The message Leakage out of range also appears at the top of the screen. When this happens, a constant disconnect flow is delivered. The flow depends on the setting of the Disconnect flow function in the startup configuration. The disconnection flow can also be set to disable.

Check catheter position/Edi invalid alarm
Another high priority alarm concerns the Edi catheter and occurs when there is no valid Edi signal for the ventilator to work with, for example if the Edi catheter or Edi cable have been accidentally disconnected. The ventilator then switches to backup ventilation and a dialog opens. As soon as the Edi catheter has been reconnected and the ventilator detects a valid Edi signal, the ventilator will switch back to NIV NAVA.

If the Edi is not synchronized with pressure and flow, this may mean that the Edi catheter is displaced and registering the electrical activity of another muscle. This will be indicated by the Inconsistent Edi signal alarm for NAVA and the Edi signal invalid alarm for NIV NAVA.

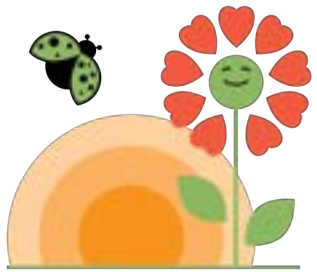
Apnea audio delay
It is also possible to set an Apnea audio delay to between 0 and 30 seconds. If, for example, the user sets the apnea audio delay to 20 seconds, while the apnea time has been set to 10 seconds, the ventilator will, after 10 seconds with no Edi signal, activate the "No patient effort" visual alarm and display the message "Alarm audio paused". If the Edi signal does not return within the next 20 seconds, a high priority audio alarm signal will be activated.

In the neonatal patient category only, the No patient effort alarm can be delayed. The setting is made by tapping Apnea audio delay, which is displayed, at the bottom of the ALARM LIMITS window.

Leakage too high
The Leakage too high alarm that occurs when leakage in NIV NAVA exceeds 95 % and can be turned off.

Note if you can't find "Leakage too high" in the alarms window you need to change the configuration of the ventilator.

Alarm message	Possible causes	Alarm management checklist
Edi signal invalid.	Backup ventilation is active due to invalid Edi signal.	Check catheter position.
Edi signal interference from ECG.	Backup ventilation is active due to interference from the ECG signal.	Backup ventilation is active due to interference from the ECG signal. Check Edi catheter position.
No patient effort.	An apnea has caused the ventilator to switch to backup ventilation.	Check patient. Check ventilator settings.
No consistent patient effort.	The ventilator has switched between supported and backup ventilation four times in two minutes. The patient has only triggered a single breath to interrupt each of two consecutive backup periods.	
Edi module disconnected.	Edi module is not properly inserted.	
Edi module error.	Hardware error in the Edi module.	Replace the Edi module.
Edi catheter error.		Replace the Edi catheter.
Volume delivery is restricted.	The pressure is limited to 5 cmH_2O below the set upper pressure limit.	Check ventilator settings. Check alarm limits.
No Edi catheter connected.	The Edi catheter is not properly connected.	Check Edi catheter connection.
Edi monitoring not active.	NAVA mode is activated when no Edi module and/or Edi catheter is connected.	Change ventilation mode. Insert the Edi module.



NAVA and NIV NAVA features and manage-ments tips

Using the Edi catheter as a feeding tube

The Edi catheter is a single-use gastric feeding tube with an array of 10 electrodes (nine measuring and one reference electrode). The Edi catheter has been validated for use for 5 days, both for feeding and when using the NAVA function.

Suctioning

During suctioning, or in case of patient disconnection, it is important to use the disconnection function to avoid activating the alarms.

Coughing and hiccups

If a patient is suffering from hiccups, they may trigger the ventilator and cause a short assist delivery. If a patient coughs, NAVA will provide assist during the inspiration phase prior to the cough, and the expiratory valve will open during the coughing itself. The usual safety mechanisms, such as the upper pressure limit, are in place to handle coughing while using the NAVA mode.

