High Flow Nasal Cannula in Children During Sleep

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University of Utah
Disclosures

Conflicts of Interest: None

Will discuss a product that is commercially available, not yet FDA approved for sleep apnea
Objectives:

• Review the effect of high flow nasal cannula on sleep disordered breathing in children.

• Discuss the Mechanism of Action of high flow cannula on breathing during sleep.

• Review the use of High Flow Nasal Cannula in children with Cystic Fibrosis.
AASM - Hypoventilation in Children during Sleep

• $\text{CO}_2 > 50$ mmHg for 25% of TST

• Children with OSA are at increased risk for peri operative morbidity if $\text{RDI} > 24$ events/hr, $\text{SpO}_2 < 80\%$, or $\text{CO}_2$ is $> 60$ mmHg

• Does not discriminate between $\text{EtCO}_2$/$\text{TcCO}_2$

Background

\[ pCO_2 = k \times \frac{VCO_2}{V_A} \]

Want to but can’t breathe
Can but won’t breathe
Upper Airway Patency

Adapted from Gold et al. Chest 1996;10:1077-1088
Want to but can’t breath

Neuromuscular/skeletal disease, Morbid Obesity, Pulmonary and cardiovascular diseases, Obstructive Sleep Apnea

12 year old with achondroplasia
RDI = 112 events/hour
OSA – Pharyngeal collapse

CRITICAL PRESSURE DURING SLEEP

NORMAL

APNEIC
Waterfall Analogue
What determines the amount of Airflow?

Constant/fixed inspiratory Airflow
Inspiratory Airflow Limitation

Flow is independent of Downstream Pressure
Therapy for OSA
Change Nasal or Critical Pressure
CPAP

Waterfall Analogue
Flow Depends on the Upstream Pressure and $P_{crit}$

- $1 \text{ cmH}_2\text{O} P_n$ increase $V_I$ by 50 ml/s
- $P_{eff} = P_{crit} + 8 \text{ cmH}_2\text{O}$
- Normal Inspiratory Airflow $> 400 \text{ ml/s}$
High Nasal Flow Therapy

1. Effect on sleep disordered breathing in children.

2. Mechanism of Action

3. High Flow Nasal Cannula and Pulmonary disease

   Preliminary data in children with CF
Treatment with Nasal Insufflation (TNI)

Warm (30-32°C)
Humidified (90-95% relative Humidity)
20 L/min

Two overnight polysomnograms
One night OFF TNI
One night ON TNI
Random order
## Children on CPAP

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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AHI Total (events/hr)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>8</td>
<td>9</td>
<td>9</td>
<td>17</td>
<td>20</td>
<td>22</td>
<td>36</td>
<td>11 3</td>
</tr>
<tr>
<td>SpO₂ nadir (%)</td>
<td>96</td>
<td>90</td>
<td>92</td>
<td>95</td>
<td>87</td>
<td>90</td>
<td>88</td>
<td>84</td>
<td>94</td>
<td>79</td>
<td>83</td>
<td>68</td>
<td>87 2</td>
</tr>
<tr>
<td>Peak CO₂ (mm Hg)</td>
<td>53</td>
<td>51</td>
<td>50</td>
<td>54</td>
<td>60</td>
<td>53</td>
<td>59</td>
<td>58</td>
<td>55</td>
<td>54</td>
<td>56</td>
<td>63</td>
<td>56 1</td>
</tr>
<tr>
<td>% TST CO₂ &gt; 50 mm Hg</td>
<td>1</td>
<td>0.1</td>
<td>0</td>
<td>3</td>
<td>52</td>
<td>1</td>
<td>37</td>
<td>5</td>
<td>1</td>
<td>7</td>
<td>7</td>
<td>56</td>
<td>14 6</td>
</tr>
<tr>
<td><strong>Daytime Symptoms</strong></td>
<td>HJC.BD</td>
<td>DS.H</td>
<td>HJC</td>
<td>HJC.BD</td>
<td>DS.H</td>
<td>None</td>
<td>HJC</td>
<td>DS.BD</td>
<td>HJC.BD</td>
<td>DS</td>
<td>DS</td>
<td>H.BD</td>
<td></td>
</tr>
</tbody>
</table>
HNFT in Children

