Humidified High Flow Nasal Cannula and Nasal Continuous Positive Airway Pressure: Use in Community Hospital NICUs

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April 2, 2015
DeKlerk AL. Adv Neonatal Care 2008; 8:98-106

Disclosure Statement

• I do not have any conflict of interest or will be discussing any off-label product use.
• This class has no commercial support or sponsorship, nor is it co-sponsored.

Objectives

• Rationale for use of HFNC (actually 3 H- heated, humidified and high)
• Safety and efficacy of HFNC
• Comparison of HFNC with NCPAP
• Identify which neonates are likely to benefit
• Recognize the risks associated with this therapy
• Recommendations for use (+ evidence base)
Goals of Continuous Positive Airway Pressure (CPAP)

- Provide low-pressure distension of the lungs (maintain airways open)
- Prevent collapse of alveoli and terminal airways during expiration (conserve surfactant)
- Recruit alveoli (decrease intrapulmonary shunt)
- Maintain functional residual capacity
- Increased lung compliance

Logistics of CPAP

- For spontaneously breathing patients
- Pressure throughout respiratory cycle
- Pressure maintained by gas flow through a closed respiratory circuit
  - Continuous flow through respiratory cycle, or
  - Variable flow during inspiration and expiration to provide constant pressure and decrease work of breathing
- Heated and humidified gas
- Intended to deliver positive airway pressure
  - consistent, predictable, and regulated

Difficulties with CPAP

- Bulky interface with patient
- Leaks around nares and mouth
- Inconsistent airway pressure (from leaks)
- Increased work of breathing
- Respiratory instability
- Increase O2 needs
- Nasal trauma
Heated, humidified, high-flow nasal cannula = (HH)HFNC

Vapotherm

Fisher & Paykel

Rationale for HFNC

- Warmth and humidity should prevent:
  - Airway water loss,
  - Airway cooling
  - Thickened secretions
  - Nasal irritation, drying, or bleeding.

- Lighter and easier-to-apply interface (compared to CPAP) might:
  - Lessen nasal septal damage
  - Allow patients to be handled more easily

Features of HFNC systems

1. Humidifier
2. Special respiratory circuit to prevent excessive precipitation (“rain-out”)
   - Vapotherm: sleeve of recirculated, warmed water encasing the delivery tube
   - F&P: heated wire coil
3. Nasal cannula with adapter that connects to the delivery circuit
   - No excess tubing
   - Minimize gas cooling and precipitation of water
4. Nasal prongs: external diameter smaller than nares to prevent occlusive seal (~50% nares)
5. F&P system with internal pressure limit
How Does HFNC Work?

- Dead space washout
  - Reduces dead space and improves minute ventilation
- Reduces inspiratory work of breathing
  - Extra flow exceed inspiratory flow and eliminates nasal resistance
- Improved lung mechanics
  - Warmed humidified gas improves compliance, resistance and lung elasticity
- Improve secretion mobilization - ideal humidification restores mucociliary function (important in post-extubation use)
- Creation of positive distending pressure (like CPAP) - ?? Studies show yes, no, maybe, probably not??

Is positive pressure reliably delivered?

Bench measurements to evaluate the theoretical effects of flow rate and nasal "leak" size on generated pressure.

The relationship of flow rate, body weight, and oral cavity pressure.

Kubicka Z et al. Pediatrics 2008;121:82-88

Is positive pressure reliably delivered?

Esophageal Balloon Pressures, & WOB with NCPAP vs. Vapotherm at 3–5 LPM; N = 18, all < 2 kg; 5 minutes for stabilization which is not enough time to establish a new steady state FRC

### Effect on Respiratory Function

<table>
<thead>
<tr>
<th>Device setting</th>
<th>Compliance (ml kg(^{-1}) cm H(_2)O)</th>
<th>Tidal volume (ml/kg)</th>
<th>Respiratory rate (breaths/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCPAP6</td>
<td>0.83 ± 0.49</td>
<td>3.53 ± 1.92</td>
<td>68.3 ± 23.3</td>
</tr>
<tr>
<td>VAPO3</td>
<td>0.80 ± 0.40</td>
<td>3.15 ± 1.36</td>
<td>71.3 ± 22.2</td>
</tr>
<tr>
<td>VAPO4</td>
<td>0.89 ± 0.42</td>
<td>3.08 ± 1.35</td>
<td>68.9 ± 21.9</td>
</tr>
<tr>
<td>VAPO5</td>
<td>1.03 ± 0.47*</td>
<td>3.21 ± 1.31</td>
<td>64.9 ± 23.4</td>
</tr>
</tbody>
</table>

N= 18; < 2 kg
Abbreviations: NCPAP6, nasal continuous positive airway pressure at 6 cm H\(_2\)O; VAPO, Vapotherm.

