High Flow Nasal Cannula: Finding Its Place

Tanusha Ramdin
Identify main mechanisms of action for High Flow Nasal Cannula

Discuss current relevant data for the use of High Flow Nasal Cannula as oxygen therapy and pressure therapy

Review weaning algorithms
High flow nasal cannula (HFNC) is a device used to deliver fixed supplemental oxygen or airflow to a patient or person in need of respiratory help.

HFNC oxygen therapy was introduced, accompanied by heated humidification systems to prevent the associated drying of upper airway mucosa and to increase patient comfort.
Vapotherm developed the 2000i High-Flow Therapy system, which consisted of a designated cannula with a heated cartridge-type humidifier using membrane technology for water vapor transfer.

The Vapotherm 2000i was recalled in 2005 due to concerns of bacterial contamination, but was reinstated after manufacturing controls and recommendations for use of only sterile water, single-patient use, and disinfection procedures.
This system uses a heated humidifier with hot-plate and single-use water chamber, similar to those for application for noninvasive or invasive mechanical ventilation.

A separate or combined air/O2 blender or air oxygen entrainment device and flow meter provide oxygen.

An oxygen analyzer is also required.

Humidified gas mixtures exit the humidifier through large bore corrugated tubing that connects to the cannula.
Beginnings of High Flow Nasal cannula

- Any flow greater than what can be accomplished with a bubble humidifier and standard NC
  - > 1 lpm in Neonates
  - > 2 lpm in Infant (<2 years)
  - > 4 lpm in Pediatric patient (2-8 years of age)
- Initially began as an alternative respiratory support to CPAP for premature infants
Beginnings of High flow nasal cannula

- Inadvertent CPAP with conventional nasal cannula (Locke et al, Pediatrics 1993)
  - Smaller (0.2cm OD) prongs negate pressure
    - Occluded only 50% of the nares
  - Larger (0.3cm OD) prongs generated pressure (mean pressure at 2 lpm = 9.8cm)
    - Intentional CPAP with conventional nasal cannula (Sreenan et al, Pediatrics 2001)
  - Snug prong
  - Mouth held closed
  - Up to 8 cmH2O with 3l/m
Continuum of Care: Where does HFNC fit in?
# High Flow Therapy: Mechanisms of Action

<table>
<thead>
<tr>
<th>MECHANISM</th>
<th>DESCRIPTION</th>
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<tbody>
<tr>
<td>Dead space washout</td>
<td>Reduce dead space making minute ventilation more efficient.</td>
</tr>
<tr>
<td>Reduce inspiratory work of breathing</td>
<td>Exceed inspiratory flow thus eliminating nasal resistance.</td>
</tr>
<tr>
<td>Improved lung mechanics</td>
<td>Warmed, humidified gas has been shown to improve conductance, compliance and lung elasticity.</td>
</tr>
<tr>
<td>Eliminate metabolic work associated with gas conditioning</td>
<td>Attenuates the energy and water loss associated with conditioning inspiratory gas.</td>
</tr>
<tr>
<td>Provision of mild distending pressure</td>
<td>Flow can be restricted such as to provide positive distending pressure for lung recruitment.</td>
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<tr>
<td>Improve secretion mobilization</td>
<td>Ideal humidification of the inspired gas has been shown to restore mucociliary function and reduce symptoms of airway exacerbations.</td>
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</table>
Flush Dead Space & Support Inspiration

High nasal flow, unimpeded at mouth, fills the upper airways – storing O₂ during exhalation and flushing CO₂

High mask flow, impeded by pressure at the mouth - stores less O₂ in the upper airways during exhalation and adds prosthetic dead space

Improved Mucociliary Ladder

- Decreases in insensible water loss
- Decreases airway inflammation
- Decreases nasal turbinate swelling due to cool gas
- Decreases airway resistance (decreases WOB)
Oxygen Therapy

- Goals

  - Accurate / Safe Levels of FiO2
    Low Flow Cannulas cannot accomplish this

  - SpO2 the principle clinical indicator to begin, adjust, and terminate oxygen therapy
What About Pressure?

