Nuts and Bolts on Humidification: Active or Passive During Pediatric Invasive Mechanical Ventilation?

Tan Herng Lee, MSc, RRT-NPS, RRT-ACCS
Senior Principal Respiratory Therapist,
Children’s Intensive Care Unit
KK Women’s and Children’s Hospital
19th August, 2017
Objectives

• Define humidification
• Why is humidification needed
• Different types of humidification devices
• Advantages and disadvantages of different types of humidification devices
• Which type of humidification devices should pediatric patients use?
Introduction

- Humidification = addition of water vapor and heat to inspired gas
- Heat and moisture exchange is a primary function of the upper respiratory tract, mainly the nose
- Optimal Humidification
  - Properly conditioned inspiratory gas
  - Maintain ciliary motility
  - Decreases airway hyper-reactivity
  - Keeps mucus from undergoing dehydration
Effects of Inadequate Humidity

Each point represents a single measurement coded as no dysfunction (diamond), mucus thick or thin (circle), mucociliary transport stopped (square), cilia stopped (X), or cell damage (+).

Rabbit models to determine effects of mechanical ventilation under varying temperature and humidity on inflammatory cytokines present in bronchoalveolar lavage (BAL) fluids

- 40 rabbits:
  - Control: \( n = 2 \), tissues used as reference
  - Dry gas: \( n = 6 \)
  - Experimental groups: Temp 30, 35, 40 and 45\(^\circ\)C, \( n = 8 \)/group
Dry gas group showed increased tumour necrosis factor alpha levels (TNF-α)

- TNF-α and interleukin-8 (IL-8) levels reached that of control group when humidification temperature was increased to 40°C
- Airway humidification in rabbits reduced mechanical ventilation-associated inflammatory response, cell cilia damage and airway water loss
Indications For Humidification

• Indications for Humidification Therapy:
  – Humidifying dry medical gas
  – Overcoming humidity deficit created when upper airway is bypassed

• Signs and symptoms of inadequate humidity
  – Atelectasis
  – Dry, non-productive cough
  – Increased work of breathing
  – Patient complained of airway dryness
  – Thick, dehydrated secretions

Walsh BK. Pediatric Airway Maintenance and Clearance in the Acute Care Setting: How to Stay Out of Trouble. Respir Care. 2011;56(9):1424-1440.
Goals of Levels of Humidification

- Prevention of adverse effects of *inadequate humidity*?
- *Minimum required humidity* to prevent ETT occlusion?
- Make inspired gas at temperature and humidity equivalent to normal spontaneous breathing? → *physiologic humidity*
- Provide *optimal humidity* to maximize mucociliary clearance?
- There appear to be no clinical demonstration of the superiority of delivering 40 vs 30 mg H₂O/L or even 33 vs 30 mg H₂O/L
- Optimum level of humidification appear to be > 30 mg H₂O/L as absolute humidity (AH) < 30 mg H₂O/L is associated with higher risk of ETT occlusion

Wikes AR. Humidification in Intensive Care: Are We There Yet? Respir Care 2014; 59(5):790-793
The upper airway provides 75% of the humidification; this means that during mechanical ventilation, a humidity level of $0.75 \times 44 \text{ mg/L} = 33 \text{ mg/L}$ needs to be generated.
Types of Humidifiers

1. Active humidifiers
   - Actively adding heat and/or moisture to device-patient interface
   - E.g. bubble humidifiers, passover humidifiers, heated humidifiers (HH), nebulizers of bland aerosols

2. Passive humidifiers
   - Recycling heat and humidity from patient
   - E.g. Heat and moisture exchangers (HMEs)
## Advantages and Disadvantages of Active and Passive Humidifiers

