Trends in Anaesthesia and Critical Care 4 (2014) 115–118

Contents lists available at ScienceDirect

Trends in Anaesthesia and Critical Care

journal homepage: www.elsevier.com/locate/tacc

REVIEW

Neurally adjusted ventilatory assist: An update

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Keywords:
Diaphragm electromyographic activity
Respiration
Neurally adjusted ventilatory assist
Weaning

SUMMARY

Neurally adjusted ventilatory assist (NAVA) is a new ventilation mode that provides a proportional assistance to the inspiratory effort of the patients. It is based on the use of the diaphragm electromyographic activity (Edi) for the control of the ventilation assistance. The ability of NAVA to improve the limitations of the conventional assisted ventilator modes has been assessed in clinical studies and discussed in this report, as the latest applications of NAVA in children and non-invasive ventilation, due to the improvement of the patient–ventilator interactions delivered by NAVA. We also review the most recent literature on a new trend to use the Edi as a predictor of weaning success or failure.

1. Introduction

The adverse effects of controlled mechanical ventilation are avoided, at least partially, by assisted ventilation. The new challenge in developing ventilation strategies thus consist of minimizing the risk of lung injury, avoiding disuse atrophy of the diaphragm, and improving the match between the patient's needs and the assistance delivered by the ventilator.[1]

The new ventilation modes provide a proportional assistance to the inspiratory effort of the patients.[2] Amongst these new modes we identify neurally adjusted ventilatory assist (NAVA). It is based on the use of the diaphragm electromyographic activity (Edi) for the control of the ventilation assistance.[3] Edi directly represents the central respiratory drive and reflects the duration and intensity of the patient's neural effort.[4] NAVA provides positive pressure that is proportional and synchronous to the patient's Edi activation.[5] Since its initial description, NAVA has been used for weaning after a period of mechanical ventilation, mainly for the management of long-term ventilated patients, and in chronic obstructive pulmonary disease (COPD) patients.[6]

In this update the latest concerns and topics about NAVA are reviewed. We focus on the latest applications of NAVA, in non-invasive ventilation (NIV) and in children. Furthermore, the Edi signal has led to some very interesting research.

2. What have been reached by NAVA as assisted ventilatory mode?

The most widely used mode of assisted mechanical ventilation is the Pressure Support Ventilation (PSV).[7] PSV applies a predetermined pressure that is independent of the respiratory demand or the gas exchange, limiting this way the variability of the breathing pattern.[8–10] Quite the opposite, with NAVA, the assistance changes between respirations and during each respiratory cycle, the pressures applied are lower during the low Edi signal, and major during the higher Edi signal. The respiratory variability is then much higher with the NAVA mode than with the PSV mode.[11]

Besides, during the PSV the respiratory muscles unload is produced, and it modifies the breathing pattern too. The NAVA mode improves patient–ventilator interactions in two ways. On the one hand, because it optimises the level of effective respiratory muscle unloading during assisted mechanical ventilation.[12–14] On the other hand, the NAVA mode uses a neural trigger, since it is the electromyographic diaphragm signal which drives the ventilator, this is a nearer signal to the genesis of the respiratory central impulse than the pneumatic trigger, and it is very much physiological.

3. The latest applications of NAVA

Due to these advantages, the NAVA mode is being used for the paediatric population ventilation, because of the particular breathing pattern of that population, and in the NIV, because of the neural trigger.

The use of NAVA in paediatric population has been compared with current standard ventilation modes as a primary ventilation

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http://dx.doi.org/10.1016/j.tacc.2014.04.008
2210-8440/

mode in paediatric critical care units. NAVA has been found to be a safe and feasible primary ventilation mode for use in children. It was able to enhance oxygenation even at lower airway pressures and led to the reduced use of sedatives during longer periods of treatment.[15] In concordance with this issue, the feasibility and security of NAVA in terms of the physiological and clinical variables in infants recovering from severe acute respiratory distress syndrome have been studied, and its results deemed safe and suitable in these kinds of patients.[16] When NAVA is compared to pressure control ventilation, neonates ventilated with NAVA have lower peak inspiratory pressures, fraction of inspired oxygen, transcutaneous partial pressure of carbon dioxide, Edi peak and respiratory rate, and better compliance.[17]

Besides, the use of NAVA in the paediatric population has been studied in specific cases, as in congenital central hypoventilation syndrome or in congenital diaphragmatic hernia. NAVA demonstrates the absence of Edi when the patient was in the quiet phase of sleep, and this finding may raise the suspicion of central hypoventilation syndrome that must be confirmed by genetic identification.[18] The respiratory weaning of patients affected by a posterolateral diaphragmatic defect allows the NAVA catheter to obtain a correct Edi signal and develop a viable NAVA ventilation.[19]

Moreover, moving the point of view to nursing, the practical feasibility for nurses working with NAVA and assessing patient comfort and safety when NAVA is initiated has been evaluated. Nurses need to gain experience in placing the NAVA catheter, but NAVA is feasible, and once an accurate Edi signal is achieved, it seems safe and well tolerated in both neonates and children.[20]

