High flow nasal cannula for OSAS

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High flow nasal cannula for OSAS in children

Why should we use it?
How does it work?
Does it work in OSAS?
Treatment of pediatric OSAS

**WHO**
Every child with an AHI > 5/h irrespective of the presence of morbidity,  
Or AHI between 1-5/h + comorbidities (cardiovascular, neurological)

**HOW**
A stepwise treatment approach, tailored on the severity of OSAS and on the presence of underlying diseases/comorbidity

n.b. OSAS treatment is a priority in the presence of: major craniofacial abnormalities; neuromuscular disorders; achondroplasia; Down syndrome; mucopolysaccharidoses; Prader Willi syndrome...
Stepwise treatment approach

- Adeno-tonsillectomy
- Control of risk factors:
  - Obesity
  - Allergy
- Sleep evaluation
- Medical treatment
- Orthodontics (Surgery)
- CPAP
- CPAP failure

Sleep evaluation
Table 2—Study group

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>56</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>12 ± 4</td>
</tr>
<tr>
<td>Range</td>
<td>2–16</td>
</tr>
<tr>
<td>Males</td>
<td>38 (68)</td>
</tr>
<tr>
<td>Race</td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>33 (59)</td>
</tr>
<tr>
<td>Caucasian</td>
<td>20 (36)</td>
</tr>
<tr>
<td>More than one race</td>
<td>3 (5)</td>
</tr>
<tr>
<td>Hispanic ethnicity</td>
<td>5 (9)</td>
</tr>
<tr>
<td>Obese</td>
<td>40 (71)</td>
</tr>
<tr>
<td>Other diagnoses</td>
<td></td>
</tr>
<tr>
<td>Genetic syndrome</td>
<td>11 (20)</td>
</tr>
<tr>
<td>Central nervous system abnormality</td>
<td>6 (11)</td>
</tr>
<tr>
<td>Craniofacial syndrome</td>
<td>3 (5)</td>
</tr>
<tr>
<td>Pulmonary disease</td>
<td>3 (5)</td>
</tr>
<tr>
<td>Growth hormone deficiency</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Neurodevelopmental disability</td>
<td>13 (23)</td>
</tr>
</tbody>
</table>
Low compliance!

mean CPAP use 3 ± 3h/night

Figure 3—Correlation between positive airway pressure use and age for month-1

The correlation between mean nightly positive airway pressure (PAP) use and age is shown for month-1. There was no significant correlation.
Factors influencing CPAP compliance

Table 3—Multiple linear regression model results, controlling for positive airway pressure mode (mode forced into the model at step 1)

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Unstandardized β coefficient</th>
<th>SE</th>
<th>β coefficient</th>
<th>p value</th>
<th>Change in R²</th>
<th>p-value for change in R²</th>
<th>Overall R²</th>
<th>Overall p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outcome = Nights Used, Month 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-3.157</td>
<td>7.507</td>
<td>0.676</td>
<td></td>
<td>0.006</td>
<td>0.585</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PAP mode</td>
<td>1.859</td>
<td>2.479</td>
<td>0.457</td>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>-</td>
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<tr>
<td>Maternal education</td>
<td>3.480</td>
<td>1.026</td>
<td>0.001</td>
<td></td>
<td>0.197</td>
<td>0.001</td>
<td>0.203</td>
<td>0.005</td>
</tr>
<tr>
<td>Outcome = Nights Used, Month 3</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-4.367</td>
<td>6.289</td>
<td>0.491</td>
<td></td>
<td>0.006</td>
<td>0.597</td>
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<td>-</td>
</tr>
<tr>
<td>PAP mode</td>
<td>-1.412</td>
<td>2.690</td>
<td>0.602</td>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>-</td>
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<tr>
<td>MOSS</td>
<td>5.466</td>
<td>1.399</td>
<td>&lt; 0.0005</td>
<td></td>
<td>0.252</td>
<td>&lt; 0.0005</td>
<td>0.258</td>
<td>0.001</td>
</tr>
<tr>
<td>Outcome = Mean Nightly Use (hours/night), Month 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>2.442</td>
<td>0.490</td>
<td>&lt; 0.0005</td>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>-</td>
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<tr>
<td>PAP mode</td>
<td>-0.066</td>
<td>0.840</td>
<td>0.938</td>
<td></td>
<td>0.001</td>
<td>0.831</td>
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<tr>
<td>Race*</td>
<td>1.943</td>
<td>0.732</td>
<td>0.011</td>
<td></td>
<td>0.130</td>
<td>0.011</td>
<td>0.131</td>
<td>0.037</td>
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<tr>
<td>Outcome = Mean Nightly Use (hours/night), Month 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>2.707</td>
<td>0.470</td>
<td>&lt; 0.0005</td>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PAP mode</td>
<td>-1.229</td>
<td>0.870</td>
<td>0.165</td>
<td></td>
<td>0.030</td>
<td>0.240</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Developmental delay*</td>
<td>2.401</td>
<td>0.927</td>
<td>0.013</td>
<td></td>
<td>0.126</td>
<td>0.013</td>
<td>0.156</td>
<td>0.022</td>
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</tbody>
</table>