<table>
<thead>
<tr>
<th>Devices</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Active</strong></td>
<td>Universal application</td>
<td>Cost</td>
</tr>
<tr>
<td></td>
<td>Reliability</td>
<td>Using water</td>
</tr>
<tr>
<td></td>
<td>Alarms</td>
<td>Condensation</td>
</tr>
<tr>
<td></td>
<td>Wide ranges of temperature and humidity</td>
<td>Risk of contamination</td>
</tr>
<tr>
<td></td>
<td>Temperature monitoring</td>
<td>Low possibility of electrical shock and burns</td>
</tr>
<tr>
<td></td>
<td>Reaches the maximum absolute humidity</td>
<td>no Filter</td>
</tr>
<tr>
<td><strong>Passive</strong></td>
<td>Cost</td>
<td>Does not apply to all patients</td>
</tr>
<tr>
<td></td>
<td>Passive operation</td>
<td>Increased dead space</td>
</tr>
<tr>
<td></td>
<td>User friendly</td>
<td>Increased resistance</td>
</tr>
<tr>
<td></td>
<td>Removal of condensation</td>
<td>Potential occlusion</td>
</tr>
<tr>
<td></td>
<td>Portable</td>
<td>Misting problems</td>
</tr>
</tbody>
</table>
Performance of Humidifiers

• Variables affecting performance of humidifiers:
  
  i. Temperature
      – Higher temperature of the gas, the more water vapor it can hold (increased capacity)
  
  ii. Surface area
      – Greater the surface area of contact between water and gas, the more opportunity for evaporation to occur
  
  iii. Time of contact
      – The longer a gas remains in contact with water, the greater the opportunity for evaporation to occur
  
  iv. Thermal mass
      – The greater the mass of water, the greater its capacity to hold and transfer heat
Active Humidification as Gold Standard?

- Effective humidification for all patients, providing AH > 33 mg H₂O/L
- Big issue is rain-out
  - Regular drainage of water condensate in ventilator circuit
  - Disconnection of circuit to drain water condensate
  - De-recruitment → desaturation, increased work of breathing, tachycardia
- Rapid bacterial colonization of ventilator tubings
  - Higher risk of ventilator-associated pneumonia (VAP)?
Efficacy of HH

- Efficacy depends on environmental factors such as temperature
- Lower ambient temperature decrease AH delivered by the HH
- Increasing HH temperature to increase AH lead to more rain out

Factors to consider when using HME

- Does it work (i.e. humidify)?
- Does it increase resistance
- Does it increase the occurrence of ETT obstruction?
- Does it increase dead space?
- Does it increase work of breathing?
- Does it increase the occurrence of VAP?
- Does cuff or cuffless ETT affect level of humidification?

Types of HME

- HME → paper with compressed metallic elements to capture particles of exhaled water vapour and heat, holding and releasing it in the next inspiration
- Hygroscopic → absorbing moisture from the air
- Hydrophobic → unable to absorb water, increase moisture conservation by repelling water that is not absorbed

<table>
<thead>
<tr>
<th></th>
<th>Function</th>
<th>Absolute Humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>HME</td>
<td>Hydrophobic</td>
<td>10-14 mgH2O/L</td>
</tr>
<tr>
<td>HMEF (Heat-and-Moisture Exchanger Filter):</td>
<td>Hydrophobic + Filter</td>
<td>18-28 mgH2O/L</td>
</tr>
<tr>
<td>HHME (Hygroscopy Heat-and-Moisture Exchanger):</td>
<td>Hydrophobic + Hygroscopic</td>
<td>22-34 mgH2O/L</td>
</tr>
<tr>
<td>HHMEF (Hygroscopy Heat-and-Moisture Exchanger):</td>
<td>Hydrophobic + Hygroscopic + Filter</td>
<td>23-35 mgH2O/L</td>
</tr>
</tbody>
</table>
Humidification Performance of 48 Passive Airway Humidifiers*

Comparison With Manufacturer Data

François Lellouche, MD, PhD; Solenne Taillé, Eng; Frédéric Lefrançois, Eng; Nicolas Deye, MD, MSc; Salvatore Maurizio Maggiore, MD, PhD; Philippe Jouvet, MD, PhD; Jean-Damien Ricard, MD, PhD; Bruno Fumagalli, Eng; and Laurent Brochard, MD; and Groupe de travail sur les Respirateurs de l’AP-HP (CHEST 2009; 135:276–286)

