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NAVA Ventilation in Neonates: Clinical Guidelines and Management Strategies

By Howard Stein, MD and Kimberly Firestone, BS, RRT

Introduction

NAVA (Neurally Adjusted Ventilator Assist) is a new mode of ventilation that may offer potential solutions to many of the challenges posed by neonatal ventilation. However, experience with the use of NAVA in the neonatal population is limited. Toledo Children's Hospital and Akron Children's Hospital neonatal intensive care units have a combined experience of using NAVA and Non-Invasive (NIV-NAVA) ventilation in over 500 neonates. In this article, we will briefly review how NAVA works, summarize our clinical experience, and provide clinical guidelines and management strategies for neonates on NAVA ventilation.

Background:

Ventilating a neonate is complicated by the need for short inspiratory times, rapid respiratory rates and small tidal volumes. These factors impose technological challenges of synchrony with the ventilator especially with breath triggering, breath termination and tidal volume measurement.¹ Synchrony contributes to effective ventilation. The ideal synchronized breath needs to be synchronous with initiation, size and termination of the breath. Asynchrony during ventilation has the potential for adverse effects including the need for increased mean airway pressure and FiO₂, and fluctuations in blood pressure and intracranial pressure.² The ideal trigger device needs to be: sensitive enough to be activated by a small premature infant, not be overly-sensitive to cause auto-triggering, have a rapid

response time to match the short inspiratory times and rapid respiratory rates, be able to compensate for variable air leaks and not add to dead space.¹ One of many disadvantages of previous triggering devices is that they only detect initiation of the breath and synchronize a preset ventilator breath with the patient.² The introduction of the diaphragmatic electromyograph (EMG) has allowed further evaluation of the flow trigger. Figure 1 shows an example of failure-to-trigger or 'missed triggering.'

“Toledo Children’s Hospital and Akron Children’s Hospital neonatal intensive care units have a combined experience of using NAVA and Non-Invasive (NIV- NAVA ventilation in over 500 neonates. In this article, we will briefly review how NAVA works, summarize our clinical experience, and provide clinical guidelines and management strategies for neonates on NAVA ventilation.”

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Figure 1: Failure-to-trigger -- This panel shows the pressure (first line), flow (second line) and Edi (fourth line) tracings in a neonate on SIMV (Press. Contr.). The Edi signal is converted to a pressure estimate (P.est) that is shown as a white line superimposed over the yellow pressure line in the upper tracing. The P.est represents what the pressure would be if the patient was in NAVA. In the upper tracing the patient appears to be apneic with no evidence of flow triggering (white circles) and is being ventilated in pressure control. The P.est represents the neonate's actual respiratory drive and demonstrates that there is a strong respiratory drive that is not detected by the flow trigger (red circles). Stein and Firestone, *Neonatology Today* 2012.



Figure 2: Ventilatory asynchrony with conventional ventilation - This panel shows the pressure (first line), flow (second line) and Edi (fourth line) tracings in a neonate on SIMV (Press. Contr.). The Edi signal is converted to a pressure estimate (P.est) that is shown as a white line superimposed over the yellow pressure line in the upper tracing. Each breath appears to be flow triggered (purple lines on the flow tracing), and breath initiation is synchronous in many breaths when compared to the Edi generated P.est (red circles). However some breaths are late (red arrow) and some are missed (white arrow). Also evident is the inadequate breath size (white circle) and termination (blue circle) asynchrony. Stein and Firestone, *Neonatology Today* 2012.

The electrical activity of the diaphragm (Edi), which represents the neonate's neural respiratory effort, is superimposed over the flow-triggered pressure tracing. Although the patient appears apneic, the Edi signal displays the strong neural respiratory drive present. Figure 2 shows what asynchronous flow triggering looks like: there is reasonable synchrony with triggering, but poor synchrony with breath size and termination. A few ventilator breaths are larger than the neonate's drive. Most ventilator breaths are smaller and shorter than what the neonate is trying to generate spontaneously.

Recently the diaphragmatic EMG had been used as a trigger to deliver mechanical breaths that are synchronized to initiation, size and termination with each patient's breath. This type of synchronized ventilation is called Neurally Adjusted Ventilatory Assist or NAVA.

How NAVA Works

There are multiple reviews available that explain the principles behind NAVA ventilation.^{3, 4} An electrical signal is generated in the respiratory center in the brain stem and travels via the phrenic nerve to stimulate the diaphragm. The electrical activity of the diaphragm is detected by electrodes embedded in a special nasogastric tube and transmitted via wires in the nasogastric tube to the ventilator. The ventilator assists the spontaneous breath by delivering a proportional pressure. The peak inspiratory pressure delivered is based on the amount of electrical activity generated by the diaphragm. The PIP is generated until the electrical activity decreases by 40 to 70% and then the breath is terminated. The neonate, by reflex control of diaphragmatic activity, determines the peak inspiratory pressure, inspiratory and expiratory time for each breath and the respiratory rate.³

NAVA Terminology

The development of NAVA has introduced a number of new terminologies not used in other ventilation modes.

Edi is the electrical activity of the diaphragm and can be thought of as a respiratory vital sign. The Servo-I (Maquet, Solna, Sweden) displays Edi as a peak and a minimum (min). Edi peak represents neural inspiratory effort and is responsible for the size and duration of the breath. Edi min represents the spontaneous tonic activity of the diaphragm, which prevents derecruitment of alveoli during expiration.

Edi trigger is the minimum increase in electrical activity from the previous trough that triggers the ventilator to recognize the increase in electrical activity as a breath and not just baseline noise.³ The use of Edi trigger will be discussed in more detail under clinical guidelines.

NAVA level is a conversion factor that converts the Edi signal into a proportional pressure. For each breath, the peak pressure is determined by the formula: Peak pressure = NAVA level x Edi (peak - min) + PEEP.³ How to determine the NAVA level will be discussed in further detail under clinical guidelines.