The unstandardized regression coefficient (β), standard error (SE) of the coefficient, p value of the coefficient, change in R² and its p-value as a result of the addition of the new predictor, overall R² for the entire model and overall p value for the model are shown for each adherence outcome. Note that the unstandardized regression coefficient (β) reflects the change in the outcome per unit change in the predictor variable. PAP, positive airway pressure.

*Coded 0 = African American, 1 = other. **Coded 0 = No, 1 = Yes.
Continuous positive airway pressure and noninvasive ventilation adherence in children

Adriana Ramirez\textsuperscript{a,b}, Sonia Khirani\textsuperscript{b,c}, Sabrina Aloui\textsuperscript{b}, Vincent Delord\textsuperscript{d}, Jean-Christian Borel\textsuperscript{e,f}, Jean-Louis Pépin\textsuperscript{f,g}, Brigitte Fauroux\textsuperscript{b,h,i,}\textsuperscript{*}

<table>
<thead>
<tr>
<th>Underlying disease (n, %)</th>
<th>Total population (N = 62)</th>
<th>Nasal mask (n = 38)</th>
<th>Facial mask (n = 14)</th>
<th>Nasal cannula (n = 10)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSA</td>
<td>51 (82%)</td>
<td>33</td>
<td>14</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Lung disease</td>
<td>5 (8%)</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Neuromuscular disease</td>
<td>6 (10%)</td>
<td>1</td>
<td>0</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Gender (female/male)</td>
<td>26/36</td>
<td>12/26</td>
<td>9/5</td>
<td>5/5</td>
<td></td>
</tr>
<tr>
<td>Age (y)</td>
<td>10.0 ± 4.7</td>
<td>7.6 ± 4.0\textsuperscript{f}</td>
<td>11.8 ± 4.6</td>
<td>15.0 ± 3.0</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>31.0 ± 21.0</td>
<td>25.6 ± 20.5\textsuperscript{f}</td>
<td>41.9 ± 16.5</td>
<td>47.0 ± 13.4</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

**CPAP and NIV adherence over the last month**

- Average use per night (h:min): 8:17 ± 2:30, 8:17 ± 2:16, 8:12 ± 3:17, 8:23 ± 2:44, P = .858
- Number of patients using treatment >8 h/night (n, %): 45 (72%), 25 (65%), 12 (86%), 8 (80%), P = .183
- Average nights use (n): 26 ± 5, 27 ± 4, 23 ± 8, 28 ± 7, P = .122

