Asynchronous Ventilation – Causes and Solutions!

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Potential Conflicts of Interest

- Received research grants from Hamilton
- Received honorarium for lecturing from Maquet and Hamilton
- Consultant for Newport, Bayer and KCI

Patient – Ventilator Interaction

- Minimal effort to trigger breath
- Initial peak flow > 80 L/min
- Inspiratory time consistent with patient neuro-inspiratory time
- Termination of inspiration coincides with patient desire to begin exhalation
- Avoid the development, minimize the level and offset the effect of auto-PEEP
Inspiratory Time

- In spontaneous breathing patients, ventilator inspiratory time should equal patient desired inspiratory time.
- Spontaneous breathing - inspiratory time ≤ 1.0 seconds.
- Patients with high ventilatory demand, inspiratory time maybe as short as 0.5 seconds.
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- 20 pts with ARDS volume ventilation 6 ml/kg,
- Richman agitation scale averaged 4
- 2.3+3.5 times/minute
- Median tidal volume 10.1 (8.8 – 10.7) ml/kg PBW
- Required smaller VT 7 to 8 ml/kg PBW or sedation

POHLMAN CCM 2008;36:3015
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PSV: Termination of Inspiration

- Primary: Patients Inspir Flow Decreases to a Predetermined Level
  - 25%, 5 LPM or 5% of Peak Flow
  - Newer ventilators 5% to 85%
- Secondary: End Inspir Pressure exceeds Target Level
- Tertiary: Lengthy Inspir Time (2 to 3 Sec)

Hess RC 2005:50:166
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Auto-PEEP – Work of Breathing

- Alveolar Pressure: +10 cmH₂O
- Airway Pressure: 0 cmH₂O
- Trigger Pressure: -2 cmH₂O
- Patient Pressure change: -12 cmH₂O

needed to trigger

PEEP Application

Gottfried SB. Ventilatory Failure (Spring-Verlag), 1991

Fabey Chest 1995;107:1387
**PEEP – Assisted Ventilation COPD**

- If auto-PEEP measured, set PEEP at 80% of measured level
- If auto-PEEP unmeasured, set PEEP at 5 cmH₂O
- If untriggered breathes still present, increase PEEP in 1 to 2 cmH₂O steps until patient rate and ventilator response are equal

**Inappropriate PSV or PA/C Level**

- To low a pressure level increases patient demand increasing patient work
- To high a level causes dysynchrony: forced exhalation, air trapping and increased ventilatory demand
- Frequently, decreasing PSV or PA/C level may be the correct choice

**Thille ICM 2008;34:1477**

- 12 pts with > 10% ineffective triggering with PS
- Reducing PS from 20 to 13 cm H₂O decreased VT from 10.2 ml/kg to 5.9 ml/kg PBW and eliminated ineffective triggering
- No change in RR 25.6 to 29.4/min, patient effort or PaCO₂
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Thille ICM 2008;34:1477

- 62 consecutive pts, MV > 24 hrs, 11 VA/C, 51 PS
- Median episodes/pt VA/C 72 (13-215), PS 16 (4-47)/30 minute period, p=0.04
- A higher incidence of asynchrony was associated with a longer period of MV 25.5 vs. 7.5 days

Thille ICM 2006;32:1515

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De Wit CCM 2009;37:2740

- 60 consecutive pts, MV > 24 hrs, 10 min during the 1st 24 hours were analyzed
- 16 patients an asynchrony index >10%
- AI >10% predicted longer LOS (21 vs. 8 days p < 0.03)

PAV

- PAV based on the Equation of Motion
- Increases or decreases ventilatory support in proportion to patient effort, airway pressure
- Similar in concept to Power Steering
- Tracks changes in patient effort and adjusts ventilator output to reduce work
- Introduced by Magdy Younes in 1992

Younes M, ARRD 1992;145:121
Equation of Motion for the Respiratory System

\[ \text{Paw} + \text{Pmus} = K_1(V' \times R) + K_2(\Delta V \times E) \]

NAVA

- Based on diaphragmatic electrical activity (Edi)
- Increases or decreases ventilatory support (pressure) based on changes in Edi
- Similar in concept to **Power Steering**
- Tracks changes in Edi and adjusts ventilator output in response to Edi
- Introduced by Christer Sinderby in 1999
  
  Sinderby Nature Med 1999;5:1433
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PAV and NAVA

- PAV – Works by responding to the mechanical output of the diaphragm and accessory muscles of inspiration
- NAVA – Works by responding to the neural input to the diaphragm
- Both – Improve patient-ventilator synchrony, even in the presence of changing ventilatory demand

Sinderby Nature Med 1999;5:1433

Younes ARRD 1992;145:114
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Younes M. AARD 1992;145:121

Sinderby Nature Med 1999;5:1433

Patrick JAP 1996;80:397
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PAV versus PSV

- PAV preserved the ability of patients to modulate $V_T$ in response to hypercapnia and changes in lung mechanics
- Changes in $V_E$ - PSV RR changes, PAV VT and/or RR change
- Increasing $V_E$ during PSV results in greater muscle effort and greater patient discomfort than PAV (Kondili only)