- Assessed 48 devices
  - 32 = HME and 16 = antibacterial filters
  - Some HMEs for pediatric use but most for adult use
- 37.5% of HMEs performed well (≥ 30 mg H₂O/L)
- 25% of HMEs performed poorly (< 25 mg H₂O/L)
- Mean difference between measured data and manufacturer data = 3.0 ± 1.4 mg H₂O/L, p = 0.0001
- Efficiency ~ 37 to 90%
- Huge variability in performance of commercially available HMEs
Measurement of heat and moisture exchanger efficiency

M. Chandler

<table>
<thead>
<tr>
<th>Category</th>
<th>Device</th>
<th>Manufacturer</th>
<th>Measured weight loss; mg.l⁻¹</th>
<th>Calculated weight loss; mg.l⁻¹</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult</td>
<td>Thermovent® 600</td>
<td>Smiths Medical International (Ashford, Kent, UK)</td>
<td>9.7</td>
<td>10.2</td>
<td>75%</td>
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<tr>
<td></td>
<td>Thermovent 1200</td>
<td>Smiths Medical</td>
<td>7.5</td>
<td>7.6</td>
<td>83%</td>
</tr>
<tr>
<td></td>
<td>Model 802874</td>
<td>Smiths Medical</td>
<td>8.5</td>
<td>9.0</td>
<td>80%</td>
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<tr>
<td></td>
<td>Mechanical Filter</td>
<td>Dar (Boulder, CO, USA)</td>
<td>6.1</td>
<td>6.4</td>
<td>86%</td>
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<tr>
<td></td>
<td>Hygrovent small</td>
<td>Philips–Medisize (Hillegom, the Netherlands)</td>
<td>8.7</td>
<td>8.6</td>
<td>81%</td>
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<tr>
<td></td>
<td>Hygrobac™</td>
<td>Nellcor Covidien (Boulder, CO, USA)</td>
<td>10.3</td>
<td>10.6</td>
<td>77%</td>
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<tr>
<td></td>
<td>Flitatherm®</td>
<td>Intersurgical (Wokingham, Surrey, UK)</td>
<td>6.3</td>
<td>6.7</td>
<td>84%</td>
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<tr>
<td>Tracheostomy</td>
<td>Model BV-4</td>
<td>Ningbo Boya Medical Co Ltd (Yuyao City, China)</td>
<td>17.8</td>
<td>17.5</td>
<td>59%</td>
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<tr>
<td></td>
<td>Trachaid</td>
<td>Icor (Vital Signs, Barnham, Sussex, UK)</td>
<td>17.0</td>
<td>17.1</td>
<td>62%</td>
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<tr>
<td></td>
<td>Hydrotach®</td>
<td>Intersurgical</td>
<td>18.1</td>
<td>18.0</td>
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<tr>
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<td>Breathe-easy</td>
<td>Vital Signs</td>
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<td>17.1</td>
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<tr>
<td></td>
<td>Edith Trach</td>
<td>Datex-Ohmeda (Helsinki, Finland)</td>
<td>16.4</td>
<td>16.9</td>
<td>62%</td>
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<tr>
<td></td>
<td>Thermovent T</td>
<td>Smiths Medical</td>
<td>15.8</td>
<td>16.1</td>
<td>66%</td>
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<td></td>
<td>Tracheolife</td>
<td>Philips–Medisize</td>
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<td>Trach-Naze® orange</td>
<td>Kapitex Healthcare Ltd (Wetherby, Yorks, UK)</td>
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<td>24.2</td>
<td>46%</td>
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<td>Trach-Naze green</td>
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<td>25.1</td>
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<tr>
<td>Neonatal/ paediatric</td>
<td>LifeTrack 7715</td>
<td>Online Surgicalsa (Chennai, India)</td>
<td>10.2</td>
<td>10.0</td>
<td>79%</td>
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<tr>
<td></td>
<td>Humidvent® Mini</td>
<td>Gibeck (Televex, Athlone, Ireland)</td>
<td>10.0</td>
<td>9.7</td>
<td>79%</td>
</tr>
<tr>
<td></td>
<td>Hygroboy</td>
<td>Nellcor</td>
<td>9.4</td>
<td>10.0</td>
<td>87%</td>
</tr>
<tr>
<td></td>
<td>Humidvent® Pedi</td>
<td>Gibeck</td>
<td>8.0</td>
<td>7.3</td>
<td>84%</td>
</tr>
<tr>
<td></td>
<td>Clearatherm Mini</td>
<td>Intersurgical</td>
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<td>7.7</td>
<td>84%</td>
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<tr>
<td>ISO test validation device</td>
<td></td>
<td></td>
<td></td>
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<td>60%</td>
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(minimum)
Performance of Pediatric HMEs