\* P=0.03.


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### Fisher-Paykel (FP) and Vapotherm (VPT)

![Diagram of test lung-high-flow nasal cannula (HFNC) experimental set-up used for measurements.](image)


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### Figure 4

Effects of mouth leak on positive distending pressure delivery at all three pressure measurement points. Data shown were collected, using the Vapotherm device under minimal leak conditions and a wall flow of 8 L/min.

What flow rate is safe and effective?

- Measured pharyngeal pressures (solid-state pressure-tip catheter) in 10 preterm infants on HFNC
- Pressure approximates HFNC flow
- However: HIGH variation between patients

HFNC Pressure at Given Flow: Measured by esophageal pressure

- Prongs sized to fill 80% of nares diameter.
- Measured pharyngeal & esophageal pressures in 20 preterm infants on HFNC (Vapotherm) & on NCPAP
- With HFNC, 75% (15/20) reached P = 4 cm H2O with flow up to 6LPM
- With HFNC, 25% (5/20) reached P = 6 cm H2O
- Poor correlation of HFNC flow rate with pressure generated
- NCPAP achieved pressures of 2, 4 and 6 cm H2O

HFNC vs. NCPAP: Respiratory Mechanics

- 20 infants, 28-33 weeks, < 96 hours, with RDS on NCPAP or HFNC; randomized to NCPAP (2, 4, 6cm H2O) & HFNC (2, 4, 6 LPM)
- Mean gestation 30±6 weeks; mean birth weight 1490 g
- All comparisons made at same end expiratory distending pressure (pharyngeal pressure) - Differs from how we use HFNC in practice
- No difference in gas exchange, work of breathing or thoraco-abdominal asynchrony
- More variability of pharyngeal and expiratory pressure with HFNC than with NCPAP (attributed to higher flow rate on NCPAP)
HFNC is not a form of CPAP

- HFNC pressure is related to flow, nasal prong size, patient size, mouth position
  - Variable
  - Unpredictable
  - Unregulated
  - May be sufficient to produce clinical effects and/or changes in pulmonary function

- Neither Vapotherm nor F-P system is approved by FDA or marketed by manufacturers as a device for providing CPAP

Randomized Trials of NCPAP vs. HFNC in “Larger” Infants
(Trials of exclusively < 1500 g infants & post-extubation in references.)

<table>
<thead>
<tr>
<th>Trial type</th>
<th>Resp Support</th>
<th>N &amp; WGA/age range</th>
<th>Findings</th>
<th>Comments</th>
<th>Ref</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCT</td>
<td>On NCPAP, ≤ 30% O₂ for ≤ 24 hrs to HFNC at 2 LPM</td>
<td>&lt;30 weeks</td>
<td>+28 weeks</td>
<td>Equal NO (2 vs 3) failed extubation; used 2 LPM in RA = off support</td>
<td>8</td>
</tr>
<tr>
<td>RCT</td>
<td>End intubation within 72 hrs (intubation guidelines); No crossover in first 12 hrs.</td>
<td>N = 432; 28-42 wks</td>
<td>≤57% post vent; &gt;32% primary res</td>
<td>No difference in adverse events</td>
<td>15</td>
</tr>
</tbody>
</table>

Nasal damage: Randomized crossover: VT improved nasal mucosal exams; Lower resp effort scores on VT

Infants randomly assigned to nCPAP (black line) had significantly shorter duration of study support mode compared with infants randomly assigned to HHHFNC (gray line); P < .01.