There is a trend to use the NAVA mode during NIV, both in the adult and paediatric populations. Non-invasive NAVA provides a truly synchronized mode of NIV, both in the time and level of assist, due to its neural drive. Piquilloud et al. determined that NAVA improved patient-ventilator synchrony during NIV by reducing the trigger delay and the asynchrony index, and avoiding ineffective efforts, and late and premature cyclings.[21] Along with Edi monitoring, NAVA can improve confidence in treating respiratory failure non-invasively.[22] Since asynchrony events are frequent during NIV with PSV in infants and in children, despite adjusting the cycling-off criterion, Vignaux et al. compared NAVA with PSV, showing that NAVA reduces trigger delay and the number of asynchrony events, thus improving patient-ventilator synchrony.[23] This improvement was also observed during NIV for acute respiratory failure and resulted in a similar upgrade in gas exchange.[24] Even in the presence of large air leaks it has been shown that NAVA optimizes patient–ventilator interaction and synchrony, and might therefore be an optimal option for NIV in neonates.[25,26]

The effects of different NAVA levels in non-invasive ventilated patients are not established. Each patient's response is not comparable to another. When examining the match between tidal volume and patients' inspiratory demand (as Edi), it is variable. Globally, the initial NAVA level minus the 50% provides the best matching between Edi and tidal volume, but the NAVA level setting should be patient-specific.[27]

4. What do we know about the diaphragmatic activity during NAVA ventilation?

The Edi is used for the control of the assisted ventilation in the NAVA mode. The Edi is measured with electrodes mounted on a specialized nasogastric tube (Edi catheter) that is placed in the oesophagus at the level of the crura of the diaphragm.[28] NAVA uses the Edi signal as a neural trigger and intrabreath controller to synchronize mechanical ventilator breaths with the patient's respiratory drive.

It was demonstrated that the voluntary crural diaphragm electromyogram (EMG) signal strength is related to global diaphragm activation and is not influenced by changes in the chest wall configuration or lung volume.[29] These results justify the use of the voluntary diaphragm EMG as a monitoring tool to evaluate neural drive to the diaphragm.[14,30] Edi provides objective information about the patient's breathing pattern both when connected to the ventilator and when breathing spontaneously.

To our knowledge, there is not an appropriate and standard method for the diaphragm EMG signal strength normalization. To overcome these problems, different methods have been used: the EMG signal strength obtained at total lung capacity,[31] or during a maximal transdiaphragmatic pressure manoeuvre.[32] Also the data have been normalized to the highest EMG signal strength obtained at any time,[33] or to an involuntarily induced maximal EMG signal strength (100% of the CVF). But these methods are not feasible in daily clinical practice.[4]

Previous studies have not yet established the behaviour of Edi or the use of the NAVA mode during the rapid weaning of postoperative patients without muscle or lung disease. A pilot study describes a simple and feasible weaning protocol in the NAVA mode, by progressively decreasing the NAVA level in steps of 0.5 $\mu V/cmH_2O$. The NAVA level decrements continued to a minimum level of 0.5 $\mu V/cmH_2O$ that was maintained for 20 min, as spontaneous breathing trial (SBT).[34] The Edi during the weaning of healthy lung patients is lower than the one described in respiratory patients. Edi max values were found around 5 μV, and Edi min values less than 1 μV.[35]

Relative diaphragm activation in healthy subjects is 8%, whereas in severe COPD or prior polio infection patients with developed or latent hypercapnia, the relative diaphragm activation is 43% and 45%, respectively, during quiet breathing.[4] In advanced Duchenne muscular dystrophy, and despite the near complete loss of diaphragm force, it is feasible to monitor Edi and it performs the 45% of maximum voluntary activation.[5] Thus, in addition to its role in NAVA ventilation, this technology provides the clinician with previously unavailable and essential information on diaphragm activity, and with a better understanding of the ventilator capacity of patients with acute neuromuscular disease.[36]

Edi has been studied at different situations, in patients with COPD, the diaphragmatic signals were four times stronger than those obtained in healthy patients,[4] likely because patients have to recruit more diaphragmatic fibres to obtain adequate tidal volume, between 6 and 8 ml kg^{-1}. Similarly, Piquilloud et al. described that in patients with COPD and other pulmonary diseases, the Edi amplitude during non-invasive ventilation was higher than in invasive ventilation (33 ± 15 μV).[21] Nevertheless, lower Edi values have been described in patients with acute respiratory distress syndrome requiring extracorporeal membrane oxygenation (9.6 ± 6.7 μV).[37] Bieleń and Sliwiński studied Edi values during exhaustive exercise in COPD patients. They found an increase of about 60% due to the dynamic hyperinflation produced.[38]

In the case of the premature newborn children not ventilated, Stein H and colleagues have obtained Edi max values around 11 μV and Edi min values of approximately 3 μV. Edi increases to obtain the adequate tidal volume of 6–8 ml kg^{-1}.[25]

5. Edi as a predictor tool of a weaning success or failure

The Edi value before weaning has already been studied from different approaches. Nowadays there is a concern about determining its use as a predictor of success or failure in the weaning, due to the crucial importance that its application would be for the overall outcome of the critically ill patient.

The readiness of the patient for weaning is followed by the SBT as a diagnostic test to determine the likelihood of successful extubation.[39] Various weaning predictors derived from breathing pattern analyses