Research Article
Humidification Performance of Heat and Moisture Exchangers for Pediatric Use

Yusuke Chikata, Chihiro Sumida, Jun Oto, Hideaki Imanaka, and Masaji Nishimura
Performance of Pediatric HMEs

Tested 10 pediatric HMEs
Mechanically ventilating pediatric lung model at:
- 20 and 30 breaths/min
- Pressure control of 10, 15 and 20 cm H₂O
- Leak of 3.2 L/min and 5.1L/min at pressure of 10 cm H₂O
Performance of Pediatric HMEs

<table>
<thead>
<tr>
<th>No.</th>
<th>Device</th>
<th>Manufacturer</th>
<th>Recommended tidal volume (mL)</th>
<th>Measured resistance, cmH₂O/L/s</th>
<th>Resistance from manufacturer’s data, cmH₂O/L/s</th>
<th>Type of HME</th>
<th>Dead space (mL)</th>
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<tbody>
<tr>
<td>(1)</td>
<td>Hygroboy</td>
<td>Tyco Healthcare</td>
<td>75–300</td>
<td>5.7</td>
<td>4.2</td>
<td>hygroscopic</td>
<td>26</td>
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<tr>
<td>(2)</td>
<td>HCH 5701</td>
<td>Vital signs</td>
<td>100–1,200</td>
<td>0.6</td>
<td>1.9</td>
<td>hygroscopic</td>
<td>30</td>
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<tr>
<td>(3)</td>
<td>Pharrma Mini</td>
<td>Pharma Systems</td>
<td>50–900</td>
<td>4.3</td>
<td>4.2</td>
<td>hydrophobic</td>
<td>28</td>
</tr>
<tr>
<td>(4)</td>
<td>HMEF Mini</td>
<td>GE Healthcare</td>
<td>60–500</td>
<td>3.5</td>
<td>3.0</td>
<td>hygroscopic</td>
<td>21</td>
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<tr>
<td>(5)</td>
<td>Servo Humidifier 161</td>
<td>Maquet</td>
<td>70–600</td>
<td>1.6</td>
<td>1.2</td>
<td>hygroscopic</td>
<td>21</td>
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<tr>
<td>(6)</td>
<td>Clear-Therm Mini</td>
<td>Intersurgical</td>
<td>75–200</td>
<td>3.3</td>
<td>3.4</td>
<td>mix</td>
<td>28</td>
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<tr>
<td>(7)</td>
<td>Humid-Vent 1</td>
<td>Hudson RCI</td>
<td>50–600</td>
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<td>0.9</td>
<td>hygroscopic</td>
<td>10</td>
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<tr>
<td>(8)</td>
<td>Hygrovent Child</td>
<td>Medisize</td>
<td>50–250</td>
<td>13.6</td>
<td>6.0</td>
<td>hygroscopic</td>
<td>12</td>
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<tr>
<td>(9)</td>
<td>Thermovent 600</td>
<td>Smiths Medical</td>
<td>&lt;600</td>
<td>1.2</td>
<td>2.9</td>
<td>hydrophobic</td>
<td>12</td>
</tr>
<tr>
<td>(10)</td>
<td>Vent Aid SK300CP</td>
<td>Fuji Medical</td>
<td>50–300</td>
<td>8.1</td>
<td>6.0</td>
<td>hygroscopic</td>
<td>12</td>
</tr>
</tbody>
</table>