A figure showing how the neural trigger works and a reference chart comparing flow triggered conventional to NAVA ventilation has been published in a previous issue of *Neonatology Today*,⁵ and is available at <http://www.neonatologytoday.net/newsletters/nt-jul10.pdf>.

Review of NAVA Neonatal and Pediatric Literature

There are few studies on the use of NAVA in pediatric and neonatal patients. These studies showed that NAVA improved patient-ventilator interaction and synchrony in neonates^{6, 7} even in the presence of large air leaks.⁸ When changing from conventional ventilation to NAVA, peak inspiratory pressures decreased,^{6, 7, 9, 10} respiratory rate increased in some studies^{7, 9} and remained the same in others.^{6, 10} Blood gases improved on NAVA in some studies^{5, 10} and remained the same in others.^{6, 7, 9} All studies showed no change in mean airway pressure and no adverse events were noted while on NAVA. Specifically, in one retrospective review, there was no change in the rate of intraventricular hemorrhage, pneumothorax or necrotizing enterocolitis.¹⁰

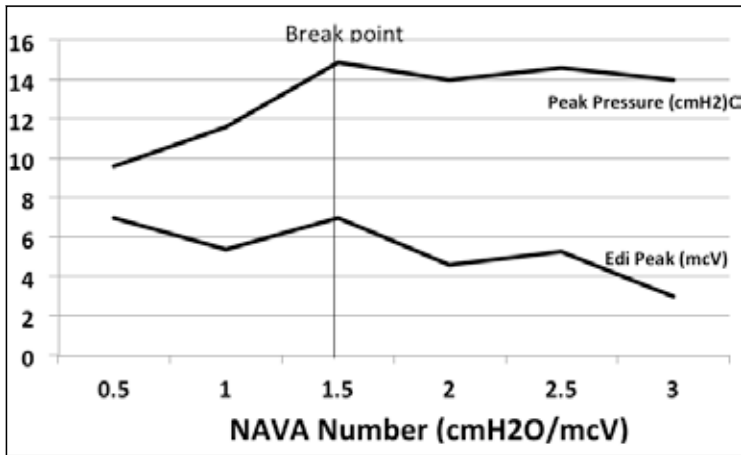


Figure 3: Edi and peak pressure data from a 3 week old premature (29 week gestation) infant, as the NAVA level is increased from 0.5 – 3 cmH₂O/mcV. It appears that, at a level of 1.5 cmH₂O/mcV, the peak pressure no longer increases and the Edi peak starts to decrease with further increases in NAVA level. The breakpoint would then be determined to be a NAVA level of 1.5 cmH₂O/mcV. Stein and Firestone, *Neonatology Today* 2012.

Clinical Guidelines and Management Strategies

In a previous article, we described how to introduce NAVA into the NICU.¹¹ In that article we offered some clinical tips for the use of NAVA. In the two years since that article, there have been significant advances in NAVA software and alarm management. In this current article, we will expand on clinical guidelines written specifically for neonates that have been modified since the previous article, or are based on previous updates in NAVA software. We will also share software updates that have recently become available.

1. **Non-invasive ventilation NAVA (NIV-NAVA) is now available.** This works like NAVA but is able to assist the patient non-invasively via nasal prongs, a single nasal-pharyngeal tube or a mask. NIV-NAVA has leak compensation so these interfaces do not need to be sealed as with CPAP and other types of non-invasive ventilation. NIV-NAVA appears to function well with leaks as high as 90-95%. Because all the clinical guidelines we discuss are applicable to NAVA and NIV-NAVA, we will refer to them both as NAVA.
2. **Placement of the Edi catheter** - The retrocardiac EKG, seen on the catheter positioning screen, should have the largest p-waves and QRS complexes in the upper lead and minimal to absent p-waves and small QRS complexes in the lower leads. At times, the superimposed blue color of the Edi signal will drift from the middle 2 leads to the upper or lower leads, but does not seem to have an impact on the effectiveness of NAVA. *Watch a related video presentation at: <http://www.NeonatologyToday.net/NAVA/4.html>. In Spanish: <http://www.neonatologytoday.net/Articles/NAVA-S/4.html>*
3. **Choosing the appropriate NAVA level** – The NAVA number is the factor that determines how much work the patient does compared to the ventilator. Company literature suggests choosing an initial NAVA level that delivers the same peak pressure the patient is getting from conventional ventilation. In neonates, the limitations of this approach is the breath-to-breath variability in peak pressure when on NAVA and the increasing use of NIV-NAVA in patients that have never been intubated and placed on conventional ventilation. The ventilator basically functions as an ‘accessory diaphragm,’ controlled by the patient, to help generate adequate pressures. As the NAVA number is increased, peak pressures will increase proportionally until a ‘break point’ is reached. After this point the peak pressure will remain stable and the Edi peak will decrease with further increase in the NAVA number.^{12, 13} This ‘breakpoint’ is the NAVA

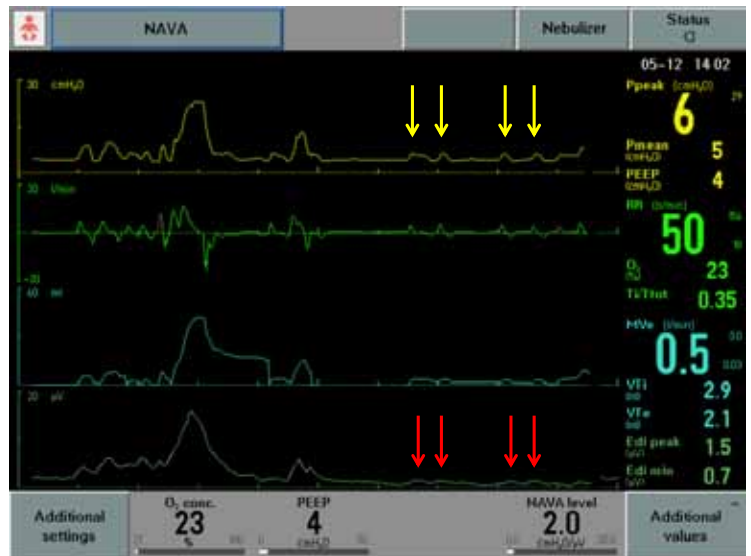


Figure 4: Edi trig set at 0.2 mcV. Small Edi signals (red arrows) are converted to small ineffective breaths (yellow arrows) and prevent the neonate from going into backup. Stein and Firestone, *Neonatology Today* 2012.



