Focus
This clinical protocol describes the rationale, patient selection, practical issues and some of the troubleshooting involved in using invasive Neurally Adjusted Ventilatory Assist (NAVA®) with pediatric patients.

Rationale
NAVA is a ventilatory mode characterized by ventilator triggering and assisting spontaneous breathing by diaphragm muscle electrical activity (Edi). The amount of pressure provided by ventilator depends on the intensity of the Edi signal (proportional support).

Edi max represents the maximal electrical activity of the diaphragm for a particular breath (in µV), and Edi min the activity of diaphragm between inspiratory efforts (in µV).

The peak inspiratory pressure (PIP) provided during a single breath is:

\[
PIP (cmH_2O) = NAVA \text{ level } (cmH_2O/\mu V) \times (Edi \text{ max } – Edi \text{ min } (\mu V)) + PEEP (cmH_2O)
\]

Patient selection
Several clinical studies have demonstrated improved patient-ventilator synchrony in NAVA compared to conventional ventilation in pediatric population. NAVA has also shown to improve patient comfort during invasive ventilation. Whether these features will lead to any improvement in survival, length of stay in PICU or time on ventilator remains to be seen.

NAVA ventilation requires sufficient respiratory effort, and should not be used in situations in which deep sedation, muscle relaxation or strict control over blood gas values is needed (i.e. patients with high intracranial pressure). However, most of these patients may be treated with NAVA in the phase of recovery.

Contraindications
- Known contraindications for naso-/orogastric feeding tube.
- Phrenic nerve injury.
- Congenital myopathy (relative contraindication).
- MRI scanning: the Edi Catheter is not approved for use in MRI environments. Remove the Edi catheter before entering the MRI area.

NAVA in practice
1. Insertion of catheter
- Choose appropriate catheter size (defined by length of patient).
- Calculate the insertion length according to formula provided (NEX measure).
- Dip the catheter with water (do not use any silicon spray or lubricant).
- Guide wire may be needed with the thinnest catheters (8Fr/100cm, 8Fr/125cm, 12Fr/125cm), especially if oral insertion is used.
- Run Edi module test and connect the Edi cable to catheter.
- Open “Neural access” menu on the ventilator and select “Edi catheter position”.
- Check catheter position: P waves and QRS complexes are high in upper leads, in lower leads P wave disappears and QRS complexes decrease and the two middle leads are highlighted blue during active inspiration.

2. Setting the initial NAVA level
   Option 1
   - Open “neural access” 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 pres-
sure delivered (based on actual Edi and NAVA level) if the patient were switched to NAVA at this time.

- Adapt the NAVA level so that the area under 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.

**Option 2**

- Set the NAVA level initially to 1 cmH₂O/µV and optimize the level as described in section 4.

3. Other settings

**PEEP**

- Initially, the same PEEP as in previous ventilation mode is used.

- During NAVA, PEEP may be optimized by observing Edi min. If Edi min is constantly >1 µV (a sign of tonic diaphragmatic activity to maintain FRC) increase PEEP.

**Trigger levels**

- Set Edi trigger to 0.5 µV initially

- Set pneumatic trigger sensitivity to optimal level individually -2 to 3.

- The ventilator provides support on a “first-come-first-served” basis in NAVA.

**Pressure support (PS)**

- Pressure support is activated if the patient triggers ventilator with pneumatic trigger, but Edi signal is low.

- Set pressure support to reach optimal PIP during PS (the same or lower than in previous mode).

- Set adequate Inspiratory Cycle Off.

**Backup**

- When patient is not triggering the ventilator in any way, backup ventilation is activated.

- Set adequate PIP, Tinsp (or I:E) and frequency (often similar to the settings of previous ventilation mode).

**Alarm limits**

- Alarm limit set for peak inspiratory pressure is the only factor limiting PIP during NAVA, and for safety reasons always needs to be set individually.

4. Optimizing the NAVA level

Optimize the NAVA level according to Edi max, which generally is targeted between 5 and 15 µV.

- If Edi max is < 5 µV, the NAVA level may be decreased.

- If Edi max is > 15 µV, consider increasing the NAVA level.

- Influence of several factors on Edi signal should be noted (See: Troubleshooting).

- Changes in NAVA level should be 0.1–0.2 cmH₂O/µV.

**The usual NAVA level is between 0.5 and 3.0 cmH₂O/µV**

- Patients with healthy lungs 0.5–1.0 cmH₂O/µV.

- Patients with low lung compliance 1.0–3.0 cmH₂O/µV in some cases even higher NAVA levels.

5. Weaning patients from NAVA

- Reduce the NAVA level as the patient’s pulmonary status improves.

- Reduce also PS and backup settings accordingly, to avoid staying in PS.

- Usually, the patient is ready to be extubated when NAVA level is ≤ 0.5 cmH₂O/µV.

6. Trend curves

- Check the trend curves for the preceding 24 hours routinely together with child’s clinical condition.
**Troubleshooting**

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) \( \rightarrow \) relatively high \( V_T \)
  - High PEEP
  - Deep sedation

**Sharp Edi signal with high Edi max**

- Insufficient NAVA level causes increased breathing drive.
- Some changes in Edi max reflect changes in sedation level.
- Other reasons for acute change in Edi shape
  - Pain
  - Discomfort, agitation
  - Nausea

**High respiratory rate**

- In NAVA 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.
- Possible causes for acute change in respiratory rate
  - Acute change in pulmonary status
  - Pain
  - Discomfort
  - Nausea
  - Fever

**Pneumatic triggering in NAVA**

- In NAVA, 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 synch” 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 (e.g. status post diaphragmatic hernia, myopathies etc.) may lead to a situation, where 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.

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