

NAVA – invasive and non invasive

CRITICAL CARE





## Table of contents

1	Introduction	4
2	Background and basic concepts	5
3	Invasive ventilation with NAVA	23
4	Alarms for invasive NAVA	31
5	The NAVA level – invasive NAVA	35
6	Example of weaning from invasive NAVA	37
7	Non invasive ventilation with NAVA	40
8	Alarms for non invasive NAVA	48
9	The NAVA level – non invasive NAVA	53
10	Example of weaning from non invasive NAVA	54
11	NAVA and NIV NAVA management tips	56
12	Glossary and definitions	63
13	References	65

# INTRODUCTION

## Introduction

This pocket guide has been produced with the aim of providing a brief introduction to Neurally Adjusted Ventilatory Assist (NAVA). NAVA is now available as both an invasive and a non invasive mode, and both are discussed below.

The two NAVA modes – invasive and non-invasive – are based on human respiratory physiology. One of the main aims of this booklet has therefore been to explain in simple terms the physiological background to NAVA, as well as its distinctive features, while providing easy-to-follow instructions. More information is provided in other presentation and training material, while operating instructions and technical details are covered in the appropriate User or Service Manuals for the SERVO-i ventilator.

While every effort has been made to keep this presentation as simple as possible, some technical terms, specialized information and unfamiliar abbreviations are unavoidable. These are explained in the definitions and glossary at the back.

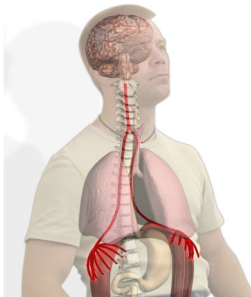
## BACKGROUND AND BASIC CONCEPTS

### Background and basic concepts

NAVA and NIV NAVA are optional modes of ventilation for the SERVO-i ventilator. One of the distinctive characteristics of NAVA, in both its invasive and non invasive forms, is that it 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 NAVA and NIV NAVA is essential to successful ventilation using these modes.

### Physiological background

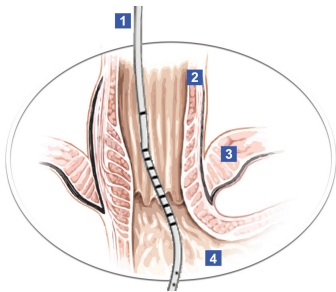
During normal respiration, a spontaneous breath starts with an impulse generated by the respiratory center in the brain. This impulse is then transmitted via the phrenic nerves and electrically activates the diaphragm (excitation), leading to a muscle contraction. The diaphragm contracts into the abdominal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



## BACKGROUND AND BASIC CONCEPTS

Muscular contraction is always preceded by an electrical impulse and this electrical activation is controlled by nerve stimuli, and ultimately, of course, 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.

When NAVA is used with the SERVO-i ventilator, the electrical discharge 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 the esophagus.



1. Edi Catheter (with electrodes marked in black – the first is the reference electrode, the others are measuring electrodes and the distance between the measuring electrodes is the Inter Electrode Distance or IED)
2. Esophageal wall
3. Diaphragm
4. Stomach

## BACKGROUND AND BASIC CONCEPTS

The electrical activity of the diaphragm captured by the electrodes is relayed to the SERVO-i, which both displays it and, in the NAVA modes, delivers assist in proportion to and in synchrony with the measured Edi signal.

Basically, invasive and non-invasive NAVA use the Edi signal to control the ventilator and assist the patient's breathing in proportion to and synchrony with his or her own effort.

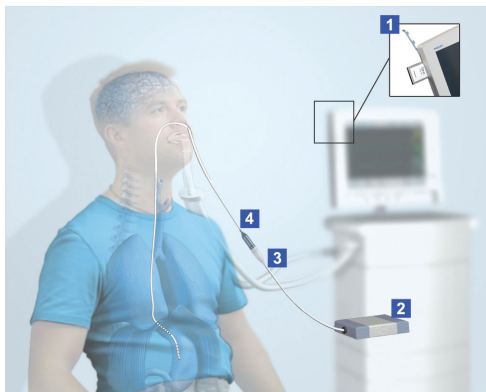
The Edi signal serves as a respiratory vital sign in that it provides:

- continuous monitoring of the respiratory drive
- decision support for unloading and assist titration
- objective criteria for intubation and extubation decisions.

## BACKGROUND AND BASIC CONCEPTS

### Basic NAVA concepts

#### The NAVA option – invasive and non invasive



In order to run invasive NAVA, the following parts are required:

1. NAVA software option – if not already factory-installed, the software can be installed using a PC Card.
2. Edi Module
3. Edi Cable
4. Edi Catheter



## BACKGROUND AND BASIC CONCEPTS

Once the software is correctly installed, the NAVA button will appear in the list in the Select Ventilation Mode window for invasive ventilation.

In order to run non invasive NAVA, one additional component is required:

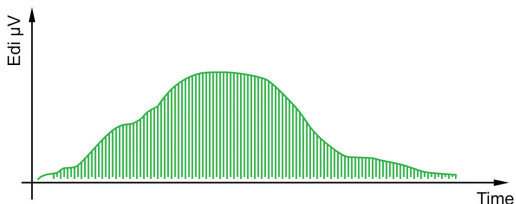
- The NIV NAVA software option – if not already factory-installed, the software can be installed using a PC card.

Once the software has been correctly installed, the NIV NAVA button will appear in the Select ventilation mode window for non invasive ventilation.

The Edi signal that is picked up by the electrodes on the Edi Catheter is filtered and processed by the Edi Module. The Edi signal is measured in microvolts 62.5 times per second. The processed Edi signal is relayed to the SERVO-i ventilator which will, depending on the NAVA level chosen, then deliver assist to the patient in proportion to and in synchrony with this signal.

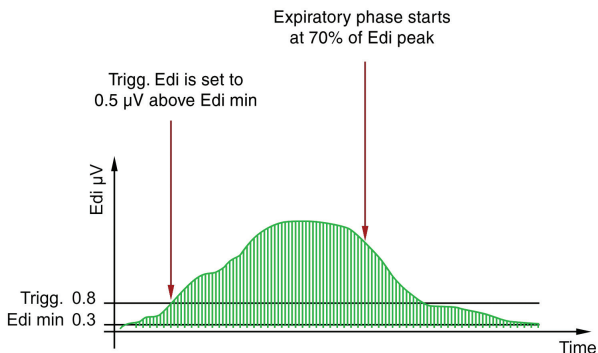
An example of an Edi curve for a single patient breath is presented in the diagram below. The vertical green lines represent Edi signals, sampled at a rate of 62.5 times per second.

## BACKGROUND AND BASIC CONCEPTS



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 Edi from its lowest value, known as Edi min, rather than a specific Edi level. In the diagram below, the Edi min is 0.3  $\mu\text{V}$  and the trigger level 0.5, which means that the ventilator will be triggered at an absolute level of 0.8  $\mu\text{V}$ .

## BACKGROUND AND BASIC CONCEPTS

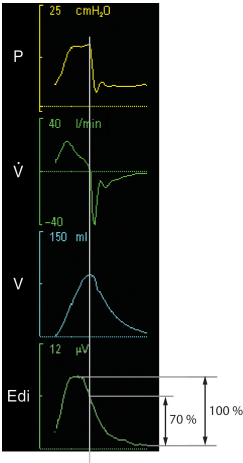
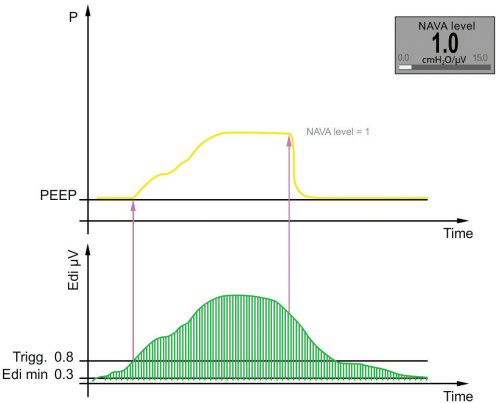


NAVA and NIV NAVA also employ a pneumatic trigger, based on flow or pressure, as a secondary trigger source. In combination with the Edi trigger, this operates on a first-come-first-served basis.