Respiratory Responses to HFNC during NREM

HNFT reduced respiratory load with inspiratory flow limitation

McGinley B et al, Pediatrics. 2009
Effect of TNI on Sleep Disordered Breathing during NREM sleep

High Nasal Flow Therapy

1. Effect on sleep disordered breathing in children.

2. Mechanism of Action

3. High Flow Nasal Cannula and Pulmonary disease

   Preliminary data in children with CF
HFNC in Apneic Children on CPAP

McGinley et al Pediatrics 2009
Effects on Ventilation

\[ pCO_2 = k \times \frac{V_{CO_2}}{V_A} \]
Acute HFNC Trials during NREM

Baseline | Nasal Insufflation | Baseline

Airflow
Inpiration
Thorax Abdomen
SaO₂ (%)
Heart Rate (b/min)
Expiration
Airflow
Inpiration
Thorax Abdomen
SaO₂ (%)

Respiratory Rate = 36/min
Vₘ = 10 L/min

Respiratory Rate = 23/min
Vₘ = 5 L/min
Effect on Ventilation

Panel A

- Arousal
- EEG
- EMG
- Flow (L/min)
- SaO2 (%)
- tc-CO2 (mmHg)

Panel B

- Respiratory Rate
- Minute Ventilation (L/min)
- CO2 (mmHg)

Graphs showing changes in respiratory parameters during different conditions.
Effects of TNI on Ventilation
High Flow Nasal Cannula

\[ pCO_2 = k \times \frac{VCO_2}{V_A} \]
In children with stable inspiratory flow limitation, TNI increased respiratory efficiency through either:

1. Decreased dead space ventilation
2. Decreased CO$_2$ production during sleep.
High Nasal Flow Therapy

1. Effect on sleep disordered breathing in children.

2. Mechanism of Action

3. High Flow Nasal Cannula and Pulmonary disease

   Preliminary data in children with CF
Cystic Fibrosis

• 20 year-old male
  – F508del homozygous

• Pancreatic insufficiency

• CF-related liver disease and cirrhosis

• CF-related diabetes on insulin
Lung Function 2003-2011

FEV1-pred (L)
Clinic Visit 9/20/2012

• FEV1: 1.55L (33.4%-predicted)

• Exhausted
  – Difficult attending to conversation in clinic
  – Mother talking for him

• Poor sleep
  – Snoring
  – Excessive daytime sleepiness
  – Did not feel refreshed in the morning
NREM Sleep on O2 3 LPM

- Respiratory rate (20-24/min)
- Increased respiratory effort
- Event rate underestimated
  SDB - events not meeting criteria
REM- Severe OSA on O2 3 LPM
Treatment Plan

BiPAP - non compliant, cited the mask

Alternative:
Nasal insufflation via nasal cannula (HNFT)
- Warm and humidified air at high flow (20 LPM)
- Efficacious for OSA in children
- May improve secretions
- Using sleep to provide “lung protective” therapy
### Sleep Study Results on Treatment

#### Baseline (3 LPM O₂)

<table>
<thead>
<tr>
<th></th>
<th>NREM</th>
<th>REM</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHI</td>
<td>11</td>
<td>43</td>
<td>16</td>
</tr>
<tr>
<td>(\text{SaO}_2) (Bsl)</td>
<td>91%</td>
<td>88%</td>
<td>89%</td>
</tr>
<tr>
<td>(\text{SaO}_2) (min)</td>
<td>82%</td>
<td>78%</td>
<td>78%</td>
</tr>
</tbody>
</table>

