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# Diaphragmatic electromyography analysis during two different mechanical ventilation techniques in patients with neuromuscular diseases

S. Mazzoleni, *Member, IEEE*, G. Vagheggini, L. Buono, E. Panait Vlad, N. Ambrosino, P. Dario, *Fellow, IEEE*

*Abstract*— **The aim of the present study is to analyse changes in the diaphragmatic electromyography integral, as a direct expression of the patients inspiratory effort and index of neural respiratory drive, and parameters associated with ventilatory function in patients with prolonged weaning under Pressure Support Ventilation (PSV) and Neurally Adjusted Ventilatoy Assist (NAVA).**

**Five patients affected by neuromuscular diseases were recruited. Each patient underwent a sequence of decreasing inspiratory support levels under NAVA and PSV, randomly assigned, from a baseline to a final level.**

**At baseline, the value of diaphragmatic electromyography integral was higher under NAVA compared to PSV and increased in both ventilation modes progressing to final level. Higher values of inspiratory time and neural inspiratory time were observed in PSV at final level compared to baseline level. Conversely, a significant decrease of neural inspiratory time from baseline level to final level was observed in NAVA. Tidal volume at final level was significantly lower than at baseline level in both ventilation modes. These preliminary results show that in prolonged weaning patients affected by neuromuscular disease NAVA ventilation is associated to a higher diaphragmatic electromyography activity compared to PSV with same level of ventilation and subjective comfort.**

## I. Introduction

During weaning, the reduction in ventilator support is associated to an increase in patient's effort until the complete amount of work of breathing is sustained by the patient.

In most patients with difficult weaning from MV respiratory muscle force and endurance are insufficient to cope with the increased work associated with spontaneous breathing. According to a recent Task Force, patients with "prolonged weaning" are those failing at least 3 attempts or requiring more than 7 days of weaning from MV after the first spontaneous breathing trial [4]. In patients affected by neuromuscular diseases (NMD), difficult weaning from MV is mainly due to lack of (i) adequate signal generation in the central nervous system, (ii) intact transmission to spinal respiratory motor neurons, respiratory muscles and neuromuscular junctions [4].

Pressure support ventilation (PSV) is one of the most widely used forms of pressure-preset ventilation. During this ventilation mode each inspiratory effort generating an inspiratory airflow beyond the set sensitivity threshold triggers ventilator cycling to the full inspiratory pressure support; this mechanical inspiratory pressure is maintained until the airflow drop below a preset level. Thus a longer or deeper inspiratory effort by the patient results in a larger tidal volume by changing inspiratory time or respiratory system compliance, respectively.

Neurally adjusted ventilatory assist (NAVA) represents a ventilation mode recently developed [5], [6]: a positive pressure during inspiration in proportion to the average electromyographic activity of the diaphragm (EAdi) recorded by a trans-oesophageal electrode array is applied.

EAdi represents the patient inspiratory effort being related to neural respiratory drive. During NAVA the ventilator can be triggered and cycled off by the EAdi signal and the delivered pressurization is proportional to the EAdi [7].

Physiologic response to PSV and NAVA has been evaluated in patients with acute respiratory failure in the Intensive Care Unit [8], [9] in postoperative patients [10], in patients recovering spontaneous breathing after acute respiratory distress syndrome. However the comparison between PSV and NAVA in patients with prolonged weaning has not been carried out so far.

The objective of this article is to analyse changes in the diaphragmatic electromyography integral in patients with prolonged weaning under different support levels in PSV and NAVA assisted ventilation.

## II. Methods

The study was performed in Respiratory Rehabilitation and Weaning Unit at the "Auxilium Vitae" Rehabilitation Centre in Volterra, Italy, according to the principles outlined in the Declaration oh Helsinki.

The local Ethics Committee approved the study and each subject gave an informed consent according to the Italian regulations.

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S. Mazzoleni is with the BioRobotics Institute, Scuola Superiore Sant'Anna, Pisa, Italy and the Laboratory of Rehabilitation Bioengineering, Volterra, Italy (corresponding author, phone: +39050883132; fax: +39050883101; e-mail: s.mazzoleni@sssup.it).