- Ranieri JAP 1996;81:426
- Grasso AJRCCM 2000;161:819
- Kondili ICM 2006;32:692

Xirouchaki ICM 2008;34:2026

- PAV vs. PSV in critically ill patients for 48 hrs
- On controlled ventilation > 36 hours
- Ability to trigger vent, minute volume > 10/min
- $\text{PaO}_2 > 60, \text{FiO}_2 < 0.65$, total PEEP < 15 cmH$_2$O
- pH > 7.30
- No severe hemodynamic instability
- No severe bronchospasm
- No severe neurologic impairment
- Failure rate 11% PAV vs. 22% PSV, $p = 0.04$
- Proportion of patients exhibiting pt-vent dysynchrony 5.6% PAV vs. 29% PSV, $p < 0.001$
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**Bosma CCM 2007;35:1048**
- PSV vs. PAV during sleep, cross over study one night each mode, randomly applied
- Both set to decrease inspiratory WOB 50%
- MV and V$_T$ lower and CO$_2$ greater PAV
- Arousals/hr 16 (2-74) vs. 9 (1-41) p < 0.02
- Overall sleep quality better PAV p < 0.05
  - Awakenings/hr 5.5 (1-24) vs. 3.5 (0-24)
  - Rapid eye movement 4% (90-23) vs. 9% (90-31)
  - Slow wave sleep 1% (0-10) vs. 3% (0-16)
- Asynchronies/hr 53±59 vs. 24±15 p < 0.02

**Proportional Assist Ventilation**
- Requires patients have an intact ventilatory drive!
- Requires ongoing assessment of lung mechanics!
- Unable however to deal with auto-PEEP
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Colombo ICM 2008;34:2010
- 14 intubated MV adults
- PSV $V_T$ 6-8 ml/kg vs. NAVA matched to PSV
- Both modes increased and decreased 50%
- No ABG differences.
- Little difference among all measurements at the two lower assist levels
- At highest level $V_T$ was higher (9.1 vs. 7.2 ml/kg), RR lower (12 vs. 18/min) and Peak EAdi higher 8.6 vs. 12.3 (all p < 0.05) in PSV
- No serious adverse events

Brander Chest 2009;135:695
- 15 adults with PaO$_2$/FiO$_2$ < 300 mmHg
- Systemically adjust NAVA levels evaluating the effect on various respiratory variables.
- Compared to conventional ventilation NAVA resulted in:
  - Lower tidal volume
  - More rapid RR
  - Lower PIP
- Systemically increasing NAVA level
  - Reduces respiratory Drive
  - Unloads respiratory muscles

Beck Pediatric Research 2009;65:663
- 7 Infants, 936 gms,
- Patient ventilator synchrony during noninvasive and invasive ventilation with NAVA vs. PA/C for 30 min.
- Pressure delivered during PA/C was not correlated with EAdi. Neural inspiratory time was longer and RR lower with NAVA and cycle off delay was shorter with NAVA than PA/C (p < 0.05)
- No serious adverse events
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Bengtsson Pediatric CCM 2010;11:253

Breathnach Pedi CCM 2010;11:7

- 16 children, 9.7 months
- PSV vs. NAVA 30 min to 4 hours
- With NAVA 65% of breaths triggered neurally p < 0.001
- With NAVA 85% of breaths cycled off neurally p < 0.0001
- PIP 30% lower with NAVA than PSV p = 0.003
- No serious adverse events

Pedro de la Oliva, Small Child, NAVA
De la Oliva Submitted for Publication

- 12 pediatric patients 5 months to 12 years
- PS, PS optimized vs. NAVA
- 30 min trials each application
- Compared asynchronies, and variability in ventilatory pattern

Pedro de la Oliva Submitted for Publication

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Pedro de la Oliva Submitted for Publication

Delisle Annuals of IC 2011;1:42

- 14 pts on sedated ready to wean
- Cross-over study: NAVA vs. PSV 2-4hr periods with each mode
- Set-up similar work of breathing
- NAVA significantly improved sleep quality over PSV

Delisle Annuals of IC 2011;1:42

- Stage 1, % 7.5 [4-15] 4 [3-5] 0.006*
- Stage 2, % 68 [66-75] 55 [52-58] 0.001*
- Stage 3 and 4, % 16.5 [17-20] 20.5 [16-25] 0.001*
- REM, % 4.5 [3-11] 16.5 [13-29] 0.001*
- Fragmentation index, 33.5 [25-54] 17.5 [8-21.5] 0.001*
- Sleep efficacy, % 44 [29-73.5] 73.5 [52.5-77] 0.001*
PAV vs. NAVA

- **PAV**
  - Uses measurement of airway pressure
  - No specific equipment needed
  - Available invasively/noninvasively (different ventilators)
  - Use with patients greater than 20 kg
  - Affected by leaks (current invasive) and autoPEEP

- **NAVA**
  - Uses measurement of diaphragm EMG (EAdi) activity
  - Requires use of a special catheter
  - Available invasively/noninvasively
  - Useful in neonates, children and adults
  - Unaffected by leaks or autoPEEP

Potential Uses of PAV or NAVA

- Patients with AI > 10%
  - Patients with chronic pulmonary disease regardless of age
  - Neonates
  - Pediatric pts with uncuffed airways
- Patients ventilated longer than 7 days

When Not to Use PAV or NAVA

- Patients requiring < 48hrs MV
- Most surgical patients
- Patients with severe hypoxemia
- Patients hemodynamically unstable

Major Question Regarding PAV and NAVA!

Who Knows Better How to Ventilate – the Clinician or the Patient?
Thank You