- Variable dead space and resistance
- Mean values of resistance between measured and those of the manufacturers’ report was -1.0±2.6 cmH₂O/L/s (p = 0.27)
Impact of RR on AH of Pediatric HMEs

- Statistically non-significant 3% drop in AH when pressure control setting increased from 10 to 20 cm H₂O
- With 3 HMEs, increasing RR statistically significantly increase AH

Figure 2: Effect of respiratory rate on absolute humidity in the absence of leakage. This figure shows the pooled results for pressure control settings of 10, 15, and 20 cmH₂O without leakage. With three HMEs, increasing the respiratory rate statistically significantly increased absolute humidity. Mean ± SD; *P < 0.01 versus respiratory rate 20 breaths/min. HME: heat and moisture exchanger. RR: respiratory rate (breaths/min).
Performance of Pediatric HMEs in Presence of Leaks

- In the presence of leaks, all HMEs delivered < 30 mg H₂O/L

* $P < 0.01$ versus no leak
† $P < 0.01$ versus small

- No leak
- Small
- Large

Figure 3: Effect of leakage on absolute humidity. This figure shows the pooled results for respiratory rates of 20 and 30 breaths/min, and with pressure control set at 10, 15, and 20 cmH₂O. HME: heat and moisture exchanger. Mean ± SD; *$P < 0.01$ versus no leakage; †$P < 0.01$ versus small leak.
Dead Space and AH of Pediatric HMEs

- Statistically significant correlation between HME dead space and AH values
- Higher dead space, higher AH → greater capacity by HME to hold moisture

Figure 4: Relationship between absolute humidity and dead space in each HME. There was a statistically significant correlation between HME dead space and AH values (\( r_s = 0.85, P = 0.018 \)). HME: heat and moisture exchanger.
The effect of a pediatric heat and moisture exchanger on dead space in healthy pediatric anesthesia

Min A Kwon

Department of Anesthesiology and Pain Medicine, Dankook University College of Medicine, Cheonan, Korea

Table 1. Patient Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>With HME</th>
<th>Without HME</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M/F</td>
<td></td>
<td>16/4</td>
<td></td>
</tr>
<tr>
<td>Age (Mo)</td>
<td>14.0 (5.7–44.2)</td>
<td>14.0 (5.0–44.2)</td>
<td></td>
</tr>
<tr>
<td>Height (cm)</td>
<td>75.1 ± 21.1</td>
<td>75.1 ± 21.1</td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>13.4 ± 6.2</td>
<td>13.4 ± 6.2</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Ventilatory and Hemodynamic Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>With HME</th>
<th>Without HME</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>EtCO₂ (mmHg)</td>
<td>42.9 ± 5.7</td>
<td>36.1 ± 5.7</td>
<td>P &lt; 0.001*</td>
</tr>
<tr>
<td>PaCO₂ (mmHg)</td>
<td>46.0 ± 6.9</td>
<td>37.9 ± 4.3</td>
<td>P &lt; 0.001*</td>
</tr>
<tr>
<td>TVe (ml)</td>
<td>133.1 ± 60.9</td>
<td>134.4 ± 61.6</td>
<td>NS</td>
</tr>
<tr>
<td>Ve (L)</td>
<td>2.1 (1.6–2.5)</td>
<td>2.1 (1.7–2.5)</td>
<td>NS</td>
</tr>
<tr>
<td>A-Et PCO₂ (mmHg)</td>
<td>3.19 ± 3.88</td>
<td>1.81 ± 3.81</td>
<td>NS</td>
</tr>
<tr>
<td>Vd/Vt (%)</td>
<td>6.4 ± 7.4</td>
<td>4.8 ± 10.8</td>
<td>NS</td>
</tr>
<tr>
<td>PP (cmH₂O)</td>
<td>12.0 (9.7–14.0)</td>
<td>13.0 (9.7–14.2)</td>
<td>NS</td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>149.4 ± 19.7</td>
<td>146.9 ± 21.6</td>
<td>NS</td>
</tr>
<tr>
<td>MBP (mmHg)</td>
<td>71.6 ± 11.7</td>
<td>67.9 ± 18.2</td>
<td>NS</td>
</tr>
<tr>
<td>Hematocrit (%)</td>
<td>31.0 (26.5–32.0)</td>
<td>29.0 (25.5–33.0)</td>
<td>NS</td>
</tr>
</tbody>
</table>

