“Patient-Ventilator Synchrony and Impact on Outcome”

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Conflict of Interest Disclosure
Robert M Kacmarek

I disclose the following financial relationships with commercial entities that produce healthcare-related products or services relevant to the content I am presenting:

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<thead>
<tr>
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<tbody>
<tr>
<td>Covidien</td>
<td>Consultant</td>
<td>Mech Vent</td>
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<td>Covidien</td>
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<td>Orange Med</td>
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<td>Venner Medical</td>
<td>Grant</td>
<td>Artificial Airways</td>
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Types of Asynchrony

- Flow asynchrony – Inadequate flow at onset of inspiration to meet patient demand
- Trigger asynchrony – Poor coordination of patients initiation of inspiration and ventilator response
  - Trigger delay
  - Double trigger
  - Missed trigger
  - Auto trigger; entrainment/reverse triggering
- Cycling asynchrony – Poor coordination of patients desire to exhale and ventilator response
  - Inappropriately short inspiratory time
  - Inappropriately long inspiratory time
- Mode Asynchrony – Inappropriate mode

Variables Controlled during Mechanical Ventilation

- Pressure, Flow, Volume and Time
- Volume Assist/Control
  - Volume
  - Flow
  - Time
- Pressure Assist/Control
  - Pressure
  - Time
- Pressure Support
- Pressure
- PAV and NAVA
- None

Younes ARRD 1992;145:114

VA/C Assist

[Graphs and images related to patient-ventilator synchrony and mechanical ventilation parameters]
Inspiratory Time

- In spontaneous breathing patients, ventilator inspiratory time should equal patient desired inspiratory time.
- Spontaneous breathing - inspiratory time \( \leq 1.0 \) seconds.
- Patients with high ventilatory demand, inspiratory time maybe as short as 0.5 seconds.

Yoshida, Amato, Fujino AJRCCM In Press

- Pleural pressure monitoring, non-dependent, dependent and esophageal
- Dynamic CT, EIT volume distribution
- Healthy and lung injured Rabbits, Swine and a single patient
- Hypothesis, during assisted ventilation VA/C results in less injurious patterns of inspiration than PA/C?
Yoshida, Amato, Fujino AJRCCM In Press

VA/C does not protect against injurious inspiratory patterns in spite of the same VT and PL(es) as with paralysis, when inspiration vigorous!

Potential for injury similar to PA/C

PL(dep) in injured lung much lower than PL(es), not true in healthy lung

This is a result of Pendaluft, local volutrama (dependent) and tidal recruitment (dependent)
Double Triggering Associated With

- Short Inspiratory Time
- Low Peak Inspiratory Flows
- Greater Respiratory Rate
- Greater Dynamic Compliance
- Patient DT and Reverse DT occurred in all patients

Chanques CCM 2013;41:2177

- 50 patients with significant double triggering > 10% of breaths in VA/C
- Interventions:
  - Sedate patient
  - Change to Pressure Support
  - Increase inspiratory time 0.4 to 1.0 sec
  - Do nothing
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

PEEP Application

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

PEEP – Assisted Ventilation COPD

- If auto-PEEP measured, set PEEP at about 70% to 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 rate are equal

Branson, Campbell RC 1998;43:1045
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)
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

Thille ICM 2006;32:1515
- 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

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)

Mellott 2015;191:A3897
Texas, Virginia Florida, Georgia
- 30 pts 79 min (range 53-92) recording of flow/press waveforms and video recording
- Asynchrony present in 23% of breaths
- Altered respiratory dynamics, accessory muscle use, altered breathing patterns associated with asynchrony
- Facial grimace, extremity movement associated with asynchrony

Beitler, Talmor AJRCCM 2015;191:A3896
- 20 early ARDS, <24 hrs MV
- 72 hr continuous measurement of flow/press
- Determined double triggering (DT) defined as VT \( \geq 2\text{ml/kg PBW over set } V_T \)
- Setting VA/C, \( V_T \) 6.7±1.0 ml/kg PBW, RR 25±5/min, \( T_I \) 0.8±0.1 sec
- DT all, 0.1 to 89.6% of breaths, median 6.0% (1.3 – 15.9%)
- In 40% of pts >10% double triggering.
- DT survivors (15) < non survivors (5) 3.7% (0.6 – 9.7) vs.19% (11-76) p=0.036

Blanch, Kacmarek ICM 2015;14:633
- 50 patients, 7,027 hrs MV, 8,731,981 breaths
- Better Care™ Evaluated asynchrony
- Ineffective efforts during expiration (IEE)
- Double Triggering (DT)
- Short cycling < 50% mean inspir time (SC)
- Prolonged cycling > 100% mean inspir time (PC)
- Asynchrony index (AI)
- Air trapping
- Secretions
- Plateau pressure
- Mode of Ventilation
Clinical characteristics