- Focus of HFNC should be the exact opposite of pressure generation
  - Goal of therapy should be allow leak
  - Prevent unintentional pressure generation
  - Leak will increase deadspace flushing
Built in Pressure Regulator

- Use the correct size cannula: Don’t upsize to provide more flow.
- A larger OD will increase resistance to expiration (no leak in the cannula setup to exhale) and decrease deadspace flushing.
Flow

- Exceeding expiratory flows flushes deadspace and improves respiratory efficiency
- Exceeding inspiratory flows likely creates pressure
HFNC is **NOT** Pressure Therapy

- The Answer is **NO**
- This study of 27 infants measuring oral cavity pressure on HFNC found large variability in pressure
- Only generates pressure if mouth is closed how can we guarantee this!
Heated, Humidified High-Flow Nasal Cannula Versus Nasal CPAP for Respiratory Support in Neonates (RCT in 432 infants betw 28 and 42 wks)

<table>
<thead>
<tr>
<th>Early Respiratory Failure in Infants Managed With nCPAP and in Those Managed With HHHFNC</th>
<th>nCPAP (n = 220)</th>
<th>HHHFNC (n = 212)</th>
<th>OR (95% CI)a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early failure, all</td>
<td>18 (8.2)</td>
<td>23 (10.8)</td>
<td>1.37 (0.71–2.61)</td>
</tr>
<tr>
<td>&lt;32 weeks' gestational age</td>
<td>5/75 (6.7)</td>
<td>3/75 (4.0)</td>
<td>0.58 (0.13–2.53)</td>
</tr>
<tr>
<td>Prestudy ventilator</td>
<td>9/145 (6.2)</td>
<td>17/146 (11.6)</td>
<td>1.89 (0.86–4.63)</td>
</tr>
<tr>
<td>Start age &lt;7 d</td>
<td>16/201 (8.0)</td>
<td>23/194 (11.9)</td>
<td>1.56 (0.80–3.04)</td>
</tr>
</tbody>
</table>

Data are shown as n (%). Data in rows 3–5 are also shown as number of failures/number of infants (%). CI, confidence interval; OR, odds ratio.

a Unadjusted.

Yoder et al, Pediatrics 2013
Heated, Humidified High-Flow Nasal Cannula Versus Nasal CPAP for Respiratory Support in Neonates (RCT in 432 infants betw 28 and 42wks)

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<tr>
<td><strong>TABLE 5</strong></td>
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<td></td>
</tr>
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<td><strong>nCPAP (n = 220)</strong></td>
</tr>
<tr>
<td><strong>HHHFNC (n = 212)</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Any adverse event</td>
</tr>
<tr>
<td>Air leak</td>
</tr>
<tr>
<td>Increased apnea</td>
</tr>
<tr>
<td>Confirmed sepsis</td>
</tr>
<tr>
<td>Confirmed NEC</td>
</tr>
<tr>
<td>Reintubation, any</td>
</tr>
<tr>
<td>&lt;72 hours</td>
</tr>
<tr>
<td>&lt;7 days</td>
</tr>
<tr>
<td>No nasal trauma</td>
</tr>
<tr>
<td>Abdominal distention</td>
</tr>
<tr>
<td>Days to full oral feedings, median (25%–75%)</td>
</tr>
<tr>
<td>Death</td>
</tr>
</tbody>
</table>

Data are shown as n (%) unless otherwise indicated. *P = .047. NEC, necrotizing enterocolitis.
Heated, Humidified High-Flow Nasal Cannula Versus Nasal CPAP for Respiratory Support in Neonates (RCT in 432 infants betw 28 and 42 wks)

| TABLE 4 Respiratory Support Outcomes Among Infants Randomly Assigned to nCPAP Compared With HHHFNC |
|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| Days on study mode                              | nCPAP (n = 216)                                  | HHHFNC (n = 211)                                 | P        |
| Delayed use of other study mode, n (%)          | 2 (1–4)                                          | 4 (2–7)                                          | <.001    |
| Days ventilated                                 | 31 (14)                                          | 19 (9)                                           | .096     |
| Days any positive pressure support              | 4 (2–8)                                          | 6 (3–11)                                         | <.001    |
| Days supplemental O₂                            | 2 (1–4)                                          | 2 (1–5)                                          | .476     |
| BPD, n (%)                                      | 12/73 (16)                                       | 15/75 (20)                                       | .575     |
| Home oxygen, n (%)                              | 38 (18)                                          | 40 (19)                                          | .698     |
| Age at discharge                                | 25 (13–47)                                       | 25 (14–49)                                       | .756     |

Data are shown as medians (25%–75%) unless otherwise indicated.