The ventilator will continue to multiply each of the subsequent measured Edi signals (the individual green lines in the diagram above) by the preset NAVA level, resulting in a pressure curve that follows the Edi signal in a smooth and consistent way.

The pressure curve in both NAVA and NIV NAVA follows the Edi signal pattern. When the Edi signal has fallen to 70% of its peak value, the patient is allowed to exhale and the ventilator no longer offers any assist until the next breath is initiated and the trigger level is again reached. An example of such a pressure curve may be seen in the illustration below.

# BACKGROUND AND BASIC CONCEPTS



## BACKGROUND AND BASIC CONCEPTS

The Edi curve is presented along with standard pneumatic curves on the screen during NAVA ventilation. 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 (shown below), including values for both Edi peak and Edi min.



The values may also be trended in all modes, as well as in Standby, enabling the user to follow the Edi trend even if the patient has been extubated.

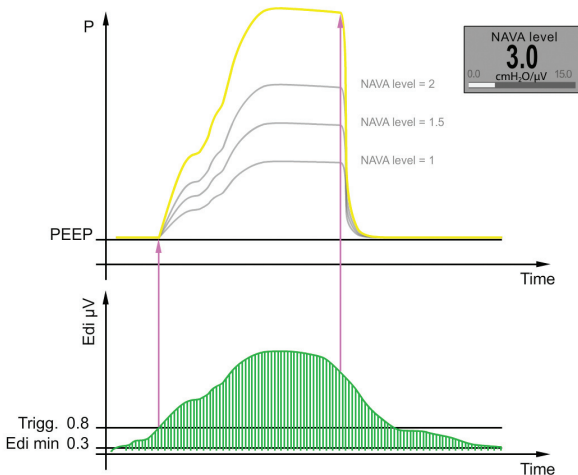
### The NAVA level

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 4.0 cmH<sub>2</sub>O/μV. The range of settings is 0.0 to 15.0 cmH<sub>2</sub>O/μV.

## BACKGROUND AND BASIC CONCEPTS

The diagram below shows the principles behind the way the Edi signal combines with the chosen NAVA level to affect the delivered pressure. It should however be noted that the patient's Edi signal normally decreases as the NAVA level increases.



The NAVA level should always be adjusted and finetuned in small steps.

## BACKGROUND AND BASIC CONCEPTS

### Insertion and positioning of the Edi Catheter

To select the appropriate Edi Catheter for the patient, you need to know the patient's height and sometimes also the weight. A tip is to consult the table below.

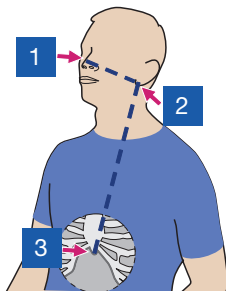
Patient height	Patient weight	Edi Catheter size	IED (Inter Electrode Distance)
> 140 cm		16 Fr 125 cm	16 mm
75 - 160 cm		12 Fr 125 cm	12 mm
> 140 cm		8 Fr 125 cm	16 mm
45 - 85 cm		8 Fr 100 cm	8 mm
< 55 cm	1.0 - 2.0 kg	6 Fr 50 cm	6 mm
< 55 cm	0.5 - 1.5 kg	6 Fr 49 cm	6 mm

Insert the Edi Module into the SERVO-i and connect the Edi Cable.

Perform the Edi Module function check.

Measure the distance from the bridge of the Nose (1) to the Earlobe (2) and then to the Xiphoid process (3). This is the NEX measurement. Make a note of it.

## BACKGROUND AND BASIC CONCEPTS



Calculate the insertion distance (Y) for the Edi Catheter. This will depend on whether the Edi Catheter is inserted orally or nasally, as well as on the size of the Edi Catheter. Use the appropriate table as shown below.

Insertion distance Y for nasal insertion	
Fr/cm	Calculation of Y
16 Fr	$\text{NEX cm} \times 0.9 + 18 = Y \text{ cm}$
12 Fr	$\text{NEX cm} \times 0.9 + 15 = Y \text{ cm}$
8 Fr 125 cm	$\text{NEX cm} \times 0.9 + 18 = Y \text{ cm}$
8 Fr 100 cm	$\text{NEX cm} \times 0.9 + 8 = Y \text{ cm}$
6 Fr 50 cm	$\text{NEX cm} \times 0.9 + 3.5 = Y \text{ cm}$
6 Fr 49 cm	$\text{NEX cm} \times 0.9 + 2.5 = Y \text{ cm}$



## BACKGROUND AND BASIC CONCEPTS

Insertion distance Y for oral insertion	
Fr/cm	Calculation of Y
16 Fr	$\text{NEX cm} \times 0.8 + 18 = Y \text{ cm}$
12 Fr	$\text{NEX cm} \times 0.8 + 15 = Y \text{ cm}$
8 Fr 125 cm	$\text{NEX cm} \times 0.8 + 18 = Y \text{ cm}$
8 Fr 100 cm	$\text{NEX cm} \times 0.8 + 8 = Y \text{ cm}$
6 Fr 50 cm	$\text{NEX cm} \times 0.8 + 3.5 = Y \text{ cm}$
6 Fr 49 cm	$\text{NEX cm} \times 0.8 + 2.5 = Y \text{ cm}$

### Example:

- Adult – height 170 cm
- Selected Edi Catheter – 16 Fr
- Insertion – nasal
- NEX – 54 cm

**Insertion distance Y** =  $54 \times 0.9 + 18 = 66.6 \text{ cm}$ , or approx. 67cm

- Infant – height 46 cm, weight 1.8 kg
- Selected Edi Catheter – 6 Fr 50 cm
- Insertion – oral
- NEX – 15 cm

**Insertion distance Y** =  $15 \times 0.8 + 3.5 = 15 \text{ cm}$

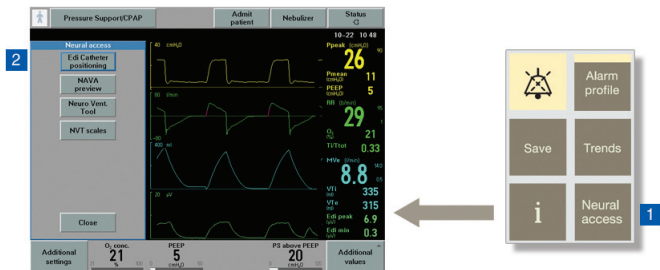
## BACKGROUND AND BASIC CONCEPTS

Dip the Edi Catheter into water for a few seconds. Do NOT use lubricants as this may destroy the Edi Catheter coating and interfere with the measurement of the Edi signal.

Insert the Edi Catheter to the Y value calculated above.

Connect the Edi Catheter to the Edi Cable.

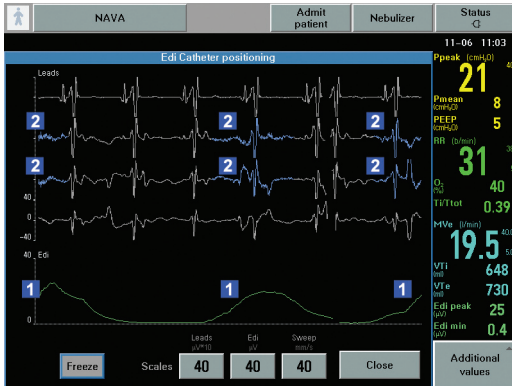
Open the “Neural access” menu (1) and select “Edi Catheter positioning” (2) to confirm the position of the Edi Catheter.