Figure 5: Edi set at 0.5 mcV. Small Edi signals are now ignored (red arrow) and the neonate remains in backup (yellow arrow) getting effective pressure control breaths. When a larger Edi signal is detected (white arrow), the neonate gets an adequate NAVA breath (blue arrow). Stein and Firestone, *Neonatology Today* 2012.

number at which the patient’s respiratory muscles are adequately unloaded and is unique to each patient. Any further increase in the NAVA number will only suppress the Edi signal and may actually cause the patient to become apneic. Although this concept of a ‘breakpoint’ has not been shown previously in neonates, Figure 3 shows the changes in both Edi Peak and peak pressure in a neonate, as the NAVA level increases, and suggests that the ‘breakpoint’ for this neonate is at a NAVA level of 1.5 cmH₂O/mcV. This reflects the NAVA level needed to provide adequate unloading of the respiratory muscles to the ventilator. From studies in adults^{12, 13} and our clinical experience, we suggest starting at a low NAVA level (0.5 – 1 cmH₂O/mcV) and observing the Edi peak and the patient’s work of breathing. If the Edi peak is consistently high (> 15-20

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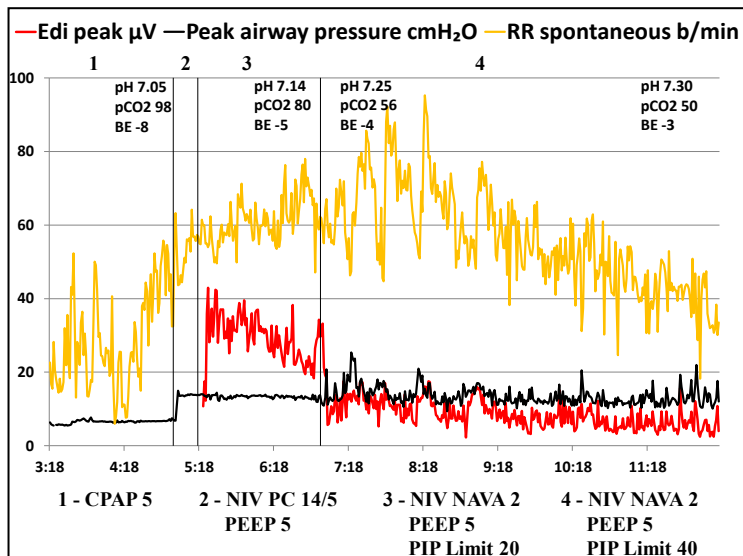


Figure 6: 1.8 kg, 32-weeks gestation male with RDS on a CPAP 5 cmH₂O. After a capillary blood gas (CBG) of pH 7.05, pCO₂ 98, he was changed to NIV pressure control. Section 1 and 2 show low peak pressures on CPAP and then on NIV pressure control. After the Edi catheter was placed, he was changed to NIV NAVA (NAVA level of 2 cmH₂O/mcV) with a PEEP of 5 and a peak pressure limit of 20 cmH₂O. The initial Edi peak was high and the true respiratory rate became evident. The peak pressure consistently reached the pressure limit, 15 cm H₂O (5 below set peak pressure limit), and was achieved with each breath as seen in section 3. Follow-up CBG was pH 7.14, pCO₂ 80. When the peak pressure limit was increased to 40 cm H₂O, there was rapid clinical improvement, as the neonate recruited alveoli and improved ventilation, and a CBG 1 hour later pH 7.25, pCO₂ 56. Section 4 shows the Edi peak decreased, but peak pressure and respiratory rate initially increased. Over next 4 hours, after adequate lung recruitment, self-weaning of peak pressures and respiratory rate occurred and the follow up was CBG pH 7.3, pCO₂ 50. Stein and Firestone, Neonatology Today 2012.

cmH₂O) and/or the patient is having significant retractions, increase the NAVA level every few minutes in increments of 0.2 - 0.5 H₂O/mcV. The adequate NAVA level will be when the peak pressure no longer increases and the Edi peak decreases with further NAVA level increases. Go to the web site to view the video on adjusting the NAVA level for a premature neonate - <http://www.NeonatologyToday.net/NAVA/2.html>. In Spanish: www.neonatologytoday.net/Articles/NAVA-S/2.html


4. **Edi trigger** – The Edi trigger is the increase in Edi that needs to occur for the ventilator to start to support the spontaneous breath. If the Edi trigger is set too low as previously suggested,¹¹ the ventilator responds to small Edi signals and converts them into small breaths as shown in Figure 4. This prevents the neonate from going into backup ventilation and may result in clinical deterioration from under-ventilation. Using a higher Edi trigger results in small Edi signals being ignored. The ventilator interprets this as apnea and triggers backup ventilation as shown in Figure 5. The neonate is then adequately ventilated in backup until a more robust Edi signal is present and NAVA ventilation resumes. Watch a related video presentation at: <http://www.NeonatologyToday.net/AVA/3.html>. In Spanish: www.neonatologytoday.net/Articles/NAVA-S/3.html
5. **Setting the peak pressure alarm** – In conventional ventilation, it is typical to set the peak pressure alarm slightly higher than the set peak pressure to protect the lung from repeated, potential over-distention. In NAVA, however, if the peak pressure is set at comparable levels to conventional ventilation, the neonate will be restricted to the maximum peak pressure allowed and will be at risk for under-ventilation. Figure 6 shows an example of a neonate with RDS who



