Patient ventilator interaction: CNS

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Disclosure: Dr. Sinderby has made inventions related to neural control of mechanical ventilation that are patented. The license for these patents belongs to Maquet Critical Care. Use of this technology provides financial benefit to Dr. Sinderby through royalties. Dr Sinderby owns 50% of Neurovent Research Inc (NVR). NVR is a research and development company that builds the equipment and catheters for research studies. NVR has a consulting agreement with Maquet Critical Care.
Conflict of interest

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Attention!

The following presentation contain strong graphical presentations including:

– Fluctuating tidal volumes
– Poor patient-ventilator interaction
– Neurally Adjusted Ventilatory Assist (NAVA)
– Diaphragm Electrical Activity (EAdi)

Viewer discretion is advised.
Prevalence of asynchrony with pneumatic control

25% severe asynchrony

Patient-ventilator asynchrony during assisted mechanical ventilation

<table>
<thead>
<tr>
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<th>Asynchrony index &lt; 10% (n = 47)</th>
<th>Asynchrony index ≥ 10% (n = 15)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration of mechanical ventilation (days; IQR)</td>
<td>7 (3–20)</td>
<td>25 (9–42)</td>
<td>0.005</td>
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</tbody>
</table>
Where it all started!

Use of a Patient-triggered Intermittent Positive-pressure Respirator in Respiratory Paralysis

N. P. S. GUNARATNA,* M.B., B.S., D.C.H.


However, in partial respiratory paralysis, when the patient requires only assistance to spontaneous respiratory efforts, the problem of providing this assistance in synchrony with the patient’s own efforts is considerable. Such patients tend to breathe against the rhythm of the respirator and increase their respiratory distress, necessitating sedation or curarization procedures which are not always desirable. The problem was overcome by the use of a patient-triggered respirator in treating two patients at the Western Hospital recently.
Efficacy of ventilator waveforms observation in detecting patient–ventilator asynchrony

Davide Colombo, MD, PhD; Gianmaria Cammarota, MD; Moreno Alemani, MD; Luca Carenzo, MD; Federico Barra, MD; Rosanna Vaschetto, MD, PhD; Arthur S. Slutsky, MD; Francesco Della Corte, MD; Paolo Navalesi, MD

Conclusions: The ability of intensive care unit physicians to recognize patient–ventilator asynchronies was overall quite low and decreased at higher prevalence; expertise significantly increased sensitivity for breath-by-breath analysis, whereas it only produced a trend toward improvement for report analysis. (Crit Care Med 2011; 39:000–000)
Patient ventilator interaction - CNS

- Mechanical ventilation
  - Synchronized assist (inspiratory muscle support)
  - Asynchronous assist (increased work or passive ventilation)
  - Dys-synchronous assist (mix of above)

- Non-mechanical ventilation
  - Sedation/analgesia (reduced impact of respiratory stimulus)
  - $\text{CO}_2$ removal (reduced respiratory stimulus)
Role of CNS

Sinderby & Beck, Neurally Adjusted Ventilatory Assist in Principles and Practice of Mechanical Ventilation, Third Edition
Editor: Tobin MJ, McGraw-Hill Medical 2013
Time and frequency plot of the discharge of motor units in human inspiratory pump muscles

The firing time for each single motor unit recorded during quiet breathing, relative to the time of inspiration.

Thick horizontal line represents the time that the firing frequency increases in the inspiratory or expiratory phase of respiration. Thin horizontal line indicates tonic firing of the motor unit at other times. The units are ordered relative to their onset time.

The colour of the thick horizontal line denotes the peak firing frequency.
Definition of quantum in English

noun (plural quanta)

• **Physics** a discrete quantity of energy proportional in magnitude to the frequency of the radiation it represents.
• an analogous discrete amount of any other physical quantity, such as momentum or electric charge.

• **Physiology** the unit quantity of acetylcholine released at a neuromuscular junction by a single synaptic vesicle, contributing a discrete small voltage to the measured end-plate potential.
Quantum vs. Newtonian Physiology

- Motor-neurons and -units are activating inspiratory muscles in quanta not following any linear rules!

