SERVO EDUCATION
NAVA in neonatal settings Study Guide
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# 1 INTRODUCTION AND BACKGROUND FACTS

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1.1 INTRODUCTION

Neonatal care is a specialized field focusing on babies in the first few weeks of life. Both in terms of size and development, these patients have special requirements.

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. In order to avoid confusion and information overload, other modes of ventilation used in the context of neonatal care are described separately, so that the user can concentrate on understanding and learning to use NAVA. It should of course be noted that this guide cannot replace the appropriate user’s manual.

The following are described:

- the physiological background to NAVA
- important central concepts, such as Edi signal and the NAVA level
- an outline of the workflow prior to beginning patient ventilation with NAVA or NIV NAVA
- patient ventilation using invasive NAVA
- non-invasive mode
- unique features of NAVA and NIV NAVA along with useful management tips relevant to neonatal care

1.2 BACKGROUND AND BASIC CONCEPTS

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.
1.3 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.

1.4 USING THE EDI SIGNAL IN NAVA

When NAVA is used with the SERVO-i ventilator, 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 the esophagus.
In neonates, the diaphragm, laryngeal and chest wall muscles work in concert to augment the function of every component and thereby protect the fragile tissues in the lungs.

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

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.

Basically, NAVA uses 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 adjusting assist and unloading
- objective criteria for intubation and extubation decisions.
1. Healthy patient with normal Edi signal

2. Diseased patient with abnormal Edi signal

The efficacy of the respiratory muscles and the degree of respiratory demand will determine the degree of respiratory center output.

In a healthy subject, the low amplitude of diaphragm excitation reflects the fact that neuroventilatory coupling is highly efficient and that only about 5% of maximum capacity is used.

The 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.
1. Edi catheter positioning

2. Raw signal

3. Disturbance filtered

4. Double subtraced

5. Edi signal over time (s)

6. Edi signal screen presentation

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.
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, known as Edi min, rather than a specific Edi level.

In the diagram below, the Edi min is 0.3 µV and the trigger level 0.5, which means that the ventilator will be triggered at an absolute level of 0.8 µV.

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 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 delivered is derived from the following formula:

\[ \text{NAVA level} \times (\text{Edi signal} - \text{Edi min}) + \text{PEEP} \]
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.

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.

The values are also trended in all modes, as well as in Standby.
1.5 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 SERVO-i 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 cmH₂O/µV. In NIV NAVA the NAVA level is generally lower than that set for invasive NAVA. The range of settings is 0.0 to 15.0 cmH₂O/µV.

1.6 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.

<table>
<thead>
<tr>
<th>Patient height</th>
<th>Patient weight</th>
<th>Edi Catheter size</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 - 85 cm</td>
<td>1.0 - 2.0 kg</td>
<td>8 Fr 100 cm</td>
</tr>
<tr>
<td>&lt; 55 cm</td>
<td>0.5 - 1.5 kg</td>
<td>6 Fr 49 cm</td>
</tr>
</tbody>
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Insert the Edi Module into the SERVO-i ventilator 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.

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

<table>
<thead>
<tr>
<th>Fr/cm</th>
<th>Calculation of $Y$</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 Fr 100 cm</td>
<td>NEX cm $\times 0.9 + 8 = Y$ cm</td>
</tr>
<tr>
<td>6 Fr 50 cm</td>
<td>NEX cm $\times 0.9 + 3.5 = Y$ cm</td>
</tr>
<tr>
<td>6 Fr 49 cm</td>
<td>NEX cm $\times 0.9 + 2.5 = Y$ cm</td>
</tr>
</tbody>
</table>

Insertion distance $Y$ for oral insertion

<table>
<thead>
<tr>
<th>Fr/cm</th>
<th>Calculation of $Y$</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 Fr 100 cm</td>
<td>NEX cm $\times 0.8 + 8 = Y$ cm</td>
</tr>
<tr>
<td>6 Fr 50 cm</td>
<td>NEX cm $\times 0.8 + 3.5 = Y$ cm</td>
</tr>
<tr>
<td>6 Fr 49 cm</td>
<td>NEX cm $\times 0.8 + 2.5 = Y$ cm</td>
</tr>
</tbody>
</table>

Examples:

- Infant – height 40 cm, weight 900 g
  
  Selected Edi Catheter – 6 Fr 49 cm
  
  Insertion – nasal
  
  NEX – 12 cm
  
  **Insertion distance $Y$** = 12 x 0.9 + 2.5 = 12.3 cm

- Infant – height 46 cm, weight 1.8 kg
  
  Selected Edi Catheter – 6 Fr 50 cm
  
  Insertion – oral
  
  NEX – 15 cm
  
  **Insertion distance $Y$** = 15 x 0.8 + 3.5 = 15 cm

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 and select “Edi Catheter positioning” 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 ECG curves, while the P waves gradually decrease and disappear in the lower ECG curves, where QRS amplitude also decreases. Check that the Edi scale is fixed and that it is set appropriately (greater than or equal to 5 µV).

If Edi deflections are present, observe which leads are highlighted in blue.

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

- If the top leads are highlighted, 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.

- If the bottom leads are highlighted, 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.

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

- hyperventilation
- sedation
- muscle relaxants
- neural disorders

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

**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.
## 2 INVASIVE VENTILATION WITH NAVA

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2.1 STARTING AND RUNNING NAVA

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

Before starting, the Edi catheter should be inserted as described in 'Introduction and background facts'.

2.2 SETTING THE INITIAL NAVA LEVEL

**Option 1:** Set the NAVA level initially to 1 cmH₂O/µV and optimize the level as described below.

**Option 2:** Open the "neural access" menu on the ventilator and select "NAVA preview". Two pressure curves appear in the upper window: a yellow one, that represents the actual pressure delivery, and a gray one that provides an estimation of the pressure delivered (based on actual Edi and NAVA level) if the patient was switched to NAVA at this time.

Adapt the NAVA level so that the estimated pressure curve (gray) resembles the actual pressure curve (yellow). If satisfactory, press "Accept". Press "NAVA" in "Select ventilation mode". The NAVA level that appears is based on the level selected in the preview window.
2.3 OPTIMIZING THE NAVA LEVEL

Optimize the NAVA level according to Edi max, which should be targeted between 5-15 µV.
- If Edi max is < 5 µV, decrease the NAVA level.
- If Edi max is > 15 µV, increase the NAVA level.

The changes in NAVA level should be in steps of 0.1-0.2 cmH₂O/µV. The changes in NAVA level are mediated in a few breaths to Edi max. The usual NAVA level is 0.5 - 2.0 cmH₂O/µV, with Edi signals between 5 - 15 µV.

2.4 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.

2.5 SETTING APNEA TIME

Set the initial apnea time at 5 seconds. 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.

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.

Avoid high pressure settings in PS and PC, this will reduce locking in PS and PC.
2.6 BACK-UP SETTINGS

Shorter apnea time (<5 seconds) increases the significance of back-up ventilation settings as there is a risk for hyperventilation. However the risk of hyperventilation is decreased in NAVA due to patients own feedback through the respiratory drive.

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

2.7 OTHER SETTINGS

Set Edi trigger to 0.5 µV and trigger sensitivity to 1 - 2 (to prefer Edi triggering).

2.8 WEANING PATIENTS FROM NAVA

Decrease the NAVA level as the patient’s pulmonary status improves. Usually the patient is ready to be extubated when the NAVA level is 0.5 cmH₂O/µV or lower.

2.9 TREND CURVES

The trend curves give information about respiratory variables for the preceding 24 hours and they should be routinely checked together with the child’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

2.10 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.

2.11 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.

2.12 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.
2.13 SWITCHING BETWEEN NAVA, 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/Ttot is more than 0.5, calculated over the last 20 seconds if the Edi Catheter position is classified as invalid.
- The Edi Ti/Ttot 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/Ttot are shown on the user interface. Edi respiratory rate and Edi Ti/Ttot 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

- An adequate Edi signal can 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.
2.14 ALARMS FOR INVASIVE NAVA

The following are high priority alarms.

**ASYNCHRONY ALARM**

In case of asynchrony between the Edi signal and pneumatic breaths, 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.