Removed or misplaced Edi catheter

If the Edi catheter is removed or displaced the ventilator will switch to backup mode.

Troubleshooting

Parameter	Investigate the reason	Management
High Edi_{peak} > 20µV	• WOB increased	• Increase NAVA level, increase Ppeak alarm limit
	• Insufficient backup support	• Increase backup pressure
	• Failing NIV treatment	• Intubate and use NAVA
	• Discomfort and Pain	• Consider light analgesics
	• Edi catheter dislocated	• Reposition Edi catheter
Low Edipeak < 5µV	• Over-assist	• Decrease NAVA level
	• Poor respiratory drive	• Decrease backup support
	• Sedation too high	• Decrease sedation
Edi_{min} consistently > 5µV	Atelectasis	• F_iO_2 high-increase PEEP by 1 • Patient clinically stable – no change

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High respiratory rate

Typical reasons for high respiratory rate are:

- In NAVA the respiratory rate is usually higher compared to pressure support, caused by absence of wasted efforts in NAVA. In addition, tidal volumes are physiological for patient and the effect of Hering-Breuer reflex on breathing frequency is lower.
- There is no way (and no need) to limit the breathing frequency in NAVA.
- It should be noted that a high respiratory rate, and in particular a chaotic breathing pattern, are characteristic of NAVA and should not routinely be regarded as agitation, but merely as a physiological breathing pattern for this particular patient.

High respiratory rate

Possible causes for acute change in respiratory rate are:

- Acute change in pulmonary status
- Pain
- Discomfort
- Nausea
- Fever

Pneumatic triggering NAVA

Typical reasons for pneumatic triggering in NAVA are:

- In NAVA, the ventilator provides support on a 'first-come-first-served' basis. If inspiratory flow is sensed before a rise in the Edi signal, the breath will be flow-triggered. However, always when Edi signal is present, the breath delivered will remain proportional to the Edi signal no matter how it is triggered.
- Pneumatic trigger should be set to the optimal level individually for each patient.

Special groups of patients

Some clinical conditions weakening diaphragm function (for example status post diaphragmatic hernia, myopathies and so on) may lead to a situation, where the patient is unable to increase the Edi_{peak} even in case of insufficient support or hypoventilation. For these patients, the correct NAVA level needs to be assessed by patient comfort, blood gas values and clinical condition.

Glossary

Abbreviation	Meaning
ECG	Electrocardiogram, a recording of the electrical activity of the heart.
Edi	The electrical activity of the diaphragm.
Edi_{peak}	The highest value of the Edi signal during a single breath cycle.
Edi_{min}	The lowest value of the Edi signal during a single breath cycle.
Fr	Abbreviation for French. The French catheter scale is commonly used to measure the outer diameter of cylindrical medical instruments including catheters. In millimeters, the diameter is equal to the number of French units divided by 3.
MV	Minute volume.
MVe	Expiratory minute volume.
NAVA	Neurally adjusted ventilatory assist, an optional mode for the Servo-u/n and i ventilators ventilator that mimics normal respiration and enhances patient-ventilator interaction.
NAVA level	The "gain factor" by which the patient's Edi signal is multiplied to deliver assist in proportion to the patient's own breathing effort.
NEX	Measurement developed specifically to help with the insertion and positioning of the Edi catheter. The distance measured is from the bridge of the Nose to the Earlobe and then to the tip of the Xiphoid process.
NIV NAVA	Non invasive neurally adjusted ventilatory assist.
P_{mean}	Mean airway pressure.
P_{peak}	Maximum inspiratory pressure.
Peep	Positive end expiratory pressure, measured in cmH_20.
Ti/Ttot	Ratio of inspiration time to total breathing cycle time.
Trigg. Edi	Neurally triggered assist (i.e. triggered by the patient's Edi signal rather than pneumatically) is triggered by an increase in the Edi from the Edi_{min}, rather than at an absolute level.
VT	Tidal volume, i.e. the volume inspired and expired with each normal breath.
VTe	Expiratory tidal volume.
VTi	Inspiratory tidal volume.

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