#### HFNT 20 LPM +2L O₂

<table>
<thead>
<tr>
<th></th>
<th>NREM</th>
<th>REM</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHI</td>
<td>0</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>(\text{SaO}_2) (Bsl)</td>
<td>91%</td>
<td>88%</td>
<td>89%</td>
</tr>
<tr>
<td>(\text{SaO}_2) (min)</td>
<td>85%</td>
<td>77%</td>
<td>77%</td>
</tr>
</tbody>
</table>
Domiciliary humidification improves lung mucociliary clearance in patients with bronchiectasis

A Hasani¹, TH Chapman², D McCool³, RE Smith¹, JP Dilworth² and JE Agnew¹

¹Department of Medical Physics, Royal Free Hospital, London, UK; ²Department of Thoracic Medicine, Royal Free Hospital, London, UK; and ³Department of Nuclear Medicine, Royal Free Hospital, London, UK

Ten subjects (37-75yrs)

High nasal Flow Therapy
• 3 hours per day
• Optiflow (30 L/min)
The clinical utility of long-term humidification therapy in chronic airway disease

RCT: HNFT vs. Control, 2 hours/day, wakefulness
Severe COPD, Bronchiectasis (n=108, 60 HNFT, 48 Control)

![Graphs showing FEV1 and FVC over study month]

**Table 2** Exacerbation endpoints.

<table>
<thead>
<tr>
<th></th>
<th>TREAT</th>
<th>CON</th>
<th>p-Value</th>
<th>Ratio</th>
<th>95% CI of ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency #/patient/year</td>
<td>2.97</td>
<td>3.63</td>
<td>0.067</td>
<td>0.818</td>
<td>(0.660, 1.014)</td>
</tr>
<tr>
<td>Annual exacerbation</td>
<td>18.2</td>
<td>33.5</td>
<td>0.045</td>
<td>0.544</td>
<td>(0.300, 0.985)</td>
</tr>
<tr>
<td>days (geometric mean)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days to 1st exacerbation (predicted median)</td>
<td>52</td>
<td>27</td>
<td>0.050</td>
<td>0.650^a</td>
<td>(0.423, 0.999)</td>
</tr>
</tbody>
</table>
Preliminary Data
Ventilatory loads are increased in CF during sleep
Preliminary Data

NI reduces ventilatory loads in CF patients during sleep
HNFT reduces energy expenditure

EEG
EOG
EMG
Airflow
EE (kcal/h)

Ventilation (mL/min/kg)

Normal: 19yrs, BMI 19
HFNI reduces EE by 60-70 kcal/night

CF: ~
30-50% reduction in ventilation could reduce EE by 300-500 kcal/night
Overall Concept
utilize sleep to prevent pulmonary cachexia

Traditional Nutritional Treatment

↑ Energy Expenditure

↑ Work of Breathing

Sleep

Pulmonary Cachexia

High Flow Nasal Insufflation
How much weight change can we expect?

Primary Snoring and Growth Failure in a Patient With Cystic Fibrosis
MacDonald KD et al Respiratory Care 2009
Patient Follow Up

• Clinic visit on 11/29/12
  – “Loves” the AIRVO
  – Improved AM sputum production
  – More daytime energy
  – No longer on daytime oxygen
  – Better mood
  – Playing video games until midnight
Lung function

- Initiated AIRVO® on 10/26/12
  - FEV$_1$: 1.4 L (29.8%-predicted)

- Clinic visit on 11/29/12
  - FEV$_1$: 2.1 L (45.9%-predicted)
Implications

1. TNI might provide an alternative to surgery and CPAP for children.

2. TNI may also have a role in treating hypercapnic respiratory diseases in children (Cystic Fibrosis, Neuromuscular Disease).

3. TNI can be used to manipulate upper airway obstruction to assess the impact of inspiratory flow limitation on the co-morbid outcomes associated with sleep disordered breathing.
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  - Philip Smith M.D.
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  - Jason Kirkness PhD

- Seleon GmbH, Germany
- HL 72126
- Johns Hopkins Pediatric Clinical Research Unit