Figure 7: The neonate has a spontaneous breath (1) and then becomes apneic. After 5 seconds of apnea the neonate receives a backup breath (2) that generates an Edi signal (3). This is Head's Paradoxical Reflex and is secondary to diaphragmatic expansion and not a signal from the phrenic nerve. Although the Edi signal is not converted into a breath, the apnea timer has been reset and the neonate remains apneic without ventilation another 5 seconds before the next backup breath occurs (4) Stein and Firestone, Neonatology Today 2012.

was failing nasal CPAP of 5 cmH₂O and was placed on non-invasive NAVA. Initial high Edi peak reflected a strong respiratory drive consistent with trying to correct the CO₂ retention. Because the peak pressure limit was set at 20 cmH₂O, the neonate was unable to recruit alveoli and continued to retain CO₂ despite being tachypneic. After the peak pressure limit was raised, the neonate recruited alveoli and improved ventilation. After adequate lung recruitment, self-weaning occurred, and peak pressures and respiratory rate decreased. We propose that premature neonates ventilated with NAVA are able to regulate minute ventilation and adjust their ventilatory peak pressure requirements and respiratory rate on an ongoing basis as long as the peak pressure limit is set high enough to allow them occasionally to take adequate recruiting breaths. Watch a related video presentation at: <http://www.NeonatologyToday.net/NAVA/5.html>. In Spanish: www.neonatologytoday.net/Articles/NAVA-S/5.html

6. **NAVA software updates:**
 - a. **Previous software locked (latched) the neonate in backup after the neonate went into backup more than 3 times in 2 minutes.** The software update allows the neonate to switch back and forth between NAVA and backup unlimitedly. The neonate can now ventilate with NAVA when there is spontaneous respiratory effort, ventilate in pressure control when apneic and return to NAVA when spontaneous respiration resumes, all without any operator intervention.
 - b. **Apnea time** – This allows the operator to set the amount of time the neonate can be apneic before going into backup. Although apnea is typically defined as no respiratory effort for longer than 20 seconds,¹⁴ this period without ventilation is often too long for small premature neonates and they can deteriorate clinically. The apnea time is the maximum time the neonate will be without any ventilation. This therefore provides a minimum guaranteed rate which is different from the backup rate. For example, setting the apnea time at 5 seconds guarantees a minimum rate of 12 breaths per minute. After 5 seconds of apnea the neonate goes into backup ventilation at the backup rate set in the NAVA setup screen. The next Edi signal will



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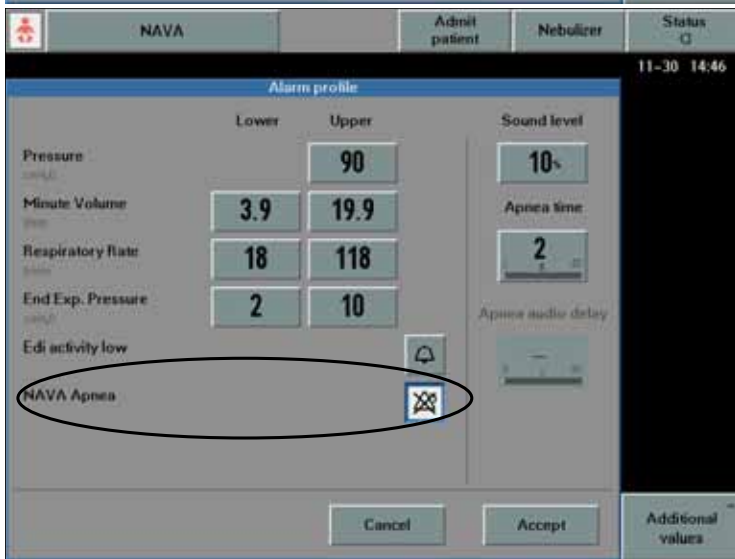
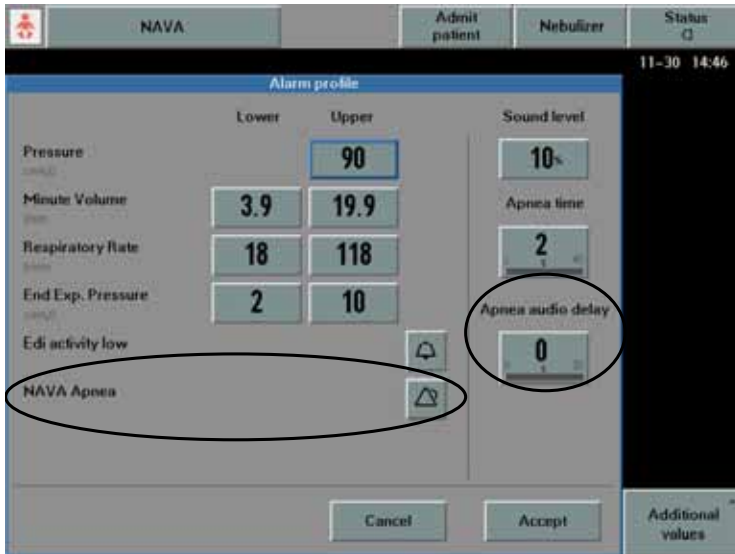


Figure 8a: (TOP) NAVA Apnea is on. The Apnea audio delay can be set from 0-30 seconds to alert the operator that the patient is in backup. Stein and Firestone, Neonatology Today 2012.