When the asynchrony alarm has been activated, the ventilator will as usual search for synchrony indices. As soon as synchrony is re-established, the message “Pneumatic-Edi synch restored” will be displayed. Press the OK button or 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. 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 or if the Edi Catheter is not properly connected. If this occurs, simply insert the Edi Module or adjust the Edi Catheter.

**REGULATION PRESSURE LIMITED MESSAGE**

"Regulation pressure limited" appears as a text message activated during NAVA at a level 5 cmH₂O 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 cmH₂O below the preset upper pressure limit.
3 NON INVASIVE VENTILATION WITH NAVA

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3.1 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. For neonates, the most commonly used interfaces are nasal prongs or nasal masks, although nasopharyngeal tubes may also be used (see management tips).

3.2 MONITORING THE 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 and unloading of the diaphragm
- objective criteria for intubation and extubation decisions.

3.3 STARTING NIV NAVA

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.
Backup ventilation for NIV NAVA is Pressure Control.

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

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.

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 been unintentionally disconnected.

The leakage fraction alarm function is enabled via Biomed and this function is only available in the NIV NAVA infant option.

**NIV NAVA IN PRACTICE**

The NAVA levels in NIV NAVA are usually lower than in invasive NAVA (0.5 - 1.0 µV/cmH₂O). Higher Nava levels may increase the amount of gas entering the stomach/intestine and cause abdominal distention.

- If Edi max is < 5 µV, decrease the NAVA level.
- If Edi max is > 20 µV, increase the NAVA level.

The changes in NAVA level should be in steps of 0.1-0.2 µV/cmH₂O, with a few breaths between each step. Usually patients can be switched to nCPAP, when the NAVA level is < 0.5 cmH₂O/µV.
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.

Apart from the NIV NAVA levels being a little lower, the following also applies:

- The 'No patient effort alarm' can be turned off
- Apnea time can be reduced
- Leakage compensation is active

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 cmH₂O below the preset upper pressure limit. The maximum peak pressure is 32 cmH₂O.

The Regulation pressure limited message appears when Ppeak is 5 cmH₂O below the upper pressure limit. The maximum available pressure level is thus 5 cmH₂O 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. When appropriate values have been set, press Accept.

RUNNING NIV NAVA
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.

**DISCONNECT FLOW**

Disconnect flow is 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 for infants
- Disabled - No pause in ventilation in case of high leakage. The SERVO-i ventilator 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.

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

**NIV NAVA ALARMS**

The following NIV NAVA alarms are described below:

- No patient effort alarm
- Leakage out of range alarm
- Check catheter position/RR and HR coupling alarm
- Unreliable Edi signal alarm
- Check catheter position/Edi invalid alarm
- Apnea audio delay
**NO PATIENT EFFORT ALARM**

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.

This alarm can also be switched off.

The leakage fraction alarm can be switched off in the Biomed configuration menu.

NAVA in neonatal settings Study Guide
LEAKAGE OUT OF RANGE ALARM

The ventilator will compensate for leakage of up to 25 l/min for infants. If leakage is excessive (>25 l/min for infants 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.

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.

The leakage out of range alarm can be switched off in the Biomed configuration menu.
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/Ttot is more than 0.5, calculated over the last 40 seconds, if the Edi Catheter position is classified as invalid.
- the Edi Ti/Ttot 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/Ttot are shown on the user interface. The Edi respiratory rate and Ti/Ttot 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.

**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 20 seconds, while the apnea time has been set to 10 seconds, the SERVO-i 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.
4 NAVA AND NIV NAVA FEATURES AND MANAGEMENT TIPS

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4.1 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 Edi decreases below 70% of the peak value during ongoing inspiration (40% for low Edi signals), or when the pressure increases 3 cmH₂O above the inspiratory target pressure, or if the Upper Pressure Limit is exceeded, or when the maximum time for inspiration specified above is exceeded.

4.2 TRIGGER COLORS

![Edi trigger indicator](image1) ![Flow/pressure trigger indicator](image2)

4.3 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.

4.4 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 patient chart.

If possible, perform an expiratory hold and verify that the positive Edi deflection coincides with a negative deflection in the pressure waveform.
4.5 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 Alarms below). The function is not used when a closed suction system is in use.