* Only surviving infants <32 weeks’ gestational age at birth.
Among infants >28 weeks’ gestational age, HHHFNC appears to have similar efficacy and safety to nCPAP when applied immediately post extubation or early as initial noninvasive support for respiratory dysfunction.
High flow nasal cannula for respiratory support in preterm infants: Meta-analysis

High flow nasal cannula for respiratory support in preterm infants: Meta-analysis

Figure 2. Forest plot of comparison: 3 HFNC versus CPAP to prevent extubation failure, outcome: 3.3 Death.
High flow nasal cannula for respiratory support in preterm infants: Meta-analysis

Figure 3. Forest plot of comparison: 3 HFNC versus CPAP to prevent extubation failure, outcome: 3.2 CLD.
High flow nasal cannula for respiratory support in preterm infants

- HFNC vs CPAP as first-line respiratory support after birth (4 studies, 439 infants), NO differences in the rates of failure, death or CLD

- HFNC resulted in longer duration of respiratory support

- HFNC used after a period of MV (total 6 studies, 934 infants), NO differences between HFNC and CPAP in the rates of death or CLD or treatment failure or reintubation.

- Infants randomised to HFNC had less trauma to the infant’s nose and a small reduction in the rate of pneumothorax

Wilkinson et al, Cochrane 2016
Similarly MA of 1112 preterm infants, (9 clinical trials) HFT appears to be similar in efficacy and safety to other conventional modes of NIV

- Associated with significantly lower odds of nasal trauma

- Caution needs to be exercised in extreme preterm infants because of the paucity of published data.
Initiation of HFNC in neonates

Indications for HHHFNC

- Non-invasive ventilation in term/pre-term infant
- Respiratory distress syndrome/Grunting
- Meconium aspiration syndrome
- Respiratory acidosis
- Respiratory support post-extubation or weaning from BiPAP
- Chronic lung disease
- Treatment & prevention of apnoea of prematurity

Start HHHFNC

- Commence 6 L/min if >1kg, 4L/min if <1kg
- FiO2 to maintain saturations
- Clinical assessment at 30 mins
- Blood gas within 2 hours
- Flow can be increased to 8 L/min if needed, if > 1kg or 6 L/min if <1kg
Our institutions use HFNC therapy to avoid endotracheal intubation in infants and children with bronchiolitis who are at risk for respiratory failure.

In small observational studies, HFNC has been associated with decreased rates of endotracheal intubation.

HFNC is a well-tolerated noninvasive method of ventilatory support that permits high inspired gas flows (4 to 8 L/min) with or without increased oxygen concentration.

The increased flows are tolerated because the air is humidified; provision of HFNC requires a special circuit.

Flow rates ≥6 L/min can generate PEEP in the range of 2 to 5 cm H$_2$O. The size of the nasal cannula, which is determined by fit, affects the size of the circuit and maximum amount of flow.

For the treatment of bronchiolitis in infants and children younger than two years, 8 L/min is generally the maximum flow rate, but higher rates may be used (cannula size permitting).
HFNC for Bronchiolitis: Protocol

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**Patient Selection**
- Moderately severe bronchiolitis: Yes
- Respiratory distress type 1 (atelectasis, pulmonary edema, pneumonia): Maybe
- Moderate asthma: Maybe
- Invasive ventilation weaning: Maybe

**Settings**
- Nasal cannula size: ½ nostril diameter
- Humidification: 34-37°C
- FiO₂ to reach pulse oximetry (SpO₂): 92-97%
- Flow rates:
  - Infants >2 L/min (i.e., 2 L/kg/min)
  - Children >6 L/min (i.e., 1 L/kg/min)

**Monitoring in PED or PICU**
- Consciousness
- Airway patency
- Respiratory rate (RR), chest rise, FiO₂ and SpO₂
- Heart rate (HR), blood pressure
- Comfort

**Success**
- Improvement in most parameters: particularly RR, FiO₂, HR, comfort

**Failure**
- Worsening of some parameters: particularly RR, FiO₂, HR, comfort

**Figure 3 HFNC initiation and monitoring.** PED, pediatric emergency department; PICU, pediatric intensive care unit; RR, respiratory rate; HR, heart rate; NIV, noninvasive ventilation.

Milesi et al, Ann Intensive care 2014
HFNC for Bronchiolitis

- **Contraindications for HFNC:**
  - Abnormalities of the face or airway that preclude an appropriate-fitting nasal cannula

- **Relative contraindications:**
  - Confusion or agitation, vomiting, excessive secretions, and bowel obstruction

- In an observational study, nonresponse to HFNC was been associated with lower pre therapy pH and higher pre therapy PCO$_2$, highlighting the importance of early initiation
HFNC for Bronchiolitis

- Complications of HFNC
  - abdominal distension,
  - aspiration,
  - barotrauma, and
  - pneumothorax (rare) _risk of pneumothorax is lower with HFNC than with mechanical ventilation following endotracheal intubation_
HFNC for Bronchiolitis

- Clinically deteriorating may develop significant respiratory acidosis (hypercapnia) despite high oxygen saturations (if they are receiving supplemental O₂).