**Nocturnal gas exchange with CPAP or NIV**

- Mean Sp\textsubscript{O}2 (%): 97 ± 2, 97 ± 2, 97 ± 3, 97 ± 2, P = .985
- Minimal Sp\textsubscript{O}2 (%): 91 ± 2, 91 ± 2, 92 ± 2, 90 ± 4, P = .328
- % of night time with a Sp\textsubscript{O}2 <90% (%): 0.3 ± 1.3, 0.5 ± 1.7, 0.0 ± 0.0, 0.0 ± 0.0, P = .233
- 4% Desaturation index (events/h): 4 ± 5, 5 ± 7, 3 ± 3, 4 ± 3, P = .936
- Mean Ptc\textsubscript{CO}2 (mmHg): 39 ± 5, 39 ± 5, 38 ± 3, 41 ± 7, P = .270
- Maximal Ptc\textsubscript{CO}2 (mmHg): 45 ± 5, 45 ± 5, 42 ± 4, 48 ± 5, P = .020
- Percent of night time with a Ptc\textsubscript{CO}2 >50 mmHg (%): 1.4 ± 6.3, 0.4 ± 2.0, 0.0 ± 0.0, 8.1 ± 15.2, P = .016
## Weaning of PPC/VNI

59 patients (25%) during 27 months

<table>
<thead>
<tr>
<th>Age at CPAP/NIV initiation (median), yrs</th>
<th>1.4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CPAP / NIV</strong></td>
<td>51 (86%) / 8 (14%)</td>
</tr>
<tr>
<td><strong>Duration of CPAP / NIV (median), yrs</strong></td>
<td>1 / 4</td>
</tr>
<tr>
<td><strong>Diagnosis</strong></td>
<td></td>
</tr>
<tr>
<td>Laryngeal disease</td>
<td>8</td>
</tr>
<tr>
<td>Prader Willi sd</td>
<td>6</td>
</tr>
<tr>
<td>Bronchopulmonary dysplasia</td>
<td>6</td>
</tr>
<tr>
<td>Treacher Collins</td>
<td>6</td>
</tr>
<tr>
<td>Pierre Robin sd</td>
<td>5</td>
</tr>
<tr>
<td>Polymalformative sd</td>
<td>5</td>
</tr>
<tr>
<td>Idiopathic OSA</td>
<td>5</td>
</tr>
<tr>
<td>Achondroplasia</td>
<td>3</td>
</tr>
<tr>
<td>Crouzon, Apert</td>
<td>2</td>
</tr>
<tr>
<td>Pycnodysostosis</td>
<td>2</td>
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<tr>
<td>Mucopolysaccharidosis</td>
<td>2</td>
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<tr>
<td>Goldenhar sd</td>
<td>1</td>
</tr>
<tr>
<td>Other</td>
<td>6</td>
</tr>
<tr>
<td><strong>Reason of withdrawal</strong></td>
<td></td>
</tr>
<tr>
<td>Improvement 75%:</td>
<td></td>
</tr>
<tr>
<td>spontaneous 2/3, after surgery 1/3</td>
<td></td>
</tr>
<tr>
<td>Non compliant, poor tolerance: 25%</td>
<td></td>
</tr>
</tbody>
</table>
IDEAS AND INNOVATIONS

Continuous Positive Airway Pressure for Upper Airway Obstruction in Infants with Pierre Robin Sequence

Amaddeo et al. Plastic and Reconstructive Surgery, 2016;137:609
Neonates with PRS evaluated over one year
n=44

Neonates seen as outpatients
n=7
- No UAO group

Neonates hospitalized
n=37
- No clinical UAO
  n=17
  - No UAO group
- Clinical UAO
  n=20
  - Moderate clinical UAO
    n=11
    Sleep study with gas exchange
  - Severe clinical UAO
    n=9
    Immediate CPAP in the NICU
    Severe UAO group

- Tracheotomy
  n=4

Moderate UAO group
CPAP
n=5
Abnormal sleep study
CPAP, n=4
Normal sleep study
n=7
Mild UAO group

Amaddeo et al.
Plastic and Reconstructive Surgery, 2016;137:609
Limitations of CPAP

