High Flow Nasal Cannula (HFNC)
• History of O$_2$ and HFNC development
• Mechanisms of action (beyond simple oxygen delivery)
• The importance of heated humidification
• COPD
  – Management today
  – The role of NHFC
  – Evidence
• Research/Case Studies
Oxygen

• Discovered in 1774 by heating red mercuric oxide
• English amateur chemist Joseph Priestley

Jeffrey Ward 2013, High-Flow Oxygen Administration by Nasal Cannula for Adult and Perinatal Patient: Respiratory Care, Jan 2013; Vol 58 No 1
Leigh 1974; Grainge 2004; Martin (website) 2011
Early Oxygen Delivery: Masks

- **Mid 1800’s**: Leaden masks
- **1930’s**: Hudson mask
- **1940’s**: Hudson mask
- **1960’s**: Hudson mask

Jeffrey Ward 2013, High-Flow Oxygen Administration by Nasal Cannula for Adult and Perinatal Patient: Respiratory Care, Jan 2013; Vol 58 No 1
Leigh 1974; Grainge 2004; Martin (website) 2011
Early Oxygen Delivery: Tents

Early 1900’s

1940’s

Jeffrey Ward 2013, High-Flow Oxygen Administration by Nasal Cannula for Adult and Perinatal Patient: Respiratory Care, Jan 2013; Vol 58 No 1
Leigh 1974; Grainge 2004; Martin (website) 2011
Early Oxygen Delivery: Nasal Cannula

Early 1900’s
Rubber catheters

1920’s
Paediatric care
Metal cannula

1930’s
Rubber tipped metal prongs

1940 +
Plastic/PVC, over the ear

Jeffrey Ward 2013, High-Flow Oxygen Administration by Nasal Cannula for Adult and Perinatal Patient: Respiratory Care, Jan 2013; Vol 58 No 1
Leigh 1974; Grainge 2004; Martin (website) 2011
A Fashionable Article in Luxury?

...circa 2008, Las Vegas NV
## Modern Oxygen Delivery

<table>
<thead>
<tr>
<th>ervoir</th>
<th>Flow Rate (L/min)</th>
<th>Oxygen Range %</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOW FLOW NASAL CANNULA</td>
<td>1 - 6</td>
<td>24 - 44</td>
</tr>
<tr>
<td>SIMPLE FACE MASK</td>
<td>5 - 15</td>
<td>40 - 60</td>
</tr>
<tr>
<td>HUMIDIFIED HIGH FLOW MASK</td>
<td>40 - 45</td>
<td>28 - 50</td>
</tr>
<tr>
<td>VENTURI STYLE MASK</td>
<td>2 - 15</td>
<td>24 - 60</td>
</tr>
<tr>
<td>RESERVOIR MASK</td>
<td>10 - 15</td>
<td>60 - 90</td>
</tr>
</tbody>
</table>
Limitations

Oxygen delivery has barely changed from initial versions of the face mask and nasal cannula, over 80 years ago

- Drying of the airway
- Energy expenditure in heating up oxygen
- Patient discomfort and stress
- Thicken secretions difficult to cough up/infection risk
- Failure to meet inspiratory demand
- Inaccurate oxygen delivery
- Multiple interfaces required
- Treatment failure, resulting in escalation of therapy

Leigh 1974; Waugh & Granger 2004
Nasal High Flow Development

1960’s
(flows up to 30 L/min)

present
(flows up to 60 L/min)

Lomholt et al 1968
A New Era: High Flow Nasal Cannula (HFNC)

The goal of HFT: to optimize spontaneous breathing

Respiratory support
- Reduction of dead space
- Dynamic positive airway pressure

Supplemental oxygen

Airway hydration

Patient comfort

Fisher & Paykel Healthcare
Dead Space

Approximately 150 ml of inhaled breath is from dead space - one third of inspiration.
Reduction of Dead Space

Clearance of expired air in the upper airways

Reduces rebreathing of gas with high CO$_2$ and depleted O$_2$

Increases alveolar ventilation

Reduction of Dead Space

Clearance of radio-active krypton tracer from upper airway model, superimposed on a CT scan of model. The clearance rate is linearly related to NHF.