- Oxygen saturation is a poor indicator of impending respiratory failure, which is better indicated by marked retractions, decreased or absent breath sounds, fatigue, and poor responsiveness to stimulation (e.g., weak or no cry).

- Blood gas analysis to assess ventilation (i.e., PCO₂ levels) may be warranted in infants receiving HFNC who become more dyspneic and/or tachycardiac.
In observational studies, HFNC has been associated with decreased rates of intubation in children <24 months of age who were admitted to a pediatric ICU with bronchiolitis compared with historical controls.

In 2014 systematic review found only one pilot study (19 patients) that met the stringent inclusion criteria (randomized or quasi-randomized controlled trials assessing the effects of HFNC) and concluded that there is insufficient evidence to determine the effectiveness of HFNC for treating broncholitis in infants.
Early high flow nasal cannula therapy in bronchiolitis, a prospective randomised control trial (protocol): A Paediatric Acute Respiratory Intervention Study (PARIS)

Donna Franklin, Stuart Dalziel, Luregn J. Schlapbach, Franz E. Babi, Ed Oakley, Simon S. Craig, Jeremy S. Furyk, Jocelyn Neutze, Kam Sinn, Jennifer A. Whitty, Kristen Gibbons, John Fraser, Andreas Schibler and on behalf of PARIS and PREDICT
Weaning from HHFNC

- Currently no evidence available to suggest the best strategy for weaning and withdrawing HHFNC as a respiratory support in preterm infants

- Research is required into the best strategy for withdrawal of HHFNC

- Clear criteria for the definition of stability prior to attempting to withdraw HHFNC needs to be established

- Clear definition are needed as to what constitutes failure of HHFNC.
Weaning HFNC in neonates

Clinical Improvement

YES

Clinical Improvement

NO

Start Weaning

<table>
<thead>
<tr>
<th>Weight</th>
<th>FiO2 21%</th>
<th>FiO2 22-25%</th>
<th>FiO2 25-30%</th>
<th>FiO2 &gt;30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 1kg</td>
<td>Wean 1 L/min 12hrly</td>
<td>Wean 1 L/min 24 hrly</td>
<td>Wean 1 L/min 24 - 48 hrly</td>
<td>Wean flow to minimum 4 L/min</td>
</tr>
<tr>
<td>&lt; 1kg</td>
<td>Wean 1 L/min 24hrly</td>
<td>Wean 1 L/min 24 - 48hrly</td>
<td>Wean flow to minimum of 6 L/min</td>
<td></td>
</tr>
</tbody>
</table>

Consider

- BiPAP
- Intubation and ventilation

- 24 hours stability at 2 L/min – discontinue HHHFNC
- Start low flow nasal cannula O2 if required to maintain saturations
- If increased WOB, RR or FiO2 return to previous settings and halt weaning for a further 24-48hrs
Initiation of HFNC occurs with one of two **goals**:

- Increasing oxygenation
- Decreasing WOB
  - Providers have variable practice

Weaning of HFNC to room air requires:

- Reducing Flow
- Reducing FiO2
Weaning should start immediately after patient is initiated (weaning to least effective dose)

- Slow weaning of Oxygen/flow can increase LOS in bronchiolitic patients
Weaning Flow

- Decrease flow by 1 lpm at a time to maintain stable WOB (unchanged or reduced respiratory rate (RR), and/or retractions)

- This can be done as often as Q1

- All bronchiolitics will be tachypnoeic the aim is not a normal RR but unchanged or improved rate
Weaning FiO2 and Baseline (RA) Challenge

- Decrease the FiO2 by 10% at a time to maintain SpO2 >90%.
- When ALL of the following parameters are met, a baseline challenge is appropriate:
  - Flow is 3 lpm or less
  - FiO2 is 30% or less
  - Stable SpO2 which is greater than 90%
- Stable WOB as measured by RR, nasal flaring, and retractions
Baseline Challenge

- Take the patient off HFNC (take the cannula out of the nares)
- Passed challenge if Spo2 and WOB/RR are unchanged compared to HFNC.
- If they fail for WOB/RR put them back HFNC if they fail for SpO2 consider Low flow cannula
- Document HR, RR, Retractions, and SpO2 with each wean and during a baseline challenge
Conclusion

- Safe, well tolerated and effective for respiratory support in neonates
- More comfortable and less nasal trauma
- Easy application
- Decrease need for possible intubation and ICU admission in bronchiolitis, especially in resource limited settings
Thank you

Special thanks to prof Ballot..

Questions??