Yoder BA, Stockard RA et al. Pediatrics 2013; 131:e1482-e1490
No Difference in Adverse Events: CPAP vs. HFNC

**Why is HFNC so popular?**

- Simplicity
- Similar to the familiar low-flow nasal cannula
- More "gentle," "developmentally-appropriate," less "invasive"
- More compatible with kangaroo care
- Compatible with breast feeding

**Recommendations**

- Monitor as if on CPAP: regular blood gases until steadily improving & chest radiographs for lack of improvement or deterioration (specifically looking for overinflation) when indicated
- Be prepared to treat pneumothorax (0.5 to 2%)
- Monitor for signs of infection – routine nasal care
- Acknowledge that HFNC remains an untested, unpredictable therapy
- Develop guidelines for using HFNC: starting, increasing and weaning HFNC
- Develop guidelines for oral feeding and positive oral stimulation on prolonged HFNC for infants greater than 35 weeks post-menstrual age
Some Nuts & Bolts of HFNC

• Nasal prong outer diameter should occupy ~50-80% of the nares internal diameter; these prongs will not create much distending pressure.

• Rule of thumb for estimating FiO2: If flow (in LPM) exceeds the baby’s body weight (in kg), the effective FiO2 = the blender FiO2.

<table>
<thead>
<tr>
<th>Flow (LPM)</th>
<th>Blender % O2</th>
<th>1.5 kg</th>
<th>2 kg</th>
<th>3 kg</th>
</tr>
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<tbody>
<tr>
<td>0.5</td>
<td>40</td>
<td>27</td>
<td>25</td>
<td>24</td>
</tr>
<tr>
<td>0.5</td>
<td>100</td>
<td>41</td>
<td>41</td>
<td>38</td>
</tr>
<tr>
<td>1</td>
<td>40</td>
<td>34</td>
<td>30</td>
<td>27</td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>74</td>
<td>68</td>
<td>47</td>
</tr>
<tr>
<td>2</td>
<td>40</td>
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<td>3</td>
<td>40</td>
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</tr>
<tr>
<td>3</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
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</table>

Draft Guideline for HFNC in Respiratory Distress: Page 1

Consider HFNC for respiratory support in infant with mild to moderate respiratory distress (RR > 80, retractions, grunting, flaring – see Downes scoring system below) and/or an oxygen requirement. Order a chest x-ray if starting HFNC or CPAP.

➢ Start flow at 3 LPM for 32-34 week gestation, 4 LPM for infant 34-36 week gestation, and 4-5 LPM for > 36 weeks gestation.

➢ Adjust FiO2 with target saturations of 90-95% and set monitor alarm limits at 88 to 97%. [If FiO2 is > 0.4 or you are concerned about possible persistent pulmonary hypertension, consider saturation goals of 92-97% with monitor alarm limits 90-99%.

You should see improvement within 1-2 hours of starting flow or CPAP.

Draft Guideline for HFNC in Respiratory Distress: Page 2

➢ Increase flow for:
  • FiO2 increasing by ≥ 0.10 or persistent FiO2 >0.40
  • PCO2 increased by ≥ 10 mm Hg, PCO2 > 60 mm Hg
  • Increased or continued moderate respiratory distress (amended Downes Score >3)
  • Poor lung expansion on chest xray done on HFNC
  • Maximum flow of 6 LPM for stable patients who need more flow. (Up to 7 LPM for unstable patients awaiting CPAP or transport.)

You should see improvement within 2 hours of a flow increase or change to CPAP. If you are not seeing improvement, consider calling Neonatologist for additional guidance.

➢ Consider change to NCPAP (at 5 to 6 cm H2O pressure) at HFNC flow of 5-6 LPM with FiO2 > 0.40, persistent respiratory acidosis (pH < 7.25 with PCO2 > 60 mm Hg), or persistent moderate respiratory distress (see amended Downes score).
NICU Respiratory Distress Symptoms (NRDS): (Amended Downes Scoring System)

**CONSIDER:** perform as part of respiratory assessment (RT or RN)

- **Score of 0-3:** Observe without change in support
- **Score of 4-5:** Increase support if evaluation and treatment as described below does not resolve the issues within 2 hours. Waiting time is to determine whether this is a transient issue.
- **Score of > 5:** Evaluation by medical provider and increase respiratory support; consider transfer.