Figure 8b: (Bottom) NAVA Apnea is off. All backup alerts will be turned off. Stein and Firestone, Neonatology Today 2012.

restart the 5 second apnea timer again. Figure 7 shows an example of a neonate with Heads Paradoxical Reflex that keeps resetting the timer. Although the neonate is apneic, there are only 2 backup breaths in a 10 second period. If this phenomenon reoccurs frequently, the neonate will only get 12 breaths per minute despite the backup rate being set much higher. This may not be sufficient respiratory support for the neonate and may result in desaturations and bradycardia. In these cases, the new software now allows the apnea time to be reduced to 4 seconds (minimum rate of 15 breaths/min), 3

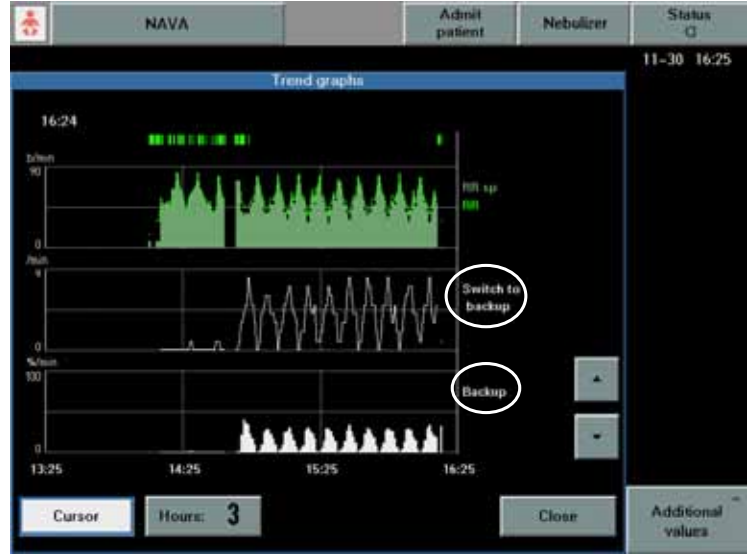


Figure 9: New trends that are now available. Number of switches to backup/min and % time in backup/min. Stein and Firestone, Neonatology Today 2012.

1. Insert an appropriately-sized NAVA catheter, verify position and record insertion depth
2. Place on NAVA NIV NAVA
3. NAVA number _____ cmH₂O/mcV, PEEP _____ cmH₂O
4. If in NAVA: PS above PEEP _____ cm H₂O
5. Back-up: PC above PEEP _____ cm H₂O, rate _____ breaths/min, IT _____ sec
6. Alarms: Peak pressure _____ cmH₂O Apnea time _____ sec
7. Blood gases _____
8. Call for increased work of breathing, increasing FiO₂, frequent desaturation or bradycardia

Figure 10: Preprinted orders for the initial set up of NAVA or NIV NAVA. Stein and Firestone, Neonatology Today 2012.

seconds (minimum rate of 20 breaths/min) or 2 seconds (minimum rate of 30 breaths/min). A neonate who remains apneic will ventilate at the preset backup rate. This permits the operator the flexibility to provide optimal backup support even in neonates with frequent but non-sustained Edi signals. Watch a related video presentation at: <http://www.NeonatologyToday.net/NAVA/1.html>. In Spanish: www.neonatologytoday.net/Articles/NAVA-S/1.html

- c. **NAVA apnea** – This alert notifies the operator that the patient is in backup ventilation by flashing the words “No Patient Effort” or “No Consistent Patient Effort” on the screen and audibly beeping. After a predetermined time in backup ventilation, the ventilator will audibly alert the operator that the patient is still in



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NAVA and NIV-NAVA Initial Setup Guide

1. Select Edi catheter for patient.
 - a. Obtain patient weight in kg and height in cm.
 - b. Refer to catheter chart to select correct Edi catheter.
2. Obtain Edi cable and Edi module and insert into SERVO-i.
3. Perform Edi module function check with Edi cable.
 - a. Plug cable into the module and the other end of the cable into itself. The check is done automatically.
4. Measure "NEX" (measure distance from nose, ear, and xiphoid) for proper insertion depth.
 - a. Refer to chart for correct insertion depth or refer to previous OG/NG insertion distance.
5. Insertion of Edi catheter.
 - a. Before insertion, dip Edi catheter in sterile water for a few seconds to activate the coating which improves electrical conductivity and easier insertion (**DO NOT APPLY any other substance than water**).
6. Verify Edi catheter position.
 - a. Connect the Edi catheter to the Edi cable.
 - b. Open the "Neural access" menu.
 - c. Select "Edi catheter positioning."
 - d. Adjust catheter position by looking for a diminishing ECG waveform progression from the 1st to the 4th waveform and the presence of a blue color in the 2nd and 3rd waveforms (refer to NAVA Pocket Guide for more info). Record the optimal insertion depth of the catheter
 - e. Stabilize the Edi catheter to the face or endotracheal tube ensuring the catheter is not bent.
7. Set the initial NAVA level.
 - a. Press the neural access button and select NAVA preview.
 - b. Press the NAVA level button & adjust the main rotary dial so that the gray super imposed curve (Pest = pressure estimate) approximates the yellow pressure tracing.
 - c. Accept by pushing the main rotary dial and press "close" to save the NAVA level.

Note: *The Edi peak goal is 5-15 and Edi min is usually < 3...be aware Edi fluctuates breath to breath.*
8. Select NAVA from mode menu and set parameters (Compensation should be on).
 - a. Initial NAVA level is automatically imported from NAVA preview setting.
 - b. Set PEEP, FiO₂, and Edi trigger. The default for the Edi trigger is 0.5 mV which is a good starting point. Avoid "artifact self triggering" which can happen when trigger is too low. (lower number is more sensitive).
 - c. If Edi signal is not detected but patient is still breathing, pressure support breaths initiate from flow trigger. Set pressure support values for pneumatic trigger, inspiratory cycle off, and press support. When Edi signal resumes, it should automatically resume NAVA. If the patient remains in NAVA (PS) return to NAVA manually. Refer to NAVA guide for reasons why the patient may remain in NAVA (PS).
Note: not applicable with NIV NAVA software.
9. If Edi signal is not detected and patient is apneic, Backup Ventilation Mode is activated. Set Pressure control level and rate to assure adequate ventilation in case of apnea. These settings need to mimic previous ventilation settings but must be re-evaluated within one hour of NAVA initiation. The patient can transition between NAVA and backup ventilation as needed without operator intervention or alarms.
10. Set appropriate alarm limits.
 - a. Upper pressure limit (UPL) initially set 10 above previous PIPs. The patient will alarm and breath will be terminated at 5 cmH₂O below UPL. If the "regulation pressure limited" warning appears frequently, consider increasing UPL in increments of 5 cmH₂O. If UPL continues to alarm and the limit appears to be excessive, reevaluate patient's clinical status to allow for occasional recruitment breaths.
 - b. Set Sound level so it audible for bedside caregiver.
 - c. Apnea time needs to be set so that the patient does not clinically decompensate. Start at 5 seconds and adjust as clinically indicated.
 - d. Minute Volume set per current NICU policy.
 - e. Respiratory Rate 5-10 to 90-100 bpm.