N. Ambrosino, G. Vagheggini and E. Panait Vlad are with the Pulmonary Rehabilitation and Weaning Unit, Auxilium Vitae Rehabilitation Centre, Volterra, Italy and the Laboratory of Rehabilitation Bioengineering, Volterra, Italy (e-mail: nico.ambrosino@gmail.com).

L. Buono is with the Biorobotics Institute, Scuola Superiore Sant'Anna, Pisa, Italy and the Laboratory of Rehabilitation Bioengineering, Volterra, Italy (e-mail: l.buono@sssup.it)

P. Dario is with the BioRobotics Institute, Scuola Superiore Sant'Anna, Pisa, Italy (e-mail: p.dario@sssup.it).

## A. Participants

Five patients (P01-P05) affected by neuromuscular diseases with prolonged weaning were recruited (2 men, 3 women, age 71.8±11.0 years, range 54-82). According to ERS definitions all patients were tracheostomised, awake, mechanically ventilated via tracheostomic canula from more than 7 days 24/24h.

## B. Protocol

All patients were ventilated by means of a Servo-I ventilator (Maquet Critical Care, Solna, Sweden), equipped with the standard commercial version of the NAVA module and software, and able of delivering NAVA and PSV. The EAdi signal was recorded through a 16 French diameter and 125 cm length Edi catheter (Maquet Critical Care, Solna, Sweden) equipped with an electrode array at the distal part. During each ventilation mode airway pressure (Paw), airflow (F) and EAdi signal were acquired at a sample rate of 100 Hz, sent via RS232 interface to a personal computer using a commercially available software (NAVA Tracker, Maquet Critical Care, Solna, Sweden), and stored for subsequent analysis. An offline analysis was carried out using custom software routines developed under Matlab environment (Mathworks, Inc., Natick, MA, USA). Tidal volume ($V_T$), peak EAdi ($EAdi_{peak}$), inspiratory time ($Ti_{Vent}$) and neural inspiratory time ($Ti_{Neur}$), were computed from Paw, F, EAdi signals. An indirect measure of total diaphragmatic effort ($I_{EAdi}$) was computed by time-integration of EAdi signal [11]. Each patient underwent a sequence of decreasing inspiratory support levels under NAVA (2.14 ± 0.46 to 0.22 ± 0.33 $cmH_2O/\mu V$) and PSV (12.00 ± 2.83 to 1.60 ± 2.19 $cmH_2O$), randomly assigned. Baseline level (BL) was defined as the ventilatory support able to prevent clinical signs of respiratory distress (i.e., tachypnoea, tachycardia, oxyhaemoglobin desaturation), and minimize dyspnoea as assessed by a Borg score <2 [12].

During each sequence, positive end expiratory pressure (PEEP = 6.64 ± 1.17 $cmH_2O$) and inspired oxygen fraction ($FiO_2$ = 0.298 ± 0.071) were kept stable. Inspiratory trigger was flow-based under PSV, whereas was EAdi-based under NAVA [9]. In both cases, inspiratory trigger sensitivity was set at the lowest level able to avoid auto-triggering phenomena. Under PSV the expiratory phase started when flow dropped under 70% of the peak inspiratory flow, and under NAVA when EAdi dropped to 70% of $EAdi_{peak}$. The amount of the inspiratory support was reduced in each mode by steps of approximately 15% of BL inspiratory support every approximately 5 minutes. The sequence was stopped when the patient reported moderate-to-severe dyspnoea as assessed by a Borg score ≥6 and/or when signs of respiratory distress appeared. This level of ventilatory support was considered as final level (FL). Signals were recorded continuously; the analysis was carried on the last three minutes of each level (BL, FL). Immediately after the appearance of signs of respiratory distress, BL was restored. The trials in each mode were separated by at least 20 minutes resting period at BL.

## C. Statistical analysis

Different steps within the same ventilator mode were compared using one way repeated measures analysis of variance (ANOVA), and Friedman repeated measures ANOVA on Ranks test in case of failure of normality test. One-way ANOVA, and Kruskal-Wallis One-way ANOVA in case of failure of normality test, was used to compare the same step under NAVA and PSV. The post-hoc pairwise multiple comparison procedure was performed using Holm-Sidak method, and Tukey test in case of failure of normality test.