4.6 PATIENT INTERFACES FOR NIV NAVA

A range of different types of patient interfaces can be used when ventilating neonatal patients with NIV NAVA. They include nasal masks and prongs and they come in a variety of sizes to suit all patients. The text below describes the Miniflow neonatal system.

More detailed information can be found in the relevant User’s Manual from Medin Innovations GmbH.

- Measure the circumference of the baby’s head with the measuring tape.
- Select a bonnet of the correct size – it has to fit loosely.
- Put the bonnet on the baby’s head – pull the bonnet as far down towards the baby’s eyes as possible.
- Choose either prongs or mask – always use the largest possible prongs. You can place the measuring tape beneath the baby’s nose to see the distance between the nostrils.
- Connect the prongs or mask to the Miniflow.
- Thread the separate strips provided with the bonnet through the two holes on either side of the prongs or mask.
- Choose the most suitable angle for the Miniflow connection – either 45° for babies weighing more than 1000 g or 60° for babies weighing less than 1000 g.
- Open the Velcro tube fastener on the bonnet.
- Place the tubes on either side of the central part of the Velcro tube fastener.
- Either place the mask over the baby’s nose, or insert the prongs halfway into the baby’s nostrils.
- Fasten the strips onto the bonnet below the baby’s ears.
- Fixate the tubes in the Velcro fastener on the bonnet.
- If desired, tie the top of the bonnet using the bonnet’s white fabric strips.

**Important:**

- If prongs are used, the semicircular edge of the base must point towards the baby’s mouth.
- Insert the prongs only halfway into the baby’s nostrils.
- The base of the prongs should not be in contact with either the baby’s nose or the skin below the nose.
- Do not pull the strips too tight.
- The Miniflow’s tubes should be angled so that the highest point is located at the baby’s nose to prevent any water from flowing back to the baby’s airways.

Please note, before starting ventilation with NIV NAVA, it is vital to prepare ahead and have all necessary interfaces and connections ready for use.

### 4.7 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.
4.8 TROUBLESHOOTING

Patient contraindications and trouble shooting are described in this section. The troubleshooting topics that are explained are as follows:

- Low or absent Edi signal during catheter positioning
- Sharp Edi signal with high Edi max
- High respiratory rate
- Pneumatic triggering in NAVA
- Special groups of patients

PATIENT CONTRAINDICATIONS

- Insufficient/absent respiratory effort (brain anomaly, medication)
- Anomaly (esophageal atresia, severe diaphragmatic hernia)
- Phrenic nerve injury
- Congenital myopathy
- MRI scanning (remove and reserve the Edi catheter before entering the MRI area)

LOW OR ABSENT EDI SIGNAL DURING CATHETER POSITIONING

Typical reasons for absent Edi in pediatric patients are:

- Catheter malposition
- High preset frequency in ventilation mode used
- High PIP in PS (or the ventilation mode used), relatively high $V_T$
- High PEEP
- Deep sedation
SHARP EDI SIGNAL WITH HIGH EDI MAX

Typical reasons for sharp Edi signal with high Edi max are:

- Insufficient NAVA level causes increased breathing drive.
- Other reasons for acute change in Edi shape:
  - Pain
  - Discomfort, agitation

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.
- Reduce preset PEEP level in case of increase in PEEP caused by high respiratory rate.
- Reduce preset PEEP level in case of increase in PEEP caused by high respiratory rate.
- Possible causes for acute change in respiratory rate are:
  - Acute change in pulmonary status
  - Pain
  - Discomfort
  - Nausea
  - Fever
PNEUMATIC TRIGGERING IN 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.

- Inadequate pneumatic trigger will cause asynchrony and alarm 'pneumatic-Edi out of sync' will be present.

- 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 max 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.
5 GLOSSARY

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 for the SERVO-i 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 cmH₂O.

**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.
6 REFERENCES


Hanna Soukka, MD and Liisa Lehtonen, MD, Department of Pediatrics, Turku University Hospital, Turku, Finland. Neurally Adjusted Ventilatory Assist, NAVA: Clinical Protocol. Category: Neonatal ICU.

Merja Ålander, MD, Department of Pediatrics, Oulu University Hospital, Oulu, Finland. Neurally Adjusted Ventilatory Assist, NAVA: Clinical Protocol. Category: Pediatric ICU.


Websites:

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