When infant is experiencing increasing symptoms of respiratory distress or apnea:

1. Check that nasal passages are not obstructed with mucous – use nasal aspirator and 1 drop of NS to each nares q3hr if secretions are thick. Avoid use of other nasal suction catheters unless possible.
2. Contact provider to evaluate respiratory status.
3. Consider evaluation including blood gas, chest x-ray, and infectious causes of deterioration.

### Resp Rate

<table>
<thead>
<tr>
<th>Score</th>
<th>Resp Rate</th>
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<tbody>
<tr>
<td>0</td>
<td>&lt; 60</td>
</tr>
<tr>
<td>1</td>
<td>60-80</td>
</tr>
<tr>
<td>2</td>
<td>&gt; 80</td>
</tr>
</tbody>
</table>

### Retractions

<table>
<thead>
<tr>
<th>Score</th>
<th>Retractions</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>None to mild</td>
</tr>
<tr>
<td>1</td>
<td>Moderate</td>
</tr>
<tr>
<td>2</td>
<td>Severe</td>
</tr>
</tbody>
</table>

### Air Entry

<table>
<thead>
<tr>
<th>Score</th>
<th>Air Entry</th>
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<tbody>
<tr>
<td>0</td>
<td>Good</td>
</tr>
<tr>
<td>1</td>
<td>Decreased</td>
</tr>
<tr>
<td>2</td>
<td>Poor air entry</td>
</tr>
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</table>

### Oxygen requirement

<table>
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<tr>
<th>Score</th>
<th>Oxygen requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Room air (with flow &gt; 2 LPM)</td>
</tr>
<tr>
<td>1</td>
<td>&gt;50% Oxygen (with flow &gt; 2 LPM)</td>
</tr>
</tbody>
</table>

### Dyspnea

<table>
<thead>
<tr>
<th>Score</th>
<th>Dyspnea</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Normal activity, alert</td>
</tr>
<tr>
<td>1</td>
<td>Agitated</td>
</tr>
<tr>
<td>2</td>
<td>Drowsy, lethargic</td>
</tr>
</tbody>
</table>

**Draft Guideline for HFNC in Respiratory Distress:** Page 3

- **Wean flow by 1 LPM increments if all of the following are sustained for 4 or more hours:**
  - FiO2 < 0.30
  - PCO2 in acceptable range (capillary 45-58 mm Hg)
  - No significant distress and RR < 80
  - Adequate lung expansion if chest xray performed.

- **Transition to room air or if supplemental oxygen is still needed, use “regular” (not heated or humidified) nasal cannula at 1 LPM or less. Recommend 0.5 LPM or less for more prolonged use of extra oxygen.**
- “Regular” nasal cannula at 1-2 LPM for prolonged periods can lead to drying of the nasal mucosa with obstruction and bleeding.
  - Using HFNC a < 2LPM can cause water condensation and water may be dumped into the baby’s nose causing distress.
- **May allow breast feeding when respiratory distress is resolved, RR < 80, and HFNC is < 4 LPM.**

**Draft Guideline for Apnea**

**Rule out treatable causes of apnea such as sepsis, nasal obstruction etc.**

- **Start flow at 2 LPM.**
- **Adjust FiO2 with target saturations 90-95%.**
- **Increase flow for:**

<table>
<thead>
<tr>
<th>Apnea Level</th>
<th>Intervention</th>
<th># treated with stimulation per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minor</td>
<td>None</td>
<td>&lt; 10</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>&lt; 2</td>
</tr>
<tr>
<td></td>
<td>Vigorous/PPV</td>
<td>8</td>
</tr>
<tr>
<td>Significant</td>
<td>HFNC</td>
<td>15-15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2-6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1-2</td>
</tr>
<tr>
<td>Severe</td>
<td>HFNC and evaluate</td>
<td>&gt;15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;2</td>
</tr>
</tbody>
</table>

**Maximum flow of 5 LPM**

- **Consider NCPAP** for flow of 5 LPM with respiratory acidosis (pH < 7.25 with PCO2 > 60 mm Hg), or persistent significant apnea.

- **Wean flow by 1 LPM increments apnea spells improve to minor category for > 12 to 48 hours.**

- **Transition to room air or if supplemental oxygen is still needed, use “regular” nasal cannula at 1 LPM.** Recommend weaning to 0.5 LPM or less for more prolonged use of extra oxygen.