Data are expressed as the means ± SD or median (range). HME: heat and moisture exchangers, EtCO₂: end tidal CO₂ concentration PaCO₂, partial pressure of arterial CO₂, TVe: expiratory tidal volume, Ve: minute ventilation, A-Et PCO₂: the difference in arterial to end tidal concentration of CO₂, Vd/Vt (%): dead space, PP: plateau pressure. *P < 0.05.
# Ability and safety of a heated humidifier to control hypercapnic acidosis in severe ARDS

Table 2 Respiratory measurements before and after removal of the heat and moisture exchanger. (HME heat and moisture exchanger, HH heated humidifier, Pplateau plateau pressure, MV minute ventilation, PEEPi intrinsic PEEP)

<table>
<thead>
<tr>
<th></th>
<th>HME</th>
<th>HH</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>MV (l/min)</td>
<td>7.7±1.2</td>
<td>7.7±1.2</td>
<td></td>
</tr>
<tr>
<td>PaO₂ (mmHg)</td>
<td>69±15</td>
<td>65±10</td>
<td>NS</td>
</tr>
<tr>
<td>SaO₂ (%)</td>
<td>88±7</td>
<td>89±5</td>
<td>NS</td>
</tr>
<tr>
<td>PaCO₂ (mmHg)</td>
<td>67±9</td>
<td>56±6</td>
<td>0.003</td>
</tr>
<tr>
<td>pH</td>
<td>7.20±0.11</td>
<td>7.26±0.06</td>
<td>0.005</td>
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<td>Pplateau (cmH₂O)</td>
<td>27±4</td>
<td>27±4</td>
<td>NS</td>
</tr>
<tr>
<td>PEEPi (cmH₂O)</td>
<td>2±1.5</td>
<td>2±1.5</td>
<td>NS</td>
</tr>
</tbody>
</table>
**Table 3** Ventilatory, gasometric and hemodynamic parameters measured during the five phases of the study. Results expressed as means ±SD