- CPAP is an effective treatment for OSAS but:
  - patients do not tolerate (interface...)
  - patients are not compliant: intellectual disability, default of family structure...
  - patients may have too severe OSAS: CPAP dependance > ~ 18/24h
- Therapeutic options?
  - Surgery: tracheostomy, mandibular distraction...
  - Tolerate OSAS despite associated morbidity
  - …High Flow?
High flow nasal cannula for OSAS in children

Why should we use it?
How does it work?
Does it work in OSAS?
High flow nasal cannula: a growing (hot) topic

Pubmed citations
Nasal High-Flow Therapy for Primary Respiratory Support in Preterm Infants.
Roberts CT, Owen LS, Manley BJ, Fréisand DH, Donath SM, Daiziel KM, Pritchard MA, Cartwright DW, Collins CL, Malhotra A, Davis PG; HIPSTER Trial Investigators.

High flow nasal cannula for respiratory support in preterm infants.
Wilkinson D, Andersen C, O'Donnell CP, De Paoli AG, Manley BJ.

High-flow oxygen through nasal cannula in acute hypoxemic respiratory failure.
High flow nasal cannula for OSAS
HFNC: how does it work?

Washout of nasopharyngeal and intrapulmonary dead space through continual gas removal during expiration (enhance CO$_2$ removal) *Nahum Resp Care Clinic 2002*
HFNC: how does it work?

Reduction of inspiratory resistance (work of breathing)

HFNC: how does it work?

Improve mucociliary clearance (by providing warm and humidified gas)  
*Chidekel et al, Pulm Med 2012*
HFNC: how does it work?

Provide support pressure Arora B, Pediatr Emerg Care

![Graph showing mean pressure at different flow rates for open- and closed-mouth states.](image)

**FIGURE 3.** Mean pressure at different flow rates for open- and closed-mouth states.

Nasopharyngeal Airway Pressures in Bronchiolitis Patients Treated With High-Flow Nasal Cannula Oxygen Therapy

Bhawana Arora, MD,* Prashant Mahajan, MD, MPH, MBA,*† Marwan A. Zidan, PhD,‡ and Usha Sethuraman, MD†

Pediatric Emergency Care • Volume 28, Number 11, November 2012
Effect of HFNC Flow Rate, Cannula Size, and Nares Diameter on Generated Airway Pressures: An In Vitro Study

Emidio M. Sivieri, MS,E,1,2 Jeffrey S. Gerdes, MD,1,2,3 and Soraya Abbasi, MD1,2,3*


Mouth valve fully open

Airway Pressure (cmH₂O)

Intra-cannula Pressure (cmH₂O)

Prongs OD Nares ID Ratio prongs/nares

- 3.0 3.0 1.00
- 3.0 3.5 0.86
- 3.0 4.0 0.75
- 3.0 4.5 0.67
- 3.0 5.0 0.60
- 3.0 6.0 0.50
- 3.0 7.0 0.43
- 3.7 3.5 1.06
- 3.7 4.0 0.93
- 3.7 4.5 0.82
- 3.7 5.0 0.74
- 3.7 6.0 0.62
- 3.7 7.0 0.53

* intra-cannula pressure (for ratio = 1.00 and 1.06)
When mouth leaks are reduced a prongs/nares > 0.9 may dramatically increase the delivered pressure.
All patients had a positive end-expiratory pressure, with a direct relation between weight and pressure drop.

End expiratory airway pressure changes during HFNC from the mean airway pressure (4 ± 1.9 cmH₂O)
High flow nasal cannula for OSAS in children

Why should we use it?
How does it work?
Does it work in OSAS?
Effect of a High-Flow Open Nasal Cannula System on Obstructive Sleep Apnea in Children

Brian McGinley, MD\textsuperscript{a}, Ann Halbower, MD\textsuperscript{b}, Alan R. Schwartz, MD\textsuperscript{c}, Philip L. Smith, MD\textsuperscript{c}, Susheel P. Patil, MD, PhD\textsuperscript{c}, and Hartmut Schneider, MD, PhD\textsuperscript{c}


