Agenda:

- Describe ventilator-induced diaphragmatic dysfunction
- Discuss asynchrony, wasted efforts and the importance of synchrony
- Neurally Adjusted Ventilatory Assist (NAVA)
- NAVA as a monitoring tool — Edi signal
- NAVA as a mode of ventilation
- Potential benefits of NAVA
**Neural Respiratory Rate**

Respiratory Control Systems

- **Neural Control System**: Involuntary/Voluntary
- **Chemical Control (Receptors)**: \( \text{O}_2, \text{CO}_2, \text{H}^+, \text{Temperature} \)

Closed Loop between afferent/efferent feedback

**Mechanical Ventilation**

Ventilatory Pump = Diaphragm/Accessory Muscles

- Mechanical ventilation supports or replaces the physiologic ventilatory pump to maintain homeostatic levels of \( \text{PO}_2 \) and \( \text{PCO}_2 \)
PATIENT-VENTILATOR INTERACTION

- Triggering (onset of inspiration)
  - Pressure
  - Flow

- Inspiration
  - Inspiratory time
  - Rise time

- Expiration
  - Breath cycle (for mandatory breaths)
  - Cycle off percentage (for spontaneous breaths)

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IDEAL TECHNOLOGY VS. CURRENT TECHNOLOGY

Central nervous system
Phrenic nerve
Diaphragm excitation
Diaphragm contraction
Chest wall, lung and esophageal response
Airway flow, pressure and volume changes

Pneumatic Triggering Modes
Flow and Pressure

Current Technology

Ventilator
THE PROBLEM OF PATIENT-VENTILATOR INTERACTION

Ventilator pump

Patient's ventilatory pump

WHAT IS THE USUAL SOLUTION TO PATIENT-VENTILATOR DYSSYNCHRONY?

- Fine tune ventilator settings
- Sedation
- Neuromuscular blockers
- What is the biggest problem with this approach?

Ventilator Induced Diaphragm Dysfunction Atrophy
“Loss of diaphragmatic force generating capacity that is specifically related to the use of mechanical ventilation”


Do wasted efforts contribute to VIDD?

Eccentric contractions:
- During wasted efforts, inspiratory muscles perform eccentric contractions (the muscle lengthens while it contracts)

Concentric contractions:
- Bicep picking up a weight (normal shortening) — if load is too high the muscle lengthens because of increased load
- Eccentric contractions are injurious for the muscle (remember muscle soreness after exercise)
A CLOSER LOOK: DAMAGE FROM ECCENTRIC MUSCLE CONTRACTION
Would monitoring the diaphragm help?

Source: Georgopoulos D
The combination of 18 to 69 hours of complete diaphragmatic inactivity and mechanical ventilation results in marked atrophy of human diaphragm myofibers. These findings are consistent with increased diaphragmatic proteolysis during inactivity.

- Greater than 50% of cross sectional area of the muscle fiber (53% fast twitch [breathing]) and 57% slow twitch (coughing).


**WHAT IS SYNCHRONY?**

- Synchrony is a simultaneous occurrence or motion
- Occurrence at the same time or movement at the same rate

*Do you have asynchrony during quiet breathing?*
POOR TIMING: ASYNCHRONY DURING SIMV (INFANTS)

Figure 4. Patient-ventilator interaction during mandatory breaths. Schematic representation of patient neural timing (upper bar) and ventilator timing (middle bar) during mandatory breaths. Upper bar, neural Ti (gray area) and neural Te (white) for the group data are presented. Middle bar, periods describing ventilator timing are displayed, including trigger delay and ventilator Ti, trigger Te, periods of infant-ventilator synchrony (white) and asynchrony (black).


PATIENT-VENTILATOR ASYNCHRONY DURING ASSISTED MECHANICAL VENTILATION

Conclusions: One-fourth of patients exhibit a high incidence of asynchrony during assisted ventilation. Such a high incidence is associated with a prolonged duration of mechanical ventilation. Patients with frequent ineffective triggering may receive excessive levels of ventilatory support.

Ineffective triggering and double triggering were the two main patterns of asynchrony.

Asynchrony was present in both ACV and PSV — higher incidence during ACV but both demonstrated equal ineffective triggering.

Causes of Ineffective triggering:
- Less sensitive inspiratory trigger
- Higher pressure support
- Higher Vt
- Auto Peep

WE HAVE A NEW GRAPHIC IN PULMONARY CRITICAL CARE

Edi Signal

WHAT IS THE EDI?