<table>
<thead>
<tr>
<th></th>
<th>DSh 120 (HME 95 ml + CSS 25 ml)</th>
<th>DSh 70 (HME 45 ml + CSS 25 ml)</th>
<th>DSh 50 (HME 25 ml + CSS 25 ml)</th>
<th>DSh 25 (HH+CSS 25 ml)</th>
<th>DSh 0 (HH)</th>
<th>ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>VT (ml)</td>
<td>380±59</td>
<td>380±59</td>
<td>381±61</td>
<td>380±59</td>
<td>379±60</td>
<td>NS</td>
</tr>
<tr>
<td>RR (breaths/min)</td>
<td>20±1</td>
<td>20±1</td>
<td>20±1</td>
<td>20±1</td>
<td>20±1</td>
<td>NS</td>
</tr>
<tr>
<td>Pplat (cmH₂O)</td>
<td>28±6</td>
<td>28±6</td>
<td>28±6</td>
<td>26±5</td>
<td>27±5</td>
<td>NS</td>
</tr>
<tr>
<td>PEEPe (cmH₂O)</td>
<td>11±3</td>
<td>11±3</td>
<td>11±3</td>
<td>11±3</td>
<td>11±3</td>
<td>NS</td>
</tr>
<tr>
<td>PEEPi (cmH₂O)</td>
<td>2.4</td>
<td>2.3</td>
<td>2.4</td>
<td>2.4</td>
<td>2.3</td>
<td>NS</td>
</tr>
<tr>
<td>pH</td>
<td>7.18±0.08</td>
<td>7.22±0.09*</td>
<td>7.24±0.09*</td>
<td>7.26±0.08*</td>
<td>7.28±0.08*</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>PaCO₂ (mmHg)</td>
<td>80.3±20</td>
<td>73.7±16</td>
<td>70.1±16*</td>
<td>65.6±13*</td>
<td>63.6±13*</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>PaO₂/FiO₂</td>
<td>157±39</td>
<td>151±47</td>
<td>146±43</td>
<td>143±42</td>
<td>149±48</td>
<td>NS</td>
</tr>
<tr>
<td>SaO₂ (%)</td>
<td>96±2</td>
<td>96±3</td>
<td>96±3</td>
<td>96±3</td>
<td>96±4</td>
<td>NS</td>
</tr>
<tr>
<td>HR (beats/min)</td>
<td>117±17</td>
<td>113±21</td>
<td>110±23</td>
<td>110±24</td>
<td>112±22</td>
<td>NS</td>
</tr>
<tr>
<td>MAP (mmHg)</td>
<td>77±12</td>
<td>77±11</td>
<td>76±9</td>
<td>77±9</td>
<td>77±5</td>
<td>NS</td>
</tr>
</tbody>
</table>

**DSh** humidification system dead space, **HR** heat rate, **MAP** mean arterial pressure, **PEEPe** external positive end-expiratory pressure, **PEEPi** intrinsic positive end-expiratory pressure, **Pplat** inspiratory plateau airway pressure, **RR** respiratory rate, **VE** minute ventilation, **VT** tidal volume

*p<0.05 compared to DSh₁₂₀*
HME and ETT Obstruction

<table>
<thead>
<tr>
<th>Function</th>
<th>Absolute Humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>HME</td>
<td>Hydrophobic</td>
</tr>
<tr>
<td>HMEF (Heat-and-Moisture Exchanger Filter):</td>
<td>Hydrophobic + Filter</td>
</tr>
<tr>
<td>HHME (Hygroscopy Heat-and-Moisture Exchanger):</td>
<td>Hydrophobic + Hygroscopic</td>
</tr>
<tr>
<td>HHMEF (Hygroscopy Heat-and-Moisture Exchanger):</td>
<td>Hydrophobic + Hygroscopic + Filter</td>
</tr>
</tbody>
</table>

- First generation HMEs were hydrophobic
  - Markedly affected by ambient temperature
  - Low ambient temperature result in reduced humidification performance and high rates of ETT obstruction
- Latest generation of HME
  - Both hydrophobic and hygroscopic components
  - Better performance

Lellouche et al. Influence of Ambient Temperature and Minute Ventilation on Passive and Active HMEs. Respir Care 2014;59(5):637-643
Cerca et al. The Open Respiratory Medicine Journal, 2015, 9, (Suppl 2: M5) 104-111
Humidification Devices and ETT Obstruction

- ETT obstruction with HH and HME
  - Both types of humidification result in progressive reduction in ETT diameter
  - AH > 30mg H₂O/L result in less occurrence of ETT obstruction

Lellouche et al. Influence of Ambient Temperature and Minute Ventilation on Passive and Active HMEs. Respir Care 2014;59(5):637-643
Resistance of HME

• HME resistance increased:
  – After several hours of use
  – Increase in density of HME material
  – Increase in flow
  – Occlusion with secretions, blood or water

• Hygroscopic HME:
  – Had less resistance than other types
  – Lesser increase in resistance when saturated

Lucato et al. Evaluation of Resistance in 8 Different HMEs: Effects of Saturation and Flow Rate/Profile. Respir Care 2005;50(5):636-643
Types of Humidification Devices and VAP