After an initial acclimation period, the alarms may need to be evaluated often and adjusted accordingly.

Figure 11: Bedside NAVA setup guide. Stein and Firestone, *Neonatology Today* 2012.

- backup ventilation and provide an option to continue in NAVA or choose another mode of ventilation. The audio alarm delay can be set between 0 and 30 seconds on the alarm screen (Figure 8a). This backup alert should be on for all neonates that should not be having apnea and going into backup ventilation (term and older premature neonates). If 'NAVA apnea' is turned off (Figure 8b) then all screen alerts ("No Patient Effort" or "No Consistent Patient Effort") and the audio alerts will be inactivated. This backup alert should be inactivated on premature neonates that are expected to go into backup ventilation due to apnea so they can transition silently between NAVA and backup as needed.
- d. **Trends** – There are 2 new trends available with the software update (Figure 9).
 - i. 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 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 number of switches to backup/min is low, the neonate is having minimal apnea at the set apnea time, consider lengthening the apnea time.
- ii. Percent (%) of time in backup ventilation/min - 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.

- iii. 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.
7. **Managing the neonate on NAVA** – Once the appropriate NAVA setting has been chosen, the neonate will self-wean pressure, respiratory rate and FiO₂ as the disease process evolves.^{5, 10} Although neonates on NAVA tend to ventilate with close to normal blood gases,¹⁰ some neonates may be under- or over-ventilated.
 - a. **Management of desaturations or poor blood gases:**
 - i. If the neonate is having frequent apnea, consider decreasing the apnea time so the neonate gets earlier support.
 - ii. If the neonate is ventilating in backup frequently, consider increasing either the backup rate or peak pressure to provide more support while in backup ventilation.
 - iii. If the neonate is working hard to breath (retracting, high Edi signals), consider increasing the NAVA level to ‘unload’ the neonate’s respiratory muscles further and allow the ventilator to do more ‘work of breathing.’
 - iv. If the neonate is setting off the high pressure alarm, consider increasing the peak pressure limit to allow alveoli recruitment and improved tidal volume.
 - b. **Weaning off NAVA** - Use the trends screen to follow peak pressure, respiratory rate, number of backups/min and % time in backup and use these as described above to help guide ventilatory management. If the patient is clinically stable consider:
 - i. Increasing the apnea time
 - ii. Decreasing the backup settings
 - iii. ‘Loading’ the respiratory muscles by decreasing the NAVA number in increments of 0.2 to 0.5 cmH₂O/mcV.
 - iv. Extubating to NIV-NAVA
 8. **Preprinted orders** – because the setup of NAVA is complex, and to ensure that new terminology, modes, and backup settings are consistently and correctly identified, Figure 10 is an example of preprinted orders that guide the initiation of NAVA on a neonate. These orders should be modified as needed for use in specific NICU’s.
 9. **Bedside NAVA setup guide** - A setup guide is suggested on Figure 11 and could be located near the patient’s bedside or in

charting areas for easy access during initial setup. Operating manuals can be used for further reference.

Conclusion

NAVA and NIV-NAVA are gaining recognition as functional modalities for neonatal ventilation. The goal of this paper was to present a practical guide for use of NAVA in neonates in order to provide the tools for investigators to study NAVA further in this patient population. It appears that NAVA works in neonates, but the question remains if NAVA makes a difference. Multicenter, randomized, control trials are needed to determine if the use of NAVA and NIV-NAVA will prevent intubation, expedite extubation, decrease the incidence of chronic lung disease and subsequently improve overall long-term outcomes.

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Howard Stein is a neonatologist at Toledo Children’s Hospital, and has worked with and studied NAVA since it became available four years ago. He has published studies in the use of NAVA, and continues to do research to determine the optimal way to use NAVA in neonates.

Kimberly Firestone is the Neonatal Outreach Educator at Akron Children’s Hospital, and was responsible for coordinating the efforts to bring NAVA into their NICU. She is trained as a respiratory therapist, and an experienced NAVA innovator and user. She and the neonatal group at Akron Children’s Hospital collaborate frequently with Dr. Stein and Toledo Children’s Hospital.

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Medical News, Products and Information

Discovery Labs Announces FDA Approval of SURFAXIN® (lucinactant) for Prevention of Respiratory Distress Syndrome

Discovery Laboratories, Inc. (NASDAQ: DSCO), a specialty biotechnology company dedicated to advancing a new standard in respiratory critical care, announced that the United States Food and Drug Administration (FDA) has approved SURFAXIN (lucinactant) for the prevention of Respiratory Distress Syndrome (RDS) in premature infants at high risk for RDS. SURFAXIN is the first synthetic, peptide-containing surfactant approved for use in neonatal medicine. Discovery Labs anticipates that SURFAXIN will be commercially available in the United States in late 2012.

“The approval of SURFAXIN is an important medical advancement for the neonatology community and parents of preterm infants who will soon have an effective alternative to animal-derived surfactants to prevent the development of RDS,” said W. Thomas Amick, Chairman of the Board and CEO of Discovery Labs. “This is a significant milestone in our continuing efforts to develop a pipeline of products to further advance the standard of respiratory critical care.”