- **May allow breast feeding when apnea is mild and HHFNC is < 4 LPM.**
Consider CPAP for respiratory support in infant with moderate respiratory distress (RR > 80, retractions, grunting, flaring) and an oxygen requirement (especially if > 40%).

For severe respiratory distress (see Amended Downes score)
- With low oxygen requirement (< 50%), CPAP may be valuable
- With high oxygen requirement (>49%), consider intubation and ventilation rather than NCPAP.

Obtain a CXR on all patients who are started on CPAP
Place an 8 Fr. Orogastric tube to vent the stomach on CPAP.

Common complications of CPAP:
- Abdominal distention
- Nasal damage – septum, nares
- Other irritation from CPAP apparatus (e.g., redness and bruising on head and scalp)
- Pneumothorax – rate is generally < 2% but has been reported up to 5%.

1. Use mask CPAP with a T-piece resuscitator while nasal CPAP is set up. Mask CPAP may be helpful you decide if the infant’s respiratory distress will respond to NCPAP.
2. Start CPAP at 5 cm H$_2$O for infants who are in less than 40% oxygen and 6 cm H$_2$O for infants in more than 40% oxygen.
3. Adjust FiO$_2$ with target saturations of 90-95% and set monitor alarm limits at 88 to 97%. [If FiO$_2$ is > 0.4 or you are concerned about possible persistent pulmonary hypertension, consider saturation goals of 92-97% with monitor alarm limits 90-99%.
4. Increase pressure by 1 cm H$_2$O for:
   - FiO$_2$ increasing by > 0.10 or persistent FiO$_2$ >0.40
   - PCO$_2$ increased by ≥ 10 mm Hg or PCO$_2$ > 60 mm Hg
   - Increased or continued moderate respiratory distress
   - Poor lung expansion on chest x-ray done on HFNC
   - Maximum CPAP of 6-7 cm H$_2$O. Consider increase to 7 cm H$_2$O as needed while arranging intubation/transport.

You should see improvement within 2 hours of application of or an increase in CPAP pressure. If you are not seeing improvement, consider calling Neonatologist for additional guidance.
5. Consider intubation/transfer. If CPAP at ≥ 6 with persistent FiO$_2$ > 0.50, persistent respiratory acidosis (pH < 7.25 with PCO$_2$ > 60 mm Hg), or persistent moderate distress.
6. Wean CPAP by 1 cm H$_2$O (minimum of 4) if all of the following are sustained for 4 or more hours:
   - FiO$_2$ < 0.30,
   - PCO$_2$ in acceptable range (capillary 45-58 mm Hg)
   - No significant distress and RR < 80
   - Adequate lung expansion if chest x-ray performed. Chest x-ray not needed if infant is progressing as expected.

If you see rapid, significant improvement in FiO$_2$ (rapid decrease to < 0.26), may wean CPAP faster (every 2 hours) to avoid complications as lung compliance increases.
7. HFNC use after NCPAP: May switch to HFNC from NCPAP when FiO2 is <0.30, respiratory distress is resolved or mild, RR < 80, and PCO2 is < 58 mm Hg. Start HFNC flow 1-2 LPM lower than the NCPAP pressure. [For example, from NCPAP of 5 cm H2O, use HFNC at 3 or 4 LPM, depending on how well the baby is doing.]

8. Low flow oxygen after NCPAP:
   a. If NCPAP is ≤ 5 cm H2O, FiO2 is < 25%, respiratory distress is resolved (likely TTNB), and PCO2 < 52 mm Hg trial room air or low flow oxygen.
   b. If in room air on CPAP, trial room air.
   c. If supplemental oxygen is still needed, use "regular" (not heated or humidified) nasal cannula at less than 1 LPM.
   d. Recommend weaning to ≤ 0.5 LPM for prolonged use of oxygen.
      i. Use of "regular" nasal cannula at 1-2 LPM for prolonged periods can lead to drying of the nasal mucosa with obstruction and bleeding.
      ii. Using HFNC at < 2 LPM can cause water condensation in the tubing, and water may be dumped into the baby’s nose causing distress, apnea, and irritation.

May allow breast feeding when respiratory distress is resolved, RR < 80, and HFNC is < 4 LPM.

References #1


References #2

Comparison of HFNC and NCPAP for respiratory distress