Verify the position of the Edi Catheter by analyzing the ECG waveforms. Ideally, P and QRS waves are present in the top leads, while the P waves disappear in the lower leads, where QRS amplitude decreases. Check that the Edi scale is fixed and that it is set appropriately (greater than or equal to 5  $\mu\text{V}$ ).

## BACKGROUND AND BASIC CONCEPTS

If Edi deflections (see screen shots below) are present, observe which leads are highlighted in blue.



1 – Edi deflections

2 – blue highlights

- If the second and third leads are highlighted as shown above, secure the Edi Catheter in this position after marking the Edi Catheter at its final position and making a note of the distance in centimeters.

## BACKGROUND AND BASIC CONCEPTS

- If the top leads are highlighted (see below), pull out the Edi Catheter in steps corresponding to the Inter Electrode Distance (IED, measured in millimeters) until the blue highlight appears in the center. Do not exceed four times the IED. Mark the Edi Catheter at its final position.



## BACKGROUND AND BASIC CONCEPTS

- If the bottom leads are highlighted (see below), insert the Edi Catheter further in steps corresponding to the IED until the blue highlight appears in the center. Again, do not exceed four times the IED. Mark the Edi Catheter at its final position.



- If the Edi signal is very low, there will be no blue highlights. If this happens, evaluate the Edi signal as described below.

## BACKGROUND AND BASIC CONCEPTS

Secure the Edi Catheter in position once the position has been verified. Check first that the marking on the Edi Catheter is in the right place and observe the ECG waveforms and their blue highlights.

Make sure that the Edi Catheter is not secured to the endotracheal tube.

Record the insertion length.

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

Evaluate the Edi signal. Please note that sedation, muscle relaxants, hyperventilation, excessively high PEEP and neural disorders can all result in a low or absent Edi signal, even if the Edi Catheter has been perfectly positioned.

If possible, perform an expiratory hold and verify that the positive Edi deflection coincides with a negative deflection in the pressure waveform.

Edi Catheter positioning may be reconfirmed after 1-2 hours if minor adjustments are necessary.

### Edi Catheter positioning summary

- Select Edi Catheter and measure NEX, calculating the insertion distance, Y.
- Dip Edi Catheter in water and insert.
- Verify the position in the positioning window.
- Secure the Edi Catheter.

# INVASIVE VENTILATION WITH NAVA

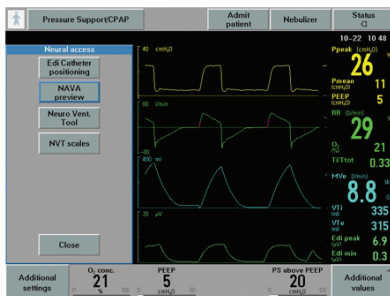
## Invasive ventilation with NAVA

### Starting and running NAVA

The information below covers the procedures involved in starting and running the NAVA mode.

### NAVA settings for invasive ventilation

To set the initial NAVA level, press “Neural access” and select “NAVA preview”.



## INVASIVE VENTILATION WITH NAVA

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



Simply press “NAVA level” and use the main rotary dial to set it appropriately. The NAVA level range is 0 to 15 cmH<sub>2</sub>O/ $\mu$ V. Generally, the first NAVA level tried should produce the same pressure as that used in the current ventilation mode, or perhaps slightly lower. By accepting and pressing “Close”, the selected NAVA level is saved to the NAVA ventilation mode window.

To set the parameters for operating the NAVA mode, choose “NAVA” in the “Select ventilation mode” window. This opens the “Set ventilation mode” parameters window.

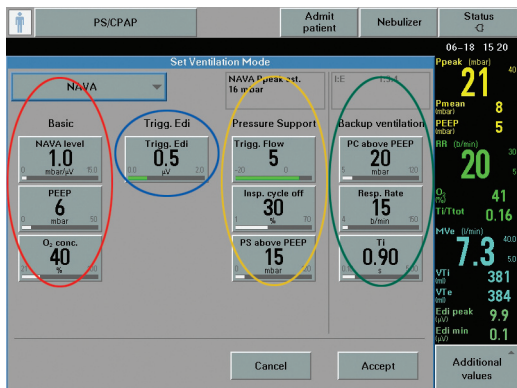
The NAVA level displayed is the initial one saved as outlined above from the “NAVA preview” window.



## INVASIVE VENTILATION WITH NAVA

The other two parameters in the “Basic” column (marked with a red ring below) are PEEP (cmH<sub>2</sub>O) and oxygen concentration (%).

Trigg. Edi (marked with a blue ring below) has a default setting of 0.5  $\mu$ V (the upper limit for variable background noise) and the range 0-2  $\mu$ V. The value set here is the one that will trigger the ventilator to assist the patient



## INVASIVE VENTILATION WITH NAVA

The remaining parameters (in the yellow ring above) refer to NAVA Pressure Support (NAVA (PS) – Trigger Sensitivity, Inspiratory Cycle off (%) and PS above PEEP (cmH<sub>2</sub>O). NAVA (PS) is the mode to which the ventilator automatically switches under certain specific circumstances (see diagram and information in the section below). It is therefore important to set adequate values here; otherwise the patient's Edi signal may be affected and the ventilator may be unable to switch back to NAVA. NAVA (PS) and Backup are described in greater detail later in this chapter.

Finally, the column for "Backup ventilation" (in the green ring) has three parameters that can be set by the user – PC above PEEP (cmH<sub>2</sub>O), Resp. Rate and I:E/Ti.

Default settings are used for the following parameters:

Parameters	Adult	Infant
I:E ratio/Ti	1:2/0.9 s	1:2/0.5 s
Respiratory rate	15 b/m	30 b/m
Inspiratory rise time	5%/0.15 s	5%/0.15 s

## INVASIVE VENTILATION WITH NAVA

The backup pressure level, respiratory rate and I:E ratio or inspiratory time are all adjustable. The default settings can be adjusted in the Edit startup configuration window.

Set appropriate alarm limits in the Alarm profile window. The apnea alarm can be set for infants (5-45 seconds) and adults (15-45 seconds).

It is important to set a suitable upper limit for pressure. The maximum available pressure level is 5 cmH<sub>2</sub>O below the preset upper pressure limit. Appropriate values should also be set for the patient's minute volume, respiratory rate and end expiratory pressure. The alarms' sound level and the apnea time are also adjusted here.

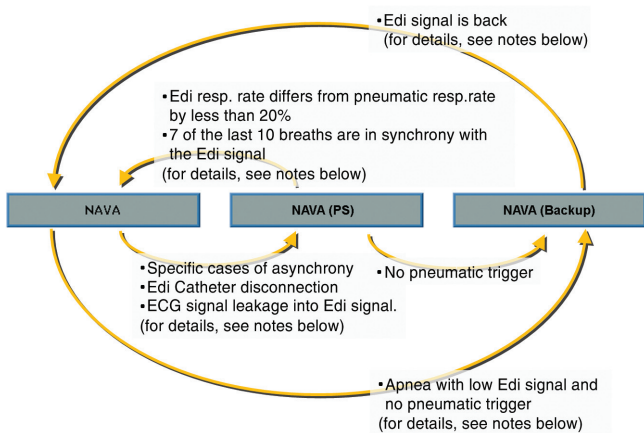
### NAVA settings summary

- Select NAVA preview via "Neural access".
- Adjust the NAVA level.
- Accept and press "Close" to save the initial NAVA level.
- Open the NAVA mode window and adjust settings.
- Set appropriate values for NAVA (PS) and NAVA Backup.
- Accept and proceed with NAVA ventilation. Remember to set appropriate alarm limits.