- Monitoring tool for the neural respiratory rate
  - “The earliest signal that can be achieved with low level of invasiveness is the diaphragm Edi”
  - “This signal is proportional to the integrated output of the respiratory center and thus controls depth and cycling of breathing”

COMPONENTS OF THE EDI SIGNAL

- **Edi peak:**
  - Displays the amount of impulse sent to generate tidal volume breath by breath

- **Edi min:**
  - Measures the tonic contractility of the diaphragm at rest — potential physiologic reflection of FRC

CONVENTIONAL SETTINGS AND NAVA SETTINGS

**Conventional:**
- I Time or Peak Flow
- Rate
- Volume/Pressure
- PEEP
- Pressure Support (spont.)
- FIO₂
- Cycle off

**NAVA:**
- Edi Trigger (microvolts)
- NAVA Level
  - cmH₂O / microvolt
- PEEP
- FIO₂
Improved synchrony when starting a breath and ending a breath — airway pressure increases and decreases proportionally to the Electrical Activity of the diaphragm.
The catheter comes in a variety of sizes and designed for a 500 gm infant up to adult

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Surfactant deficiency and compliant chest wall lends itself to the tendency to de-recruit

- Strong vagal reflexes
-Leaks common during conventional ventilation with intubation (uncuffed tubes)
-Leaks cause hyperinflation
-Leaks cause increased WOB due to larger trigger threshold and increased expiratory asynchrony (cycle off)
-Apnea of prematurity

"Maggie" 500 g at birth (image used with permission of parents)
INCREASING TONIC EADI BY REMOVAL OF PEEP


ADAPTATION TO NEURAL DRIVE

- Pressure support has a linear pressure delivery regardless of the neural drive
- Can cause dynamic hyperinflation and increased injury to the lung
- NAVA allows the patient’s own neural efforts to dictate the level of assist that the patient receives

- Diagnosis of central apnea/obstructive apnea
- Diagnosis of respiratory pattern (Biots, Cheyne Stoke, Kussmaul)
- Titration of caffeine based on Edi
- Enhancement of conventional settings
- Monitoring bronchodilator effectiveness (decreasing Edi signal)
- Sedation titration
- Vasoactive titration (spontaneous breathing enhancing V/Q matching)
INAPPROPRIATE TIME PATIENT EFFORT DURING INSPIRATORY PHASE

IMPRESS SYNCHRONY WITH CONVENTIONAL SETTINGS
NAVA MODE

PATIENT-VENTILATOR INTERACTION (810 G)

Asynchrony? Synchrony
STARTING POINT NAVA LEVEL 2.0

NAVA LEVEL 1.0
• All of benefits of synchronized spontaneous breathing with less sedation
  • Neural trigger
  • Pressure delivery in relation to patient’s Edi signal
  • Neurally cycle off
  • Objective measurement of patient workload
• Better monitoring for crucial bedside decisions for your critically ill patients
  • Objective measurements of patient changes real time

What we know so far:
• Improves patient ventilator synchrony (less sedation)
• Allows on-line monitoring of respiratory drive
• May provide protective ventilation based on vagal reflexes
• Adapts to patient altered respiratory drive and reflexes

Potential uses:
• May provide efficient respiratory muscle unloading even at high levels of assist (Edi monitoring)
• May help prevent disuse atrophy of the diaphragm
• Potential for more efficient delivery of NIV
• Potential diagnostic capabilities (e.g. apnea / differential diagnosis)
ADULT CASE STUDY
- 65 Year-old female

VOLUME CONTROL (AC) WITH POSSIBLE MISSED TRIGGERS DUE TO EARLY SMALL AIRWAY COLLAPSE AND AUTO-PEEP

? Missed trigger?
Early sm airway collapse
PATIENT SWITCHED TO PS AND EDI INCREASED

OVERLAYING
SEVERAL MISSED TRIGGERS IN PSV

MORE SLIDES OF PSV WITH EDI MONITORING
EVEN WHEN TRIGGER ASYNCHRONY IS IMPROVED
THE PSV BREATHS ARE LATE

PLACED ON NAVA MODE

Auto-PEEP
TOTAL SYNCYRONY

NICU CASE STUDY
- 26 week, 28 days old
MAQUET
GETINGE GROUP

ON NIV NAVA ON X 30 MIN

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