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<th>Value</th>
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<tbody>
<tr>
<td>Number of patients</td>
<td>59</td>
</tr>
<tr>
<td>Age – yr</td>
<td>63.5 (68.7 – 73.2)</td>
</tr>
<tr>
<td>Female gender – no. of patients (%)</td>
<td>16 (32)</td>
</tr>
<tr>
<td>COPD diagnosis – no. of patients (%)</td>
<td>1 (5)</td>
</tr>
<tr>
<td>Adverse diagnoses:</td>
<td></td>
</tr>
<tr>
<td>Severe sepsis – no. of patients (%)</td>
<td>7 (14)</td>
</tr>
<tr>
<td>Acute respiratory failure – no. of patients (%)</td>
<td>24 (48)</td>
</tr>
<tr>
<td>Acute respiratory distress syndrome – no. of patients (%)</td>
<td>9 (18)</td>
</tr>
<tr>
<td>Postoperative – no. of patients (%)</td>
<td>3 (6)</td>
</tr>
<tr>
<td>Cardiogenic pulmonary edema – no. of patients (%)</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Coma – no. of patients (%)</td>
<td>6 (12)</td>
</tr>
<tr>
<td>APACHE II</td>
<td>12 (9.2 – 16.9)</td>
</tr>
<tr>
<td>SAPS 3</td>
<td>40 (29.2 – 50)</td>
</tr>
<tr>
<td>SOFA</td>
<td>7 (5 – 10)</td>
</tr>
<tr>
<td>Length of mechanical ventilation – days</td>
<td>8.5 (5–15)</td>
</tr>
<tr>
<td>Length of ICU stay – days</td>
<td>14 (7 – 20)</td>
</tr>
<tr>
<td>Patients with tracheostomy</td>
<td>18 (30%)</td>
</tr>
<tr>
<td>ICU mortality – no. of patients (%)</td>
<td>10 (20%)</td>
</tr>
<tr>
<td>Hospital mortality – no. of patients (%)</td>
<td>14 (20%)</td>
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Physiologic respiratory variables

<table>
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<tr>
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<tr>
<td>Ventilator triggered rate (breaths/min)</td>
<td>20.7 (16.6 – 24.4)</td>
</tr>
<tr>
<td>Applied PEEP (cmH2O)</td>
<td>6.0 (5.5 – 7.9)</td>
</tr>
<tr>
<td>Trigger sensitivity:</td>
<td></td>
</tr>
<tr>
<td>Pressure (cmH2O)</td>
<td>-2 [-2]</td>
</tr>
<tr>
<td>Flow (L/min)</td>
<td>5 (5 – 5)</td>
</tr>
<tr>
<td>Tidal volume (mL)</td>
<td>440 (399 – 492)</td>
</tr>
<tr>
<td>Peak Airway Pressure (cmH2O)</td>
<td>24.0 (19.4 – 26.6)</td>
</tr>
<tr>
<td>Plateau airway pressure (cmH2O)</td>
<td>19.5 (16.9 – 22.6)</td>
</tr>
<tr>
<td>Cvs (mL/cmH2O)</td>
<td>35.4 (28.6 – 46.3)</td>
</tr>
<tr>
<td>Total Flow (cmH2O/L/h)</td>
<td>10.2 (1.9 – 13.6)</td>
</tr>
<tr>
<td>Breaths with airflow &gt; 32 cmH2O</td>
<td>530 (0.019%)</td>
</tr>
<tr>
<td>Breaths with air trapping</td>
<td>1.555.382 (18.87%)</td>
</tr>
<tr>
<td>Breaths with secretions</td>
<td>165.047 (1.83%)</td>
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Blanch, Kacmarek ICM 2015;14;633
Studied ineffective triggering in 110 pts, MV day 1, 3 and 6, 2931 hrs of MV; 4,456,537 breaths All MV in PSV or PAV Clustering ineffective triggering (events) 30 in 3 min, AI about 35%, 42 of 110 pt Clustering associated with >8 days MV and mortality

Asynchrony is Harmful!
- Asynchrony occurs in all patients
- The less control by the ventilator the less asynchrony
- Asynchrony is present even during sedation
- Can be minimized by careful selection of mode
- Can be minimized by careful adjustment of the details of setting the mode
- Asynchrony is associated with a longer course of mechanical ventilation
- Asynchrony is associated with mortality?

Vaporidi ICM 2017:43:183

Vaporidi ICM 2017:43:183

Vaporidi ICM 2017:43:183