• Take home point from various guidelines on prevention of VAP: (Centers for Disease Control and Prevention, American Thoracic Society, European Care Bundle, European HAP Workgroup, VAP Guidelines Committee and the Canadian Critical Care Trials Group, American Association for Respiratory Care)

  – No recommendation can be made for the preferential use of either HMEs or heated humidification to prevent VAP in patients requiring mechanical ventilation

  – Colonization of ventilator tubings with HH does not translate to higher incidence of VAP

  – No significant reduction in VAP rate with use of HMEs despite HMEs consisting of chemical substances that are poor media for bacterial growth

  – No direct link between humidification devices and the pathophysiology of VAP (silent aspiration of contaminated oropharyngeal and/or gastric secretions)

Safe Duration of HME use

AARC Clinical Practice Guideline
Humidification During Invasive and Noninvasive Mechanical Ventilation: 2012

Ruben D Restrepo MD RRT FAARC and Brian K Walsh RRT-NPS FAARC
[Respir Care 2012;57(5):782–788. © 2012 Daedalus Enterprises]

• Passive humidifiers do not need to be changed daily for reasons of infection control. They can be used safely for at least 48 hours

• HMEs are better suited for short-term use (≤ 96 hours) and during transport

BUT

• HMEs are the default and sometimes the only humidification device in some ICUs

• HMEs could be routinely used under cautious surveillance and replaced by HH if difficulty in suctioning occurs (Misset et al, Chest 1991 Jul;100(1):160-63)
• 13 RCTs, 2580 patients > 15 years comparing HH and HME use

• No difference in:
  – VAP
  – Mortality
  – Length of ICU stay,
  – Duration of mechanical ventilation
  – Episodes of airway occlusions

• HMEs were cheaper than HH in each of the RCTs
HH or HME?

33 trials, only 3 studies reported data for infants or children
No overall effect on artificial airway occlusion, mortality, pneumonia or respiratory complications
Higher PaCO₂ and minute ventilation with HME use
Lower body temperature and lower cost with HME use
Little evidence of an overall difference between HMEs and HH
More research needed in the use of HME in pediatric and neonatal population
Limitations / Challenges

• Limited data and studies in pediatric population
  – Most studies are in the adult setting
  – Bulk of studies were done more than 10 years ago \( \rightarrow \) relevancy of these studies to current setting/practices
  – Advances and changes in technology in HH, HME and Mechanical Ventilators

• Heterogeneity of studies
  – Types of HMEs used
  – Duration of studies
  – Ability to translate lung model simulation studies to clinical practice

• Choice of Humidification Devices
  – Clinical Judgement and Discretion
• **Humidification** of inspired gas during mechanical ventilation is **mandatory when an endotracheal or tracheostomy tube is present**

• There are no contraindications to providing physiologic conditioning of inspired gas during mechanical ventilation
• HMEs are contraindicated when:
  – Frank bloody or thick, copious secretions
  – Expiratory $V_T < 70\%$ of delivered $V_T$ (i.e. when there is huge leak from artificial airways)
  – During low $V_T$ ventilation (due to addition of dead space)
  – Body temperature $< 32^\circ C$
  – Spontaneous minute ventilation $> 10$ L/min

• HH to be used for patients with contraindications for HME use
Conclusion

- Humidification of inspired air is required for all patients with artificial airways
- Both HH and HME are able to provide adequate humidification
- Best approach to humidification is unclear
- Cognizant of variability in performance of different brands of HME
- No difference in rate of VAP, ETT obstruction, and other important clinical outcomes such as ICU length of stay, duration of mechanical ventilation and mortality between HH and HME use
- Choice of humidification devices depends on:
  - Clinical assessment and judgment of patients’ condition i.e. elevated PaCO₂
  - Presence of leakage from artificial airways
  - Presence of thick secretions, pulmonary edema and/or hemoptysis
  - Institutional preferences and available resources
THANK YOU!

tan.herng.lee@khh.com.sg