## INVASIVE VENTILATION WITH NAVA

### Switching between NAVA, NAVA (PS) and NAVA (Backup)

#### NAVA – NAVA (PS) – NAVA (Backup)



#### NAVA (PS) and NAVA (Backup)

When running invasive NAVA, the ventilator has several modes between which it switches freely under specific conditions. These are described and explained here.

### Switching from NAVA to NAVA (PS)

- The Edi respiratory rate differs from the pneumatic respiratory rate by more than 25% for at least 5 seconds. The calculated respiratory rates are based on the last 20 seconds.
- The Edi  $Ti/T_{tot}$  is more than 0.5, calculated over the last 20 seconds if the Edi Catheter position is classified as invalid.
- The Edi  $Ti/T_{tot}$  is more than 0.6, calculated over the last 20 seconds if the Edi Catheter position is classified as valid.
- The Edi Catheter is disconnected.
- There is ECG leakage into the Edi signal.

### Switching from NAVA (PS) to NAVA

- The Edi respiratory rate differs from the pneumatic respiratory rate by less than 20%
- At least 7 of the last 10 breaths are classified as being in synchrony with the Edi signal

**Note:** Pneumatic respiratory rate and  $Ti/T_{tot}$  are shown on the user interface. Edi respiratory rate and Edi  $Ti/T_{tot}$  are not shown on the user interface.

### Switching from NAVA to NAVA (Backup)

- Apnea with a permanently low Edi signal and no pneumatic trigger.

### Switching from NAVA (Backup) to NAVA

- The Edi signal can now be detected

### Switching from NAVA (PS) to NAVA (Backup)

- When the ventilator is in NAVA (PS) for any of the above reasons, and the pneumatic trigger can no longer be detected, the ventilator will switch to backup mode (Pressure Control)

There are, however, certain restrictions on the number of times the ventilator may switch back and forth automatically between NAVA and NAVA (Backup). The ventilator will thus lock in backup ventilation if:

- the patient switches between NAVA and NAVA (Backup) more than three times in the space of two minutes OR
- the patient only triggers a single breath with the Edi signal to interrupt each of two consecutive backup periods.

A dialog box will then open where the user may either review the ventilatory settings or return to the supported mode by pressing one of the two buttons displayed.

## Alarms for invasive NAVA

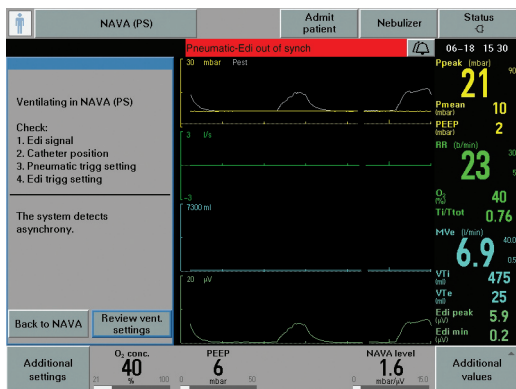
The following are high priority alarms.

### Asynchrony alarm

In case of asynchrony, the ventilator will switch back and forth without triggering an alarm until one of the following conditions is fulfilled:

- the ventilator has been in NAVA (PS) for more than 120 seconds;
- there have been six switches from NAVA to NAVA (PS) in the last five minutes.

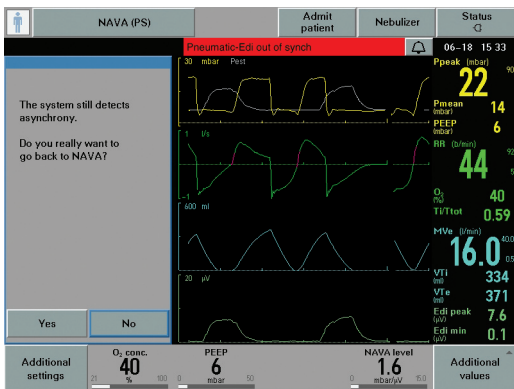
In either case, the asynchrony alarm will be activated and the message "Pneumatic-Edi out of synch" will appear, since the measured Edi signal is out of phase with the pressure and flow signals generated by the patient. There will also be a message to tell the user to check the Edi Catheter position. In addition, the user should check and if necessary adjust the trigger settings. The ventilation mode can also be changed.



## ALARMS FOR INVASIVE NAVA

When the asynchrony alarm has been activated, the ventilator will as usual search synchrony indices. As soon as synchrony is re-established, the message “Pneumatic-Edi synch restored” will be displayed. Press the OK button or simply wait for ten seconds, and the ventilator will switch back to NAVA. You can also choose to return to NAVA manually by pressing the “Back to NAVA” key on the user interface if the patient’s Edi signal is in synchrony with the pneumatic breath.

If asynchrony is still detected, a message will appear followed by a question, as shown in the screen shot below.



Users then need to confirm that they wish to return to NAVA.

### No Edi monitoring alarm

The message “Edi monitoring not active” appears when the NAVA mode is activated without an Edi Module being connected. If this occurs, simply insert the Edi Module.



## ALARMS FOR INVASIVE NAVA

The following are medium priority alarms.

### Edi Module alarms:

- In case of disconnection, the message “Edi Module disconnected” appears when the Module is not properly inserted.
- In case of error, the message “Edi module error” appears to signify a hardware error. In this case, the Edi Module should be unplugged and reinserted. If this does not help, change the Edi Module and contact a service technician.

### Edi Catheter alarms:

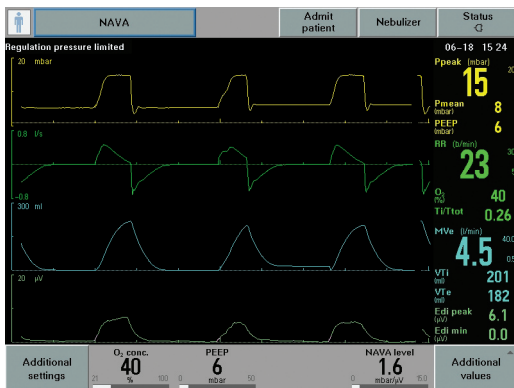
- In case of connection failure, the message “No Edi Catheter connected” appears. When this happens, the Edi Catheter should be properly connected.
- In case of error, the message “Edi Catheter error” appears. An Edi Module Test should then be performed and if it is successful, the Edi Catheter is to blame and should be replaced.
- If the Edi Catheter has been incorrectly positioned or has shifted position, the message “No Edi signal detected” appears to signal that the position of the Edi Catheter should be checked.

### Edi activity low alarm:

- The message “Edi activity low” appears when the measured Edi activity is low while using NAVA. When this happens, check the Edi Catheter position, and if necessary adjust the Edi trigger setting. Failing this, change to another ventilation mode.

## ALARMS FOR INVASIVE NAVA

"Regulation pressure limited" appears as a text message activated during NAVA at a level 5 cmH<sub>2</sub>O below the set Upper Pressure Limit. If you then increase the NAVA level, the ventilator will make a beeping sound to draw your attention to the message. The maximum available pressure level is thus 5 cmH<sub>2</sub>O below the preset upper pressure limit.



