Spontaneous breathing pattern parameters correlate poorly with directly measured indices of respiratory muscle workloads for patients with respiratory failure

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INTRODUCTION

- Spontaneous breathing pattern parameters, breathing frequency (**f**), tidal volume ($\mathbf{V_T}$), minute ventilation (**MV**), and the index of rapid shallow breathing ($\mathbf{f / V_T}$), are commonly used for inferring respiratory muscle workloads when deciding on a level of pressure support ventilation (**PSV**) to unload the respiratory muscles of patients with acute respiratory failure.
- Conflicting reports in the literature concerning the validity of this approach exist. In some studies, poor relationships between **f**, $\mathbf{V_T}$, $\mathbf{f / V_T}$ and measured work of breathing (**WOB**) are apparent. [1, 2] Others contend that spontaneous breathing pattern parameters are always appropriate for assessing whether respiratory muscle workloads are in a fatiguing or tolerable range when using PSV. [3, 4]

RESEARCH HYPOTHESIS

- It is unclear whether the aforementioned spontaneous breathing pattern parameters always correlate with directly measured indices of respiratory muscle workloads for patients with respiratory failure treated with PSV.
- We hypothesize that at times, spontaneous breathing pattern may or may not correlate with directly measured indices of respiratory muscle workloads.

METHODS

- IRB informed consent was obtained on 16 intubated adults (age: 69 ± 10 yrs, weight: 80 ± 9 kg, 13 males, 3 females) diagnosed with acute respiratory failure receiving intermittent mandatory ventilation (range 2 - 4/min), PSV (range 5 - 30 cm H_2O), and positive end expiratory pressure (range 5 - 20 cm H_2O).
- A nasogastric (**NG**) tube with an incorporated esophageal balloon was inserted (occlusion test verifying placement) to measure intraesophageal pressure (**Pes**) and the **esophageal pressure**-time product (**PTP**) as the area within the change in Pes over time during spontaneous inhalation.
- A combined pressure/flow sensor, positioned between the ventilator Y-piece and endotracheal tube, measured **f** and $\mathbf{V_T}$, and thus **MV**.
- These data, directed to a monitor (Novametrix-Respironics) and computer/software (NeuroDimension), were used to measure **WOB** using the Campbell diagram [2] (**Fig. 1**).
- Power of breathing (**POB**) was measured as the **WOB** averaged over one minute. The average recording time per patient was 6.5 hours.
- Decisions by the medical staff to vary **PSV** were based on using **f**, $\mathbf{V_T}$ and $\mathbf{f / V_T}$ data as well as the presence or absence of sternocleidomastoid muscle contraction.
- The medical staff was blinded to the measured indices of respiratory muscle workloads, i. e., **PTP**, **WOB**, and **POB**.
- Data were analyzed using regression analysis; alpha was set at 0.05 for statistical significance.

RESULTS

- *Weak correlation coefficients* **(r)** were found for all breathing pattern parameters and measured indices of respiratory muscle workloads (**Fig. 2**)

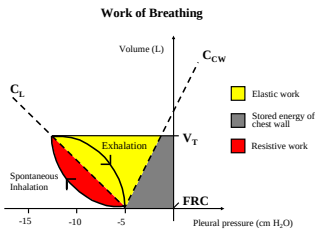

Figure 1. Campbell diagram used for measuring the work of breathing (WOB) is shown. Tidal volume (V_T) is plotted on the vertical axis and pleural pressure (measured indirectly using intraesophageal pressure) is plotted on the horizontal axis. For this example, during spontaneous inhalation, as pleural pressure decreases from minus 5 to minus 12 cm H_2O, V_T increases. During exhalation, as V_T comes out of the lungs, pleural pressure gradually returns back to minus 5 cm H_2O. These changes in pressure and volume form a pressure-volume loop moving in a clockwise direction, the slope of which is lung compliance (C_L). Chest wall compliance (C_{CW}) is obtained previously by mechanically ventilating a relaxed patient. Under these conditions, the pressure-volume loop moves in a counterclockwise direction (not shown); the slope of the loop is C_{CW}. Total resistive work to overcome the series resistance of the endotracheal tube and physiologic airways is the lower half of the pressure-volume loop (area in white). Physiologic elastic work to expand the respiratory system is the triangular shaped area subtended by the C_L and C_{CW} lines (lightly shaded area). Total WOB equals total resistive work plus elastic work.