12 children, age 10 ± 2 years, with OSAS + mean BMI of 35 ± 14 kg/m\(^2\)

One night titration study with a high flow cannula system
5 patients with OSAS who did not tolerate CPAP:

1. Prematurity, bronchopulmonary dysplasia, *age 22 months*
2. Severe psychomotor retardation, *age 15 yrs*
3. Polymalformatif syndrome, *age 3 yrs*
4. Hypotonia, retrognatia, *age 2 yrs*
5. Treacher Collins, decanulation after mandibular distraction, *age 3 yrs*
No data about objective adherence
Population

• children aged 0 to 18 yrs with OSAS defined by:
  – \(\text{AHI}>10/\text{hour}\) and/or
  – oxygen desaturation index > 15/\text{hour}\) and/or
  – minimal \(\text{SpO}_2<90\%\) and/or
  – maximal \(\text{PtcCO}_2>50\ \text{mmHg}\)

• non compliant with an optimal CPAP therapy defined by a use < 2 hours/night, after at least 2 weeks of CPAP trial
High flow nasal cannula for OSAS: Necker protocol

Primary endpoint

• **objective compliance** (number of hours use / night) evaluated on the device after one month as the mean of the device usage time during the 4th week of use (sole option)

Secondary endpoints

• **objective compliance** after one week as the mean of the device usage time

• correction of OSAS on PG with HF
High flow nasal cannula for OSAS: Necker protocol

Procedure - 1

- High Flow is delivered by the myAIRVO device from Fisher Paykel with appropriate nasal cannula
- The highest tolerable flow and the largest cannula tolerated by the patient are chosen (in order to reach the highest pressure)
High flow nasal cannula for OSAS: our protocol

Procedure - 2

• HF is initiated during a 2 hours outpatient consultation or during hospitalisation
• A control visit is organized 1 week after initiation
• A respiratory polygraphy is performed between 1-3 months after initiation, when the patient tolerates the HFN for at least 6h/night.
## High flow nasal cannula for OSAS: Necker experience

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age (yrs)</th>
<th>Disease</th>
<th>AHI (n/h)</th>
<th>AHI with HFNC (n/h)</th>
<th>Flow (l/min)</th>
<th>Treatment adherence (h/night)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient 1</td>
<td>0.1</td>
<td>Pierre Robin sequence</td>
<td>14</td>
<td>6</td>
<td>10</td>
<td>6.8</td>
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<tr>
<td>Patient 2</td>
<td>1.8</td>
<td>Down syndrome</td>
<td>11</td>
<td>1</td>
<td>15</td>
<td>7.5</td>
</tr>
<tr>
<td>Patient 3*</td>
<td>6.4</td>
<td>Pfeiffer syndrome</td>
<td>13</td>
<td>0.5</td>
<td>10</td>
<td>6.5</td>
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<td>Patient 4</td>
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<td>64</td>
<td>awaiting control PG</td>
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<td>Patient 5</td>
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<td>Down syndrome</td>
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<td>0.5</td>
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<td>Patient 6</td>
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<td>46</td>
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<td>failure</td>
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<td>Down syndrome</td>
<td>26</td>
<td>awaiting control PG</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Patient 8</td>
<td>16.8</td>
<td>Down syndrome</td>
<td>10</td>
<td></td>
<td>20</td>
<td>failure</td>
</tr>
</tbody>
</table>

2 patients with developmental delay and behavior problems did not tolerate HF

* Patient 3 was tracheostomised after developing tracheal stenosis following neurosurgical intervention
Conclusion - 1

- HF seems to be efficient in mild to moderate OSAS in children
- HF may be better tolerated than CPAP, and could represent an alternative to CPAP in non-compliant patients
- Future studies
  - patient selection ?
  - optimal flow rate ?
Conclusion - 2

• Limitations of HF
  • no pressure monitoring: risk of high pressure when use with large cannula
  • no battery, alarms (security risk) and no in-built software