### One way to manage the NAVA level

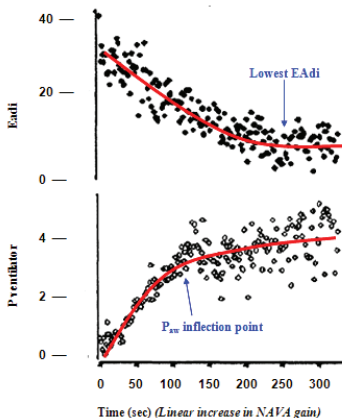
The method below involves a titration procedure suggested in an article by Brander et al (see references), which can be summarized in brief and simple steps as follows:

1. Once a reliable Edi signal with a constant pattern and satisfactory amplitude has been obtained, the user activates the NAVA preview window, setting a NAVA level such that the pressure delivered is equal to or slightly below the set Pressure Support level.
2. Set an Upper Pressure Limit that is acceptable to the patient.
3. Open the Neuro Ventilatory Tool.
4. In order to increase the patient's respiratory drive while not provoking too much distress, the NAVA level is reduced to a minimum level of 0.0 cmH<sub>2</sub>O/μV or slightly higher, resulting in a minimal level of assist. This is maintained for a few minutes or until the Edi signal reaches its maximum. During this period, the patient should be carefully observed as discomfort or hemodynamic instability may occur.
5. The NAVA level is then gradually increased in steps of 0.1 to 0.2 cmH<sub>2</sub>O/μV, while observing the trend graphs for Ppeak, VT and Edi.
6. As the NAVA level increases, the P peak and VT levels will also increase and the Edi will gradually decrease. Typically, an initial steep increase in airway pressure and VT is followed by a less steep increase in the airway pressure and by a plateau in VT, while the Edi signal continues to decrease. When the Edi reaches its minimum level, the increases in airway pressure and VT may resume.
7. When a transition from a steep to a less steep increase in airway pressure and tidal volume becomes visible, activate the cursor and read off the NAVA level at the end of the transition zone.

## THE NAVA LEVEL – INVASIVE NAVA

8. The NAVA level at the end of the transition zone presumably represents an assist level of adequate respiratory muscle unloading and should be set with the help of the "NAVA level" quick access knob. Normally, the NAVA level is set between 1 and 4  $\text{cmH}_2\text{O}/\mu\text{V}$ . If a patient fails to react to an increase in the NAVA level, do not run NAVA.
9. Check and readjust the NAVA level at regular intervals.

Diagram from article by Lecomte, Brander et al (see references).



### NAVA level optimization summary

- Make sure you have a stable Edi signal in NAVA mode.
- Open the Neuro Ventilatory Tool and reduce the NAVA level to a minimum for a few minutes or until the Edi signal reaches its maximum.
- Gradually increase the NAVA level in steps of 0.1 to 0.2  $\text{cmH}_2\text{O}/\mu\text{V}$  while observing P peak, VT and Edi.

## EXAMPLE OF WEANING FROM INVASIVE NAVA

### One way to wean patients from invasive NAVA

This chapter describes one procedure that can be followed when weaning a patient from NAVA. An often overlooked fact is the time that the patient has been on mechanical ventilation. Lengthy CMV is a good predictor of a more prolonged weaning phase, as shown among others by Levine (see References).

When the patient is on NAVA, an objective measure of the patient's progress becomes available – the Edi signal. The first sign to look for is a decline in the Edi signal with unchanged tidal volumes. This represents an improvement in neuromuscular coupling in the sense that diaphragm performance is unchanged at a lower level of stimulation.

As soon as this situation is achieved, the airway pressure will be lower. The patient is in effect giving us a signal that he or she is now ready to be weaned. For all practical purposes, the patient can then be left with an essentially unchanged NAVA level and will wean him- or herself off the ventilator, while we watch the progress in the shape of a falling Edi signal.

The process may however be speeded up to allow earlier disconnection from the ventilator. The procedure suggested below is one example of how this may be done.

### **Standard extubation criteria according to Lellouche (see References)**

1. P/F ratio over 200
2. PEEP of 5 cmH<sub>2</sub>O or lower
3. Efficient cough in patients with abundant secretion
4. Epinephrine or norepinephrine infusion rate of 5 mg/h or lower
5. Glasgow Coma Score over 8
6. Little or no sedation.

## EXAMPLE OF WEANING FROM INVASIVE NAVA

### Weaning procedure example:

1. The first sign that it is possible to wean the patient is a decline in the Edi signal with maintained tidal volume.
2. Please remember the following differential diagnosis – sedation bolus or increase in maintenance dose of opiates/sedatives. If an increase in sedation is not the cause of the decline in the Edi signal, however, then the decrease provides confirmation of an improvement in neuromuscular coupling. The mechanical efficiency of the diaphragm has improved and the patient will be receiving less support – weaning has in effect been started automatically.
3. When the patient is stable and the tidal volume is unchanged while the Edi signal is declining or unchanged, reduce the NAVA level in steps of 0.1-0.2 cmH<sub>2</sub>O/ $\mu$ V.
4. If VT is reduced and the Edi signal increases disproportionally, go back to the previous setting. The reaction may indicate one of the two following situations:
  - a. The patient is not yet ready to be weaned. Allow the patient to rest on the previous setting and try again later.
  - b. The initial assist is too low (look for a slow upstroke in the Edi and flow curve, and an increase in neural Ti). This is commonly seen in COPD patients who require a high initial gas delivery in order to overcome intrinsic PEEP. The phenomenon may actually lead to a higher peak pressure and a high Edi peak, with a lengthening of the inspiratory phase and a shortening of expiration, thus increasing intrinsic PEEP. In such a situation, it may be wise to remain at the previous setting and allow the patient to wean him- or herself off at an unchanged NAVA level.
5. Weaning progress can be monitored by the decline in the Edi signal. When the peak pressure minus PEEP has fallen to 10 cmH<sub>2</sub>O, extubation may be attempted.

## EXAMPLE OF WEANING FROM INVASIVE NAVA

### Summary of weaning example

- While keeping the NAVA level unchanged, verify a decrease in the Edi amplitude with a maintained tidal volume.
- Decrease the NAVA level in steps of 0.1-0.2 cmH<sub>2</sub>O/μV. Observe a decrease in peak pressure minus PEEP with a maintained tidal volume.
- The patient is considered to have been weaned when the peak pressure minus PEEP is 10 cmH<sub>2</sub>O.

## NON INVASIVE VENTILATION WITH NAVA

### NIV NAVA

#### Introduction to NIV NAVA

Synchronized non invasive respiratory assist enables smooth transition to natural breathing and provides proportional assist in synchrony with the patient's own breathing efforts. Patient and ventilator are thus in synchrony.

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, including oronasal masks, full-face masks, nasal masks and helmets. For neonates, the most commonly used interfaces are nasal prongs or nasal masks, although nasopharyngeal tubes may also be used.

Before starting ventilation with NIV NAVA, it is essential to reassure the patient and make sure that he or she is comfortable. It is therefore vital that personnel should be calm and take the necessary time to ensure that the patient is too. It is also vital to prepare ahead and have all necessary interfaces and connections ready for use.

#### Monitoring the respiratory drive

The Edi signal can be used in to monitor the patient's respiratory drive since it represents the integrated motor output to the diaphragm. The Edi signal is modulated by neural feedback and thus reflects the way in which the neural inspiratory breathing pattern is affected by changes in metabolic demand, respiratory muscle function, respiratory load and changes in the ventilatory assist. The Edi signal thus enables bedside monitoring of the way in which sedative and analgesic medication affect the patient's respiratory drive. The Edi signal can be monitored in all modes of ventilation, both invasive and non invasive, as well as in Standby.



## NON INVASIVE VENTILATION WITH NAVA

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

- continuous monitoring of the respiratory drive
- decision support for unloading and assist titration
- objective criteria for intubation and extubation decisions.

### Starting and running NIV NAVA

#### Settings

To access NIV NAVA, the user must be in the Standby position and select the relevant patient category (adult or infant) and non invasive ventilation. Please note that when NIV is selected, the frame on the screen turns from grey to yellow.