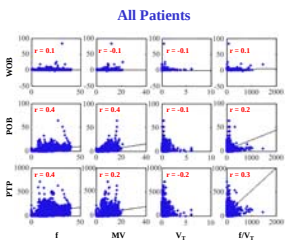

Figure 2. Relationships for directly measured indices of respiratory muscle workloads; work of breathing (WOB), power of breathing (POB), and pressure-time product (PTP), are plotted on the vertical axes over spontaneous breathing pattern parameters plotted on the horizontal axes; breathing frequency (f), minute ventilation (MV), tidal volume (V_T), and the index of rapid shallow breathing (f / V_T). As indicated by the weak correlation coefficients (r), there were no significant relationships for any of the indices of respiratory muscle workloads and spontaneous breathing pattern parameters.

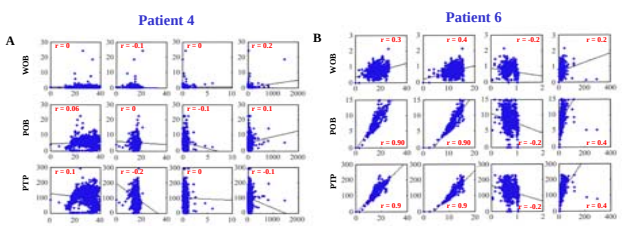

Figure 3. Examples of two patients are shown. For the patient in panel "**A**," weak relationships between directly measured indices of respiratory muscle workloads and spontaneous breathing pattern parameters were observed. *Almost all patients responded in this manner.* For the patient in panel "**B**," strong, positive relationships were observed for some indices of respiratory muscle workloads and spontaneous breathing pattern parameters (note correlation between POB and f, POB and MV, PTP and f, and PTP and MV).

DISCUSSION

- For a few patients, at times, some breathing pattern parameters correlated appropriately with WOB, POB, and PTP (**Fig. 3 B**).
- However, for most patients, most of the time, *breathing pattern parameters correlated poorly with WOB, POB, and PTP.* (**Figs. 2** and **3 A**).
- Some patients had an acceptable breathing pattern while breathing with a fatiguing workload (increased **WOB**, **POB**, **PTP**); others demonstrated an increased **f** and decreased $\mathbf{V_T}$ while breathing with a tolerable to normal measured workload (**Fig. 4**).
- Although indicated, withholding increases in **PSV** for those with an acceptable breathing pattern, but with a fatiguing workload risks respiratory muscle fatigue, while increasing **PSV** for those with increased **f**, decreased $\mathbf{V_T}$, and a low workload unloads the respiratory muscles too much predisposing to disuse respiratory muscle atrophy.
- Both of these scenarios may prolong ventilatory support longer than necessary. [1]
- We conclude **clinicians may be misled using the breathing pattern alone** as an inference of respiratory muscle workloads when setting PSV.
- These findings may explain, in part, why some patients receive ventilatory support for too long a period.
- It may be prudent to consider using a better method for determining an appropriate level of PSV, i. e., directly measured indices of respiratory muscle workloads like POB or PTP.

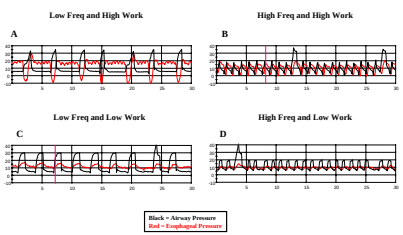

Figure 4. In panel "**A**" the patient had a spontaneous breathing frequency (f) of 14 per min, tidal volume (V_T) 0.42 L, and a measured work of breathing (WOB) of 1.85 Joule / L (normal adult range 0.3 – 0.7 Joule / L). Note the large decreases in intraesophageal pressure (red) during inhalation, indicative of an increased, fatiguing WOB. A different patient in panel "**B**" had an f of 42 per min, V_T 0.25 L, and WOB 1.3 Joule /L (the higher peak pressures at about 40 cm H_2O are intermittent mandatory ventilation breaths). Another patient in panel "**C**" demonstrated an f of 15 per min, V_T 0.66 L, and WOB 0.05 Joule / L. Still another patient in panel "**D**" demonstrated an f of 38 per min, V_T 0.48 L, and WOB 0.22 Joule / L. For patient "**A**" it would have been appropriate to increase pressure support ventilation (PSV) to unload the respiratory muscles, however, because of the acceptable breathing pattern this was not done – *this scenario predisposes to respiratory muscle fatigue*. Conversely, for patient "**D**" because of increased f , PSV was increased from 10 to 15 cm H_2O even though WOB was negligible – *this scenario predisposes to disuse respiratory muscle atrophy*. For patients "**B**" and "**C**" the PSV levels were appropriately increased and decreased, respectively.

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