RDS is a condition in which premature infants are born with an insufficient amount of pulmonary surfactant, a substance produced naturally in the lungs and essential for breathing. Today, infants with RDS often require animal-derived surfactant replacement therapy along with mechanical ventilation to survive. Approximately 90,000 premature infants in the United States are treated annually with currently available animal-derived surfactants.

SURFAXIN (lucinactant intratracheal suspension) is a synthetic, peptide-containing surfactant. SURFAXIN is indicated for the prevention of respiratory distress syndrome (RDS) in premature infants at high risk for RDS. The safety and efficacy of SURFAXIN for the prevention of RDS in premature infants was demonstrated in a large, multinational phase 3 clinical program that included 1294 patients. Discovery Labs anticipates that SURFAXIN will be commercially available in late 2012.

SURFAXIN (lucinactant intratracheal suspension) is intended for intratracheal use only. The administration of exogenous surfactants, including SURFAXIN, can rapidly affect oxygenation and lung compliance. SURFAXIN should be administered only by clinicians trained and experienced with intubation, ventilator management, and general care of premature infants in a highly supervised clinical setting. Infants receiving SURFAXIN should receive frequent clinical assessments so that oxygen and ventilatory

support can be modified to respond to changes in respiratory status.

Most common adverse reactions associated with the use of SURFAXIN are endotracheal tube reflux, pallor, endotracheal tube obstruction, and need for dose interruption. During SURFAXIN administration, if bradycardia, oxygen desaturation, endotracheal tube reflux, or airway obstruction occurs, administration should be interrupted and the infant's clinical condition assessed and stabilized. SURFAXIN is not indicated for use in Acute Respiratory Distress Syndrome (ARDS).

For more information about SURFAXIN, visit www.surfaxin.com.

Preemies Still Receive Inhaled Nitric Oxide Despite Lack of Supporting Evidence and Standards

Many premature infants throughout the United States continue to receive inhaled nitric oxide (iNO) during their NICU stay, despite the lack of evidence to support its use. Whether or not a preemie will receive iNO treatment, when and for how long, varies greatly throughout the country, as its use in premature infants appears to be unstandardized. These are the findings of a Nationwide Children's Hospital study appearing in the journal *Pediatrics*.

Inhaled nitric oxide (iNO) is a selective pulmonary vasodilator approved for use in term and near-term infants with hypoxic respiratory failure. It has been hypothesized that iNO might help prevent complications of prematurity in infants born less than 34 weeks gestation. However, the National Institutes of Health (NIH) and the Agency for Healthcare Research and Quality (AHRQ) have concluded that there is no evidence to support the routine use of iNO in preterm infants who require respiratory support.

“Despite years of data unable to support its off-label use, iNO treatment in preterm infants remains common in US children's hospital NICUs,” said Michael R. Stenger, MD, Nationwide Children's neonatologist and lead study author. “It's important to determine how iNO is being used in this patient population, as we may need to implement evidence-based standards of care.”

To help characterize variation in recent practice, Nationwide Children's faculty and members of the Ohio Perinatal Research Network (OPRN) performed a retrospective study using the Child Health Corporation of America's Pediatric Health Information Database. The study cohort included 22,699 premature infants born less

than 34 weeks gestation admitted to NICUs in 37 US children's hospitals during a three-and-a-half-year period. Documented care was delivered immediately before the aforementioned NIH and AHRQ statements.

Findings revealed that the use of inhaled nitric oxide in premature infants was variable, even when controlling for demographic characteristics and disease. There was substantial variation in the age of initiation of iNO treatment and the average number of days of use. Hospitals that used iNO in more patients also used iNO for a longer duration. Higher volume NICUs used less iNO and had lower mortality rates. Northeastern hospitals reported less use of iNO. Infants who received iNO were less likely to survive, suggesting that iNO is used in infants already at high risk of death.

“Overall, we found that there is a pervasive lack of standardization in iNO use across NICUs,” said Dr. Stenger. “Adherence to National Institutes of Health consensus guidelines may decrease variation in iNO use.”

Since this study's data are observational, investigators cannot be certain whether or not premature infants benefitted from iNO use. Yet, Dr. Stenger says that the findings suggest that the use of iNO in extremely low birth weight infants with the most severe forms of respiratory failure did not improve mortality rates.

“It is clear that there is a need for adherence to and further development of evidence-based protocols to standardize care to avoid unnecessary and costly treatment,” said Dr. Stenger.

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The Neonatal Expensive Care Unit: Can Physicians Create an Alternative History?

By Dennis T. Costakos, MD

In the 1990's, I was feeling good as I looked around our NICU, and saw patients beating the odds of death and major disability as a result of severe prematurity, infection, congenital anomalies, or just bad "fortuna" for the baby. However, a senior resident in the Mayo Clinic Health System—La Crosse Family Medicine program doing a rotation with me made me realize that there was more to the picture. She said she was looking forward to her rotation in the NICU, but she needed to know why some people called Neonatal Intensive Care Units "Neonatal Expensive Care Units." That expression, Neonatal "Expensive" Care Unit, inspired me to be attentive to true cost savings, and I wanted to look for savings in systems engineering, not just at the bedside where I thought we were already quite efficient, and despite the fact that I realized money spent on neonates divided by the life span of the patient was a bargain compared to intensive care for adult patients. In standard economic approaches, treatments are considered cost-effective if they provide a quality-adjusted life year for less than \$50,000.¹ In neonatology, each quality-adjusted life year costs less than \$10,000, even for infants at the lowest birth weights.²