In the Select Ventilation Mode window, the user selects NIV NAVA and the Set Ventilation Mode window opens. This is where the parameters are set for NIV NAVA.

The screenshot shows the 'Set Ventilation Mode' window for NIV NAVA. The window has a yellow header bar with buttons for 'NIV NAVA', 'Admit patient', 'Nebulizer', and 'Status'. Below the header, the title 'Set Ventilation Mode' is displayed. The main area contains several parameter settings: 'Basic' (NAVA level 0.5 cmH2O, PEEP 5 cmH2O, O2 conc. 40%), 'Trigg. Edi' (Trigg. Edi 0.5 μV), and 'Backup ventilation' (PC above PEEP 5 cmH2O, Resp. Rate 30 b/min, Ti 0.50 s). A 'Previous Mode' button is at the bottom left, and 'Cancel' and 'Accept' buttons are at the bottom center. A status bar at the bottom right shows 'Additional values' and a timestamp '04-21 10:30'.

## NON INVASIVE VENTILATION WITH NAVA

The NIV NAVA parameters are:

### Basic settings:

- NAVA level – range 0.0 to 15.0 cmH<sub>2</sub>O/μV. Default – 0.5 cmH<sub>2</sub>O/μV for both infants and adults. For NIV NAVA, the estimated pressure delivered will be: NAVA level x (Edi peak – Edi min) + PEEP + 2 cmH<sub>2</sub>O
- PEEP – range 2 to 20 cmH<sub>2</sub>O
- O<sub>2</sub> concentration – range 21 to 100%
- Trigg. Edi – range 0.0 to 2.0 μV

Backup ventilation for NIV NAVA is Pressure Control.

The backup parameters are:

Parameters	Adult	Infant
I:E ratio/Ti	1:2/0.9 s	1:2/0.5 s
Respiratory rate	15 b/m	30 b/m
PC above PEEP	5 cmH <sub>2</sub> O	5 cmH <sub>2</sub> O

## NON INVASIVE VENTILATION WITH NAVA

The backup settings should be chosen so as to ensure adequate ventilation in case of apnea. It is important to consider that apnea is particularly frequent in infants, particularly premature infants, and the backup settings should be made with this in mind. When suitable values have been selected, press Accept.

Before starting ventilation by pressing the Start button in the bottom left corner of the user interface, it is important to check the alarm profile.

The screenshot shows the 'Alarm profile' settings screen for NIV NAVA. The interface has a top navigation bar with buttons for 'NIV NAVA', 'Admit patient', 'Nebulizer', and 'Status'. The 'Status' button shows a signal icon and the time '06-01 15:48'. The main area is titled 'Alarm profile' and contains a table for setting lower and upper limits for various parameters. The parameters are Pressure (cmH<sub>2</sub>O), Minute Volume (l/min), Respiratory Rate (b/min), and End Exp. Pressure (cmH<sub>2</sub>O). The 'Upper' column for Pressure is currently selected, showing a value of 20. To the right of the table, there are settings for 'Sound level' (100%) and 'Apnea time' (10 seconds). At the bottom, there are 'Cancel' and 'Accept' buttons, and an 'Additional values' button on the right.

	Lower	Upper	
Pressure cmH <sub>2</sub> O		20	
Minute Volume l/min	2.0	5.0	
Respiratory Rate b/min	20	50	
End Exp. Pressure cmH <sub>2</sub> O	2	10	

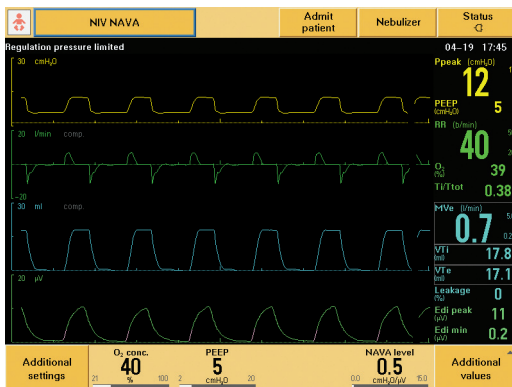
Sound level: 100%

Apnea time: 10

Buttons: Cancel, Accept, Additional values

It is important to set a suitable upper limit for pressure. The maximum available pressure level is 5 cmH<sub>2</sub>O below the preset upper pressure limit. Appropriate values should also be set for the patient's minute volume, respiratory rate and end expiratory pressure. The alarms' sound level and the apnea time are also adjusted here.

# NON INVASIVE VENTILATION WITH NAVA



The Regulation pressure limited message appears when Ppeak is 5 cmH<sub>2</sub>O below the upper pressure limit. The maximum available pressure level is thus 5 cmH<sub>2</sub>O below the preset upper pressure limit. The maximum peak pressure is 32 cmH<sub>2</sub>O.

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.

## NON INVASIVE VENTILATION WITH NAVA

When appropriate values have been set, press Accept

If the patient is already being ventilated in NIV PS or NIV PC, the initial NAVA level can be set in the NAVA preview window, which is opened via the Neural access fixed key. There are thus different ways to start NIV NAVA.

### Summary of different ways to set the initial NAVA level:

- If NIV NAVA is the first ventilation choice, the NAVA preview window cannot be used. The NAVA level is instead set in the Set ventilation mode window by choosing a low level and then slowly increasing to a level at which the patient is adequately unloaded. The process of setting and optimizing the NAVA level is discussed in a separate section below.
- If the patient is being ventilated with NIV PS, NIV PC, or an invasive mode other than invasive NAVA, the NAVA preview window can also be used – the user presses “NAVA level” in this window and uses the main rotary dial to set it appropriately. Generally, the first NAVA level should be low and then slowly increased in steps of  $0.1 \text{ cmH}_2\text{O}/\mu\text{V}$ .

## NON INVASIVE VENTILATION WITH NAVA

After starting ventilation by pressing the Start button in the bottom left corner of the user interface, a waiting position for NIV NAVA will be initiated, which gives the user an opportunity to adjust the ventilator and/or the patient interface (i.e. the mask, prongs, helmet or other). The time shown is counted by the ventilator from the time that the waiting position is entered.

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

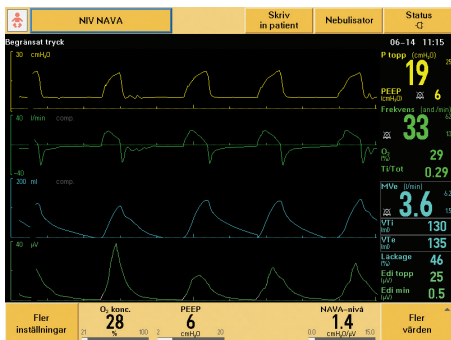
- the ventilator detects that the patient is connected to the ventilator
- the user presses the Start ventilation soft key.

If neither of these criteria has been met within two minutes, an alarm will be activated to remind the user that it is appropriate to start ventilation. During the waiting phase, all audible patient related alarms are deactivated and no ventilation is delivered. There is however a bias flow of 7.5 l/min.

## NON INVASIVE VENTILATION WITH NAVA

When the Start ventilation button is pressed, NIV NAVA will be started without further delay.

The screen shot below shows the SERVO-i ventilator running in NIV NAVA. The screen displays the pressure, flow, volume and Edi curves, as well as measured values relating to each curve on the right. Note that the Edi deflections are synchronous with the assist delivered.



## ALARMS FOR NON INVASIVE NAVA

### NIV NAVA alarms

#### No patient effort alarm

Some new alarms are used in NIV NAVA. If the Edi signal disappears, the ventilator will sound a high 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 and the function of the third and fourth direct access knobs at the bottom of the screen is changed so that they can be used to adjust the respiratory rate and PC above PEEP.