- Conventional mechanical ventilators deliver assist in targeted linear fashion!
PCV, PSV, NAVA

• PCV (conventional)
  – Pneumatic and/or timed trigger and timed cycling-off with fixed assist

• PSV (conventional)
  – Pneumatic trigger and cycling-off with fixed assist

• NAVA (neural)
  – Neurally controlled trigger, cycling-off and assist
PSV in COPD
NAVA in COPD
Patient ventilator interaction - CNS

PSV overriding the Hering Breuer inspiratory inhibiting reflex (off-switch)
NAVA vs. PSV response to increasing assist

Sinderby & Beck, Neurally Adjusted Ventilatory Assist in Principles and Practice of Mechanical Ventilation, Third Edition
Editor: Tobin MJ, McGraw-Hill Medical 2013
Adapted from Colombo et al Crit Care Med 2011
Increasing PSV on VT at $EAdi_{\text{peak}}$
Patient ventilator interaction - CNS

Effect of applied inspiratory rate
Increasing mandatory flow rate increases breathing frequency
Patient ventilator interaction - CNS

PEEP on the Hering Breuer inspiration/deflation inhibiting reflexes
Influence of neurally adjusted ventilatory assist and positive end-expiratory pressure on breathing pattern in rabbits with acute lung injury

Jean-Christophe Allo, MD; Jennifer C. Beck, PhD; Lukas Brander, MD; Fabrice Brunet, MD; Arthur S. Slutsky, MD; Christer A. Sinderby, PhD

Crit Care Med 2006
Research

Short-term effects of positive end-expiratory pressure on breathing pattern: an interventional study in adult intensive care patients

Christoph Haberthür and Josef Guttmann
Patient ventilator interaction - CNS

Effect of sedation on PSV & NAVA
Effects of Propofol on Patient-Ventilator Synchrony and Interaction During Pressure Support Ventilation and Neurally Adjusted Ventilatory Assist

Rosanna Vaschetto, MD, PhD; Gianmaria Cammarota, MD, PhD; Davide Colombo, MD, PhD; Federico Longhini, MD; Francesca Grossi, MD; Andrea Giovannillo, MD; Francesco Della Corte, MD; Paolo Navalesi, MD

CCM 2013
Patient ventilator interaction - CNS

Effect of excessive assist/ventilation/sedation on PSV & NAVA
Excessive assist:
Pressure support ventilation causes apnea which cannot be detected without EAdi
Excessive assist during NAVA
Synchrony causes irregular breathing pattern - apnea is detected

Respiratory pattern during neurally adjusted ventilatory assist in acute respiratory failure patients

- Flow (l/s)
- Paw (cmH₂O)
- Vt (ml)
- EAdi (μV)

Time (s)
Patient ventilator interaction - CNS

Non-invasive ventilation

Influence of upper airways:
A complex crossroad of airway and food pathways
Upper airway - diaphragm synchrony

Courtesy of Dr Leo Heunks, UMC St Radboud, Nijmegen, Netherlands
Patient ventilator interaction - CNS

- Delayed trigger/occl. (Load ↑, EAdi ↑, Ti ↑)
- Delayed off-cycling (Te ↑, Fb ↓)
- ↑ Flow (Fb ↑)
- ↑ Vt (Fb ↓)  (paradox!)
- ↑ Synchronized assist (EAdi ↓, Pes ↓)
- ↑ Ventilation (EAdi ↓, Pes ↓)
- ↑ Propofol (EAdi ↓, Pes ↓)
- ↓ PaCO₂ (EAdi ↓, Pes ↓)
Conclusion

• To deliver synchronized assist to a system - as complex as the respiratory system - one needs neural integration

• To control the respiratory system, i.e. to impose dys/a-synchrony, one needs to know purpose and reflexes to influence: this requires bed-side information about responses in neural respiratory timing and drive
Where does the squared wave of pressure fit in?

Kundalini Yoga Breathing Technique: “Yoga Breath Of Fire”
Thank You

VentQuest.ca
Effect of ventilatory mode and patient-ventilator interaction in ARDS
ARDS P/F 143

PCV

PSV

NAVA

60 s

10 s
ARDS P/F 75

PCV

PSV

NAVA

60 s

10 s
ARDS P/F 175

PCV

PSV

NAVA

60 s

10 s
ARDS P/F 177

PCV

PSV

NAVA

60 s

10 s