I took the resident's remark as an honest appraisal of the next generation of physicians, but I remembered too that Dr. John Wennberg made the same point to me and my Dartmouth classmates 10 years earlier (1980's) when he presented scientific work about unwanted variation, and the idea that not only cost matters, but more expensive care is not always better, and that physicians should not ignore these issues.³ I could see that opportunity when I decided to make believe I knew nothing about neonatology, and I was a member of the community board of directors, (interestingly, in 2012, I was elected to the board as physician representative for Mayo Clinic Health System-La Crosse) just observing activities from an eye-in-the-sky across our system. In the Mayo Clinic System there are two Neonatal Intensive Care Units. One unit is in Rochester, Minnesota, and the other in La Crosse, Wisconsin; each has its own neonatal transport

team. These two NICU's are 1.5 hours apart by car ambulance, and closer in travel time by air ambulance. Why not have one team and one set of equipment for both NICU sites? This would not only eliminate the need for duplicate equipment (transport carriers cost \$70,000), but would decrease the number of transport personnel, eliminate call pay and also call hours for people already working full time. The patient's family, physician and medical condition all would help decide the appropriate NICU to use. One well-staffed, highly competent neonatal transfer team would move the baby. This arrangement, worked out with the help of a mirror team of nurses and administrators managed by Dr. William A. Carey, a neonatologist at Mayo Clinic, Rochester for Rochester, and a similar team for our Mayo Clinic Health System—La Crosse site, has allowed a reduction in truly variable costs.⁴

Several years ago, I helped a team that included my partner, Dr. Jose Yuvienco, and Scott Mihalovic of Pharmacy, develop a "local, homegrown" software program for electronic ordering of neonatal total parenteral nutrition, because at the time, such software was not commercially available.⁵ This seemed like something that should be done as a Harvard study published in JAMA reveals that medication errors were common in the inpatient pediatric setting, and that potential adverse drug effects occurred more frequently in neonates, particularly in the NICU.⁶ This software did the calculations to account for arterial line and enteral fluid volumes, as well as calories from enteral nutrition. The software not only improved efficiency, but through a decision support system, helped avoid potentially life-threatening mistakes.⁷ This resulted in less semi-variable healthcare costs when calories and osmolarity calculations suggested no need for TPN.

But why stop at cost savings after babies enter the world? In the early part of this decade, I collected medical and billing data to convince our Obstetrics and Family Medicine colleagues to delay any elective delivery until at least 39 weeks. I compared two periods of time prior to 2006. In time Period 1 (January 2003 to September 2004), I led an education campaign. In Period 2 (October 2004

"Whether at the bedside, or teleconferencing with colleagues, I believe physicians can find opportunities to make an alternative cost history for many parts of the health system."

through December 2005), the relevant elements of the American College of Obstetrics and Gynecology guidelines became standard throughout our practice with the adoption of standardized, evidenced-based care accompanied by monitoring for compliance so that elective deliveries would not occur before 39 weeks or more. The result was a 3% decrease in overall NICU admissions; just by putting this monitoring in place, such that babies born by elective delivery were at least 39 completed weeks by dates. This meant that for term babies that were ill, born by vaginal or operative elective delivery, the average monthly hospital charges decreased by almost 400% in Period 2 as compared to Period 1. In 2006, these results were presented at the program of the Central Association of Obstetricians and Gynecologists, and later confirmed by a multicenter study.^{8,9}

Whether at the bedside or while teleconferencing with colleagues, I believe physicians can find opportunities to make an alternative cost history for many parts of the health system.

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Global Neonatology Today Monthly Column - The Problem of Hyper-Mortality Among Working Age Men in Russia

By Dharmapuri Vidyasagar, MD, FAAP, FCCM

The 2010 National Human Development Report (NHDR) states that while achieving the United Nations Millennium Development Goals #4 and #5 (To Reduce Child Mortality, and To Improve Maternal Health) is important, there is an even more urgent need to improve the health of the Russian working-age male and, hence, this goal deserves a very high priority.

“Achievement of MDGs #4 and #5 cannot be regarded as priority goals for overall healthcare policy in Russia.”

It states, “Achievement of MDGs #4 and #5 cannot be regarded as priority goals for overall healthcare policy in Russia.” The report concludes that the “hyper-mortality among men” has been an unresolved issue since the 1960s. Russian men on the average live 5-10 years less than men in Central Asia, and almost 20 years less than men in Western Europe. The gap has remained for a long time. Thus, the report placed greater emphasis on reduction of “the hyper-mortality among working age group of men than on reduction of MDG #4 and #5 in Russia. The overall life expectancy is considerably lower than European Union (EU) and other Western countries. They expect continuation of current trend beyond 2015 and up to 2020. It may reach the current better levels of life expectancy of Central Asia and the Baltics by 2015, but it will not reach EU levels of life expectancy until 2020.

The report observes that the current measures of successful implementation of health care programmes are largely based on “figures for numbers of people, who receive medical assistance, and on increases of health spending.” They [report authors] recommend that, efficient programmes are ones which have maximum

effect at minimum cost, and effect should be measured by quality of people’s lives and by indicators such as life expectancy. They see the need for strong measures to control and reduce tobacco and alcohol consumption using the model of Northern Europe.

Although the report did not show direct relationship between “hyper-mortality” [*Define as “an extraordinary tendency toward death.”] among working age men, and MMR or IMR, it can be said that the impact of measures to decrease the hyper-mortality of working men in Russia will have measurable impact on their members of their family.

Source: *National Human Development Report in the Russian Federation, 2010; Millennium Development Goals in Russia: Looking into the Future Moscow 2010 - www.undp.ru/nhdr2010/National_Human_Development_Report_in_the_RF_2010_ENG.pdf.*

The 2010 National Human Development Report (NHDR) for the Russian Federation has been prepared by a team of Russian experts and consultants. The analysis and policy recommendations in this report do not necessarily reflect the views of the UN and other institutions by which the experts and consultants are employed. Chief Author: Prof. Sergey N. Bobylev, Dr. Sc. (Economics), Faculty of Economics at Lomonosov Moscow State University; Chapter 5. Reduction of Child Mortality and Better Maternal Care. Health Priorities for Russia Alexey V. Bobrik, PhD (Medicine), Executive Director, Open Health Institute Foundation.

The Clock is Ticking !!!

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