TABLE I. PATIENT-VENTILATOR INTERACTION

| | BL | FL | p |
|---|---|---|---|
| **$I_{EAdi}$ NAVA [µVs]** | 11.15 ± 6.08 | 15.69 ± 8.69 | < 0.001 |
| **$I_{EAdi}$ PSV [µVs]** | 4.67 ± 0.91 | 11.86 ± 5.29 | < 0.001 |
| **$V_T$ NAVA [ml/kg]** | 3.09 ± 1.65 | 2.27 ± 1.07 | < 0.001 |
| **$V_T$ PSV [ml/kg]** | 3.04 ± 1.27 | 2.32 ± 0.89 | < 0.001 |
| **$Ti_{Vent}$ NAVA [s]** | 0.95 ± 0.17 | 0.94 ± 0.13 | ns |
| **$Ti_{Vent}$ PSV [s]** | 0.72 ± 0.14 | 0.88 ± 0.07 | < 0.001 |
| **$Ti_{Neur}$ NAVA [s]** | 1.35 ± 0.12 | 1.19 ± 0.09 | < 0.05 |
| **$Ti_{Neur}$ PSV [s]** | 0.98 ± 0.08 | 1.02 ± 0.07 | < 0.001 |

Values expressed as mean ± SEM

# III. Results

Table I shows the values of different parameters under PSV and NAVA at BL and FL. The value of $I_{EAdi}$ was higher in NAVA compared to PSV both at BL and FL. The value of this parameter increased from BL to FL in both ventilation modes.

In PSV higher values of $Ti_{Vent}$ and $Ti_{Neur}$ were observed at FL compared to BL. Conversely, a significant decrease of $Ti_{Neur}$ from BL to FL was observed in NAVA. The value of $V_T$ at FL was significantly lower than that observed at BL in both ventilation modes. Figure 1 and Figure 2 show $I_{EAdi}$ and $V_T$ values for each patient, respectively. $Ti_{Vent}$ and $Ti_{Neur}$ for each patient are shown in Figure 3 and Figure 4, respectively.

# IV. Discussion and Conclusions

The preliminary results presented in this study show that in NMD prolonged weaning patients NAVA ventilation is associated to a greater diaphragmatic electromyography activity with same level of ventilation and subjective comfort compared to PSV. Both at BL and FL, NAVA showed better coupling between diaphragmatic and ventilator inspiratory time compared to PSV.

A previous study on a different patients group showed similar changes from BL to FL [13] under both ventilation modes. These results should be confirmed by further studies on larger number of NMD patients due to the important clinical implications. In particular, 1) the relationship between toleration of diaphragmatic effort and patient-ventilator coupling in NAVA and 2) the patients effort related to the ventilator cycling during the two ventilator modes should be investigated in detail.

Moreover, $I_{EAdi}$ analysis during MV may represent a useful tool in NMD prolonged weaning patients to evaluate diaphragmatic functional reserve related to the work of breathing.

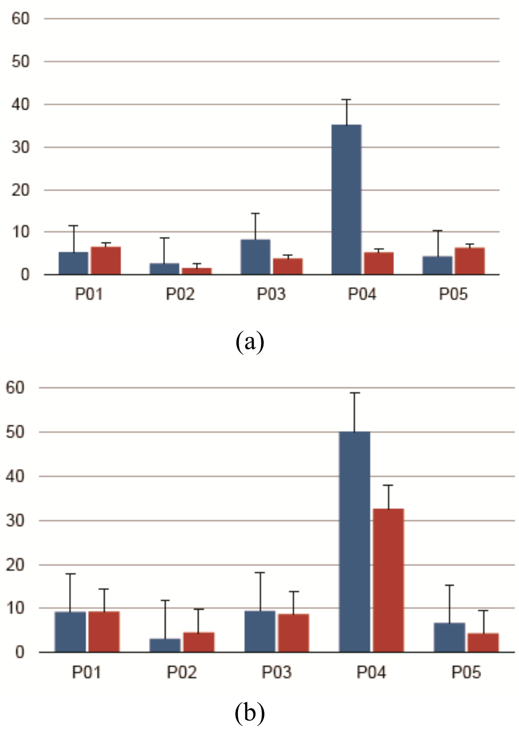


Figure 1. Integration of EAdi signal in NAVA (blue) and PSV (red): (a) BL, (b) FL. Bar values expressed as mean ± standard error.