Once the ventilator detects a valid Edi signal again, it will automatically return from backup ventilation to NIV NAVA (please note that the ventilator will only return to NIV NAVA if triggered by the Edi, not if there is a pneumatic trigger). There is no limit on the number of times the ventilator can switch back and forth between NIV NAVA and backup ventilation.

#### Leakage out of range alarm

The ventilator will compensate for leakage of up to 25 l/min for infants and 65 l/min for adults.

If leakage is excessive ( $>25$  l/min for infants and  $>65$  l/min for adults 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 Edit startup configuration window. The default value is 7.5 l/min.



## ALARMS FOR NON INVASIVE NAVA

Once leakage has been reduced or the patient has been reconnected, ventilation will automatically resume and the screen dialog will disappear after three breaths. It is also possible to start ventilation manually by pressing the "Resume ventilation" button. This brings the ventilator out of its pause position and returns it to NIV NAVA, but a message ("Operator-initiated breath") will appear and the alarm will still be active.

It may be noted that NIV NAVA is less sensitive to autotriggering at high leakage levels because the pneumatic trigger is deactivated when 60% of the maximum leakage compensation is reached.

### Disconnect flow summary

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 for infants
  - 40 l/min for adults
- Disabled - No pause in ventilation in case of high leakage. The SERVO-i will continue to deliver assist even when leakage is excessive. The Leakage out of range alarm will then go from high priority to medium priority.

## ALARMS FOR NON INVASIVE NAVA

There is also a special low priority leakage fraction alarm for the NIV NAVA infant option. It is activated if leakage is  $> 95\%$ . This feature is useful when ventilating infants with NIV NAVA, as it gives personnel the possibility to adjust prongs or other non invasive interfaces that have come loose.

This is what the alarm profile looks like when the leakage fraction alarm function is enabled via Biomed. This function is only available in the NIV NAVA infant option.

Alarm profile		Sound level
	Lower	Upper
Pressure <small>cmH<sub>2</sub>O</small>		20
Minute Volume <small>l/min</small>	0.5	5.0
Respiratory Rate <small>b/min</small>	20	50
End Exp. Pressure <small>cmH<sub>2</sub>O</small>	2	10
Leakage fraction		10

Sound level: 100%

Apnea time: 10

Additional values:

- Ppeak (cmH<sub>2</sub>O): 13
- PEEP (cmH<sub>2</sub>O): 5
- RR (b/min): 40
- O<sub>2</sub> (SpO<sub>2</sub>): 40
- TI/Tot: 0.39
- MVe (l/min): 0.9
- VTi (ml): 21
- VTe (ml): 21
- Leakage (ml): 3
- Edi peak (µV): 10
- Edi min (µV): 0.3

## Check catheter position/RR and HR coupling alarm

In this high priority alarm, RR refers to the respiratory rate and HR to the heart rate. This alarm is activated when there is leakage of the ECG signal into the Edi signal. The ventilator switches automatically to backup ventilation. The Edi Catheter position should be checked by going to the Edi Catheter positioning window (via the Neural access fixed key), where adjustments can be made to the position of the Edi Catheter. The alarm will then disappear and the ventilator should automatically return to NIV NAVA.

### Unreliable Edi signal alarm

A further high priority alarm is "Unreliable Edi signal", which occurs in cases of extreme asynchrony between the detected Edi signal and the pneumatic parameters. The alarm is activated if one or more of the following conditions are fulfilled during NIV NAVA ventilation:

- the Edi respiratory rate differs from the pneumatic respiratory rate by more than 25% for at least 5 seconds, assuming that leakage is low. The calculated respiratory rates are based on the last 20 seconds.
- the Edi  $Ti/T_{tot}$  is more than 0.5, calculated over the last 40 seconds, if the Edi Catheter position is classified as invalid.
- the Edi  $Ti/T_{tot}$  is more than 0.6, calculated over the last 40 seconds, if the Edi Catheter position is classified as valid.

**Note:** The pneumatic respiratory rate and  $Ti/T_{tot}$  are shown on the user interface. The Edi respiratory rate and  $Ti/T_{tot}$  are not shown on the user interface.

This alarm does not cause the ventilator to switch automatically to backup ventilation. Instead the user should press the alarm fixed key for more details.

When the "Bell" fixed key on the right of the user interface is pressed, a dialog box opens in which the user is recommended to check the Edi Catheter position and asked if he wishes to turn the alarm audio off for the duration of the alarm situation. Once the Edi Catheter position has been corrected, the alarm should disappear and NIV NAVA ventilation should continue normally.

## ALARMS FOR NON INVASIVE NAVA

### 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 box 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.

### Apnea audio delay

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

## THE NAVA LEVEL – NON INVASIVE NAVA

### One way to manage the NAVA level

When ventilating in NIV NAVA, the treatment is normally started at a low NAVA level and then slowly titrated to the level that will ensure comfortable unloading of the patient. The Edi signal provides the information needed to perform this procedure efficiently.

- If possible, start by setting the NAVA level to 0 (for 30-60 seconds). The resulting Edi peak value that is then registered will provide information that allows the clinician to assess the total muscle load, as well as any muscular weakness.
- The NAVA level is then increased in steps of 0.1 cm H<sub>2</sub>O/μV with the aim of achieving a decrease in the Edi signal. If the aim is, for example, to unload 50% of the patient's work of breathing, the target for the decrease in the Edi signal will be 50%.
- The Edi signal is followed carefully while the NAVA level is slowly increased in small increments. The Edi signal helps the clinician to quantify and continuously evaluate the patient's respiratory work.
- Once the target is reached, the Edi signal should be followed without changing the NAVA level. A decrease in the Edi signal with a maintained tidal volume indicates an improvement in neuromuscular and neuroventilatory coupling.

## EXAMPLE OF WEANING FROM NON INVASIVE NAVA

### One way to wean patients from NIV NAVA

As for invasive NAVA, weaning from NIV NAVA is largely a matter of self-weaning.

The Edi signal can be used during ventilation with NIV NAVA as an objective measure of the patient's progress. The first sign to look for is a decline in the Edi signal with unchanged tidal volumes. This represents an improvement in neuromuscular coupling in the sense that diaphragm performance is unchanged at a lower level of stimulation.

As soon as this situation is achieved, the airway pressure will be lower. The patient is in effect giving us a signal that he or she is now ready to be weaned. For all practical purposes, the patient can then be left with an essentially unchanged NAVA level and will wean him-or herself off the ventilator, while we watch the progress in the shape of a falling Edi signal.

The process may however be speeded up to allow earlier disconnection from the ventilator. The procedure suggested below is one example of how this may be done.

#### Weaning procedure example:

1. The first sign that it is possible to wean the patient is a decline in the Edi signal with maintained tidal volume.
2. Please remember the following differential diagnosis – sedation bolus or increase in maintenance dose of opiates/sedatives. If an increase in sedation is not the cause of the decline in the Edi signal, however, then the decrease provides confirmation of an improvement in neuromuscular coupling. The mechanical efficiency of the diaphragm has improved and the patient will be receiving less support – weaning has in effect been started automatically.
3. When the patient is stable and the tidal volume is unchanged while the Edi signal is declining or unchanged, reduce the NAVA level in steps of 0.1-0.2 cmH<sub>2</sub>O/μV.

## EXAMPLE OF WEANING FROM NON INVASIVE NAVA

4. If VT is reduced and the Edi signal increases disproportionately, go back to the previous setting. The reaction may indicate one of the two following situations:
  - a. The patient is not yet ready to be weaned. Allow the patient to rest on the previous setting and try again later.
  - b. The initial assist is too low (look for a slow upstroke in the Edi and flow curve, and an increase in neural Ti). This is commonly seen in COPD patients who require a high initial gas delivery in order to overcome intrinsic PEEP. The phenomenon may actually lead to a higher peak pressure and a high Edi peak, with a lengthening of the inspiratory phase and a shortening of expiration, thus increasing intrinsic PEEP. In such a situation, it may be wise to remain at the previous setting and allow the patient to wean him- or herself off at an unchanged NAVA level.