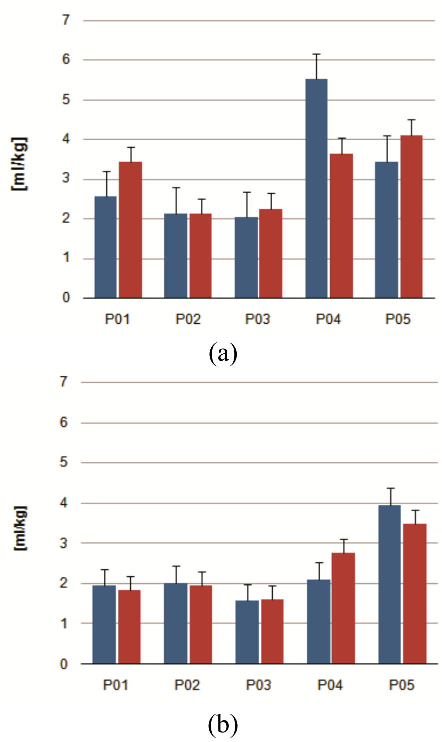


Figure 2. Tidal Volume ($V_T$) in NAVA (blue) and PSV (red): (a) BL, (b) FL. Bar values expressed as mean ± standard error.

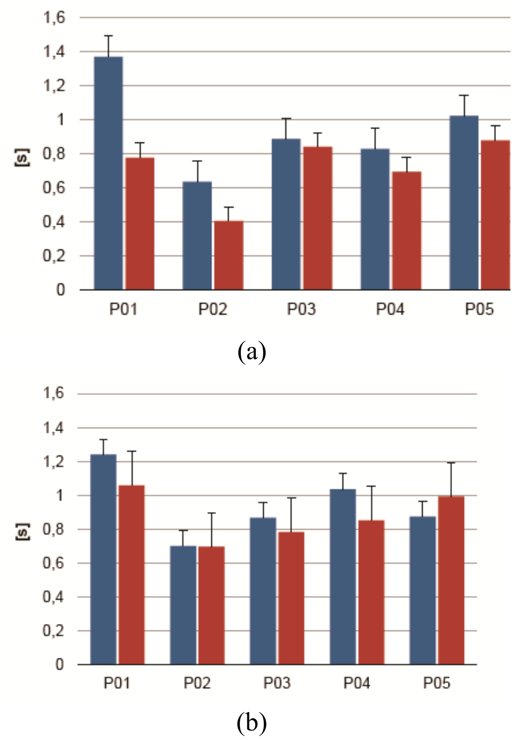


Figure 3. Inspiratory time ($Ti_{Vent}$) in NAVA (blue) and PSV (red): (a) BL, (b) FL. Bar values expressed as mean ± standard error.

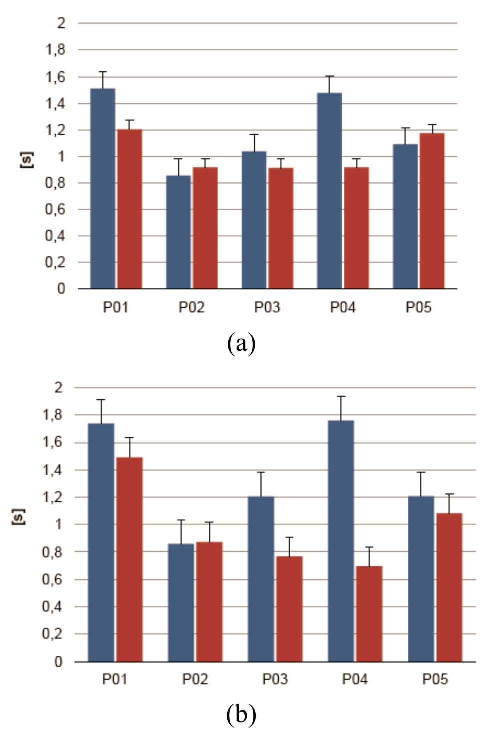


Figure 4. Neural inspiration time ($Ti_{Neur}$) in NAVA (blue) and PSV (red): (a) BL, (b) FL. Bar values expressed as mean ± standard error.

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