### Summary of weaning procedure

- While keeping the NAVA level unchanged, verify a decrease in the Edi amplitude with a maintained tidal volume.
- Decrease the NAVA level in steps of 0.1-0.2 cmH<sub>2</sub>O/μV. Observe a decrease in peak pressure minus PEEP with a maintained tidal volume.

## NAVA AND NIV NAVA MANAGEMENT TIPS

### NAVA and NIV NAVA features and management tips

#### The NAVA respiration cycle

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 a varying pressure proportional to the patient's Edi signal.

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 2.5 seconds for adults and 1.5 seconds for infants.

Expiration begins when the pressure increases 3 cmH<sub>2</sub>O above the inspiratory target pressure, or when the Edi decreases below 70% of the peak value during ongoing inspiration (40% for low Edi signals), or if the Upper Pressure Limit is exceeded, or when the maximum time for inspiration specified above is exceeded.

#### Trigger colors



Edi trigger indicator    Flow/pressure trigger indicator

#### 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.

#### Noting Edi Catheter insertion length

Remember to mark the Edi Catheter at its final position and make a note of the final distance in centimeters in the hospital chart.



### Suctioning

During suctioning, or in case of patient disconnection, it is important to use the Suction Support function to avoid activating the asynchrony alarm (see the Alarms chapter below). The function is not used when a closed suction system is in use.

### What happens if...

- ... there is no Edi signal, or if it is low:  
Check that the Edi Catheter is correctly placed and connected by using the Edi Catheter Positioning Window. If it is, check the patient for signs that the PS level is too high, or of hyperventilation or oversedation.
- ... the patient is apneic:  
In case of apnea, the SERVO-i will automatically switch to Backup ventilation, which is the Pressure Control mode. The apnea time is set under the alarm profile.
- ... the Edi Catheter has been accidentally removed:  
If the Edi Catheter is pulled out by mistake, the SERVO-i will automatically switch to NAVA (PS) for invasive NAVA or to NAVA (Backup) for non invasive NAVA.

### Treating COPD patients

When treating COPD patients, it may sometimes be necessary to increase the flow to ensure that the patient is both comfortable and adequately ventilated. An easy way to do this with NAVA is to increase the assist level by switching to a higher NAVA level and checking the values of Ppeak, VT, RR and Edi to see if the assist level is adequate. By carefully setting an upper pressure limit in the Alarm profile, it is always possible to avoid excessive peak pressure values.

## NAVA AND NIV NAVA MANAGEMENT TIPS

### The Ventilation Record Card

The Ventilation Record Card enables patient data and screen shots to be transferred from the SERVO-i to a computer, where they can be accessed. This feature is useful for teaching as well as for diagnostic purposes. For more details, refer to the relevant SERVO-i training material and user manuals.

### Disconnection of the Edi Module

If the Edi Module becomes disconnected, the SERVO-i will, if in invasive NAVA, automatically switch to NAVA (PS) and an alarm will be activated. If the SERVO-i is in non invasive NAVA, it will switch to PC.

### Scale settings

It is important to verify that the Edi scale is fixed and set appropriately (i.e. greater than or equal to 5  $\mu$ V). Avoid clipping the Edi signal by imposing too low an upper limit on the scale.

### NAVA and Heliox

NAVA can be used together with Heliox.

### Trends

Trends are extremely useful when following a patient's progress on NAVA.

### 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.

## NAVA AND NIV NAVA MANAGEMENT TIPS

### Asynchrony



This screen shot is an example of total asynchrony. In such a case, do not switch to NAVA. The only thing to do is to start again from the beginning and measure the NEX carefully. Open the Edi catheter positioning window and proceed as usual with verification before trying to run NAVA again.

## NAVA AND NIV NAVA MANAGEMENT TIPS

### Titrating the PEEP level

An important parameter to optimize when ventilating patients in NAVA is the PEEP level. A titration procedure for optimizing the PEEP level has been described in a recent article by Brander and colleagues. The article concludes that during NAVA ventilation using an adequate NAVA level, increasing PEEP reduces respiratory drive, and monitoring the ratio of tidal volume to Edi signal (the neuroventilatory index) during PEEP changes allows identification of a PEEP level at which tidal breathing occurs at minimal Edi cost.

The basic procedure is summarized below.

The idea is to arrive at an optimal PEEP level by increasing PEEP in small increments. If the Edi signal drops with each stepwise increase in PEEP, while tidal volume is maintained (increasing neuroventilatory index), this indicates that the patient is having to perform less work of breathing. This in turn means that the respiratory muscles are being unloaded.

If the Edi signal instead increases while tidal volume remains the same (lower neuroventilatory index), this may signify that the lungs are hyperinflated and that the PEEP level is too high. If this happens, the user should instead lower the PEEP level.

**Note:** The neuroventilatory index –  $VT/Edi$

### Patient interfaces for NIV NAVA

A range of different types of patient interface can be used when ventilating patients with NIV NAVA. They include helmets, facial masks, oronasal masks and nasal masks and prongs and come in a variety of sizes to suit all patients from tiny neonates to adults.

### NIV NAVA – independent of leakage

This mode of ventilation is based on a neural signal (the Edi signal) and the triggering and cycle off of the breath are thus unaffected by leakage.

### Monitoring the Edi signal – a respiratory vital sign

The Edi signal can be monitored in all modes of ventilation, as well as in the standby position. This includes Edi peak and Edi min values on a breath-by-breath basis, and these are trended and can be followed in the trend graphs. This enables clinicians to follow an important respiratory parameter easily and reliably at a level not previously accessible in practical clinical work.

Since the Edi signal reflects the patient's own respiratory drive and neural effort, it can be used as a respiratory vital sign that is continually monitored. It provides crucial information about the patient's ability or inability to breathe spontaneously, as well as about synchrony, or lack of synchrony, between patient and ventilator.

## NAVA AND NIV NAVA MANAGEMENT TIPS

The Edi signal represents the integrated motor output to the diaphragm and reflects the bio-feedback loop at work during human breathing, enabling it to be studied in real time. This feedback loop is controlled by the respiratory center in the brain based on input from the receptors concerning levels of certain chemicals in the circulating blood, such as oxygen ( $pO_2$ ), carbon dioxide ( $pCO_2$ ) and hydrogen ions (pH).

The Edi thus reflects the way in which the neural inspiratory breathing pattern is affected by changes in metabolic demand, respiratory muscle function, respiratory load and changes in the ventilatory assist. This means that it enables bedside monitoring of the way in which sedative and analgesic medication affect the patient's respiratory drive.

In addition, the Edi signal provides objective criteria for clinicians' decisions about intubation and extubation.

## GLOSSARY AND DEFINITIONS

### List of terms

**CMV** - Controlled Mechanical Ventilation.

**ECG** – electrocardiogram, a recording of the electrical activity of the heart.

**Edi** – the electrical activity of the diaphragm. Varying versions of the acronym EAdi are sometimes used to denote the same thing.

**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.

**IED** – inter-electrode distance, the distance in millimeters between two measuring electrodes on the Edi Catheter.

**MV** – minute volume.

**MVe** – expiratory minute volume.

**NAVA** – Neurally Adjusted Ventilatory Assist, an optional mode of ventilation for the SERVO-i 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.

## GLOSSARY AND DEFINITIONS

**PEEP** – positive end expiratory pressure, measured in  $\text{cmH}_2\text{O}$ .

**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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### Websites:

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