Dynamic Positive Airway Pressure

Beyond traditional oxygen delivery:

- Respiratory support
  - Reduction of dead space
  - Dynamic positive airway pressure
- Airway hydration
- Patient comfort
- Supplemental oxygen
Dynamic Positive Airway Pressure

Compared to unassisted breathing, tidal volume increases and respiratory rate reduces as flow increases.

Dynamic Positive Airway Pressure

The slower breath and longer expiratory phase allows for improved alveolar ventilation.

**Dynamic™ Positive Airway Pressure**

- Breath- and flow-dependent airway pressure¹
- Promotes slow and deep breathing¹
- Increases alveolar ventilation¹

Increased airway pressure was significantly correlated with increased lung volume of 25.6%
Supplemental Oxygen

Beyond traditional oxygen delivery:

Respiratory support
- Reduction of dead space
- Dynamic positive airway pressure

Airway hydration

Patient comfort

Supplemental oxygen
Supplemental Oxygen

Confidence in the delivery of blended, humidified oxygen\textsuperscript{1,2}

1 Ritchie J. et al. Anaesth Intensive Care, 2011
Supplemental Oxygen

Providing confidence in the delivery of blended humidified oxygen

1 Ritchie J. et al. Anaesth Intensive Care, 2011
Airway Hydration

Beyond traditional oxygen delivery:

- Airway hydration
- Respiratory support
  - Reduction of dead space
  - Dynamic positive airway pressure
- Patient comfort
  - Supplemental oxygen
**Optimal Humidity**

- Emulates the natural balance of heat and humidity in healthy lungs\(^1\)
- Enables the comfortable delivery of high flows\(^2\)
- Improves mucociliary clearance\(^3\)

37°C
44 mg H\(_2\)O/L gas

2. Roca et al. Respir Care. 2010
Airway Hydration

**OPTIMAL HUMIDITY**

Prevents desiccation of the airway epithelium\(^1,2\)

Improves mucus clearance\(^1,2\)

---

Nebulized Water vs. Active Humidification
Patient Comfort

Beyond traditional oxygen delivery:

- Respiratory support
  - Reduction of dead space
  - Dynamic positive airway pressure

- Patient comfort

- Airway hydration
- Supplemental oxygen
Patient Comfort

Heating and humidification of gas improves patient comfort and tolerance of therapy.

1. Roca, O et al. Respir Care 2010
2. Maggore et al AJCCM 2014
Physiological outcomes

NASAL HIGH FLOW PROMOTES:

- Reduced respiratory rate
- Reduced carbon dioxide
- Reduced work of breathing
- Increased tidal volume
- Increased end expiratory lung volume
- Improved mucus clearance
- Improved oxygenation

Respiratory support
- Reduction of dead space
- Dynamic positive airway pressure

Airway hydration

Supplemental oxygen

Patient comfort
Timeline of Events

Sztrymf et al, 2011 associated HFNC with sustained and beneficial effects on oxygenation and clinical parameters in patients with acute respiratory failure

Similarly, Rittayamai et al 2013, showed significant improvement in post-extubation patients

- **Heart rate**: 10 minutes
- **Respiratory rate**: 5 minutes - 15 minutes
- **Oxygenation**: 10 minutes - 15 minutes
- **Dyspnea**: 10 minutes - 30 minutes
- **Supraclavicular retraction**: 30 minutes
- **Thoracoabdominal asynchrony**: 30 minutes
Today in the hospital environment, HFNC is being utilized for a variety of patients with different diseases.

### Patients that Benefit from HFNC

<table>
<thead>
<tr>
<th>Acute respiratory failure</th>
<th>Post-cardiac surgery</th>
<th>Do-not-intubate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intensive care</td>
<td>Heart failure</td>
<td>Bronchoscopy</td>
</tr>
<tr>
<td>Chronic airway disease</td>
<td>Post-extubation</td>
<td>Bronchiectasis</td>
</tr>
<tr>
<td>Weaning from tracheostomy*</td>
<td>Chest trauma*</td>
<td>Pre-oxygenation prior to anesthesia*</td>
</tr>
</tbody>
</table>
COPD

Chronic Obstructive Pulmonary Disease

Chronic and progressive lung disease, characterized by:

- Persistent airflow limitation
- Enhanced chronic inflammatory response

Exacerbations and comorbidities contribute to the overall severity in individual patients

The current healthcare model treats patients in the acute phase, but very few receive active management for the chronic component
COPD in the United States

- The third leading cause of death \(^1\)
- 15 million Americans have been diagnosed \(^2\)
- 50% of adults with poor pulmonary function were not aware that they had COPD \(^2\)
- COPD accounts for 1 out of 5 index for readmission within 30 days \(^3\)
- 15 States reported that the 30 day readmission rate for any diagnosis of COPD was 17.3% \(^3\)

3. AHRQ Statistical Brief #121 (2008)
Costs of the COPD Patient

Costs attributable to having COPD were projected to increase to $49 billion by 2020
Where are the Direct Costs?

- ER visits
- Length of stay
- Avoidable admissions

Costs were significantly higher for readmissions to that of initial stays. On average a COPD 30-day readmission costs more than 50% higher than any other diagnosis.  

1 AHRQ Statistical Brief #121 (2008)
Goal: Prevent Exacerbations (AECOPD)

- With each exacerbation, lung function is reduced
- The previous level of lung function is never reached again
- The patient continues to deteriorate with each exacerbation
  - Increased infection risk
  - Increased frailty
  - Comorbidities
  - Decreased ventilation
  - More likely to need ER visit
Global Initiative for Chronic Obstructive Lung Disease

Initiated in 1998, recommendations for management of COPD based on best scientific information available.

Simple system for classifying COPD severity

Reviewed yearly
According to GOLD

02 Delivery:
Venturi masks (high flow devices) offer more accurate and controlled delivery of oxygen than do nasal prongs, but are less likely to be tolerated by the patient.

NIV:
Has been shown to improve acute respiratory acidosis, decrease respiratory rate, work of breathing, but doesn’t improve a patient’s quality of life.

Exacerbations:
The most common causes appear to be respiratory tract infections

*Routine follow-up is essential in COPD*
Airway infection is the main cause of exacerbation

- Mucous retention and clearance problems, leads to poor ventilation and a breeding ground for infection
- Poor ventilation/chronic cough, leading to respiratory fatigue
- Inactivity and reduced quality of life
- Exacerbations, requiring antibiotics, steroids and possible ER visit/hospitalization
- Each exacerbation, the patient does not return to the previous lung function level
- As lung function decreases, patient is more vulnerable to exacerbations and co-morbidities
Breaking the Cycle

Where to intervene?

Prevent infections that cause exacerbations, by clearing secretions and improving ventilation

- Improve Mucous Clearance
- Reduce Bacterial/Viral Infections
- Improve Ventilation, Hypoxemia, Anxiety
- Reduce rate of declining lung function and improve quality of life
- Reduce Exacerbations that lead to treatment measures
Present COPD Management

Smoking cessation
Pulmonary rehab
Flu vaccination
Long-term oxygen therapy
LAMA – long acting muscarinic antagonist
LABA – long acting beta antagonist
ICS – inhaled corticosteroids
Non-invasive ventilation
Lung volume reduction surgery
Transplant

Few non-pharma therapies available for home use!
HFNC in the Home

Rea et al. 2010

**STUDY**

*Rea et al. 2010*, compared long-term humidification therapy (LTHT with Optiflow) with usual care on frequency of exacerbations, lung function, quality of life and exercise capacity in COPD patients.

**METHOD**

- COPD or bronchiectasis patients
- n=48 usual treatment
- n=60 LTHT group (≥2 hours every day for 12 months)
- Optiflow was delivered at 37°C at a flow rate of 20 or 25 mL/min

**RESULTS**

- Significantly lower number of exacerbation days over 12 months from 33.5 to 18.2 days
- Median time to first exacerbation was significantly longer from 27 to 52 days


DEVICES USED: F&P MR880 and F&P Optiflow
### Rea et al. 2010

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control</th>
<th>Treatment</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decreased exacerbation frequency by 18 %</td>
<td>3.63</td>
<td>2.97</td>
<td>0.067</td>
</tr>
<tr>
<td>Decreased no. of exacerbation days by 46 %</td>
<td>33.5</td>
<td>18.2</td>
<td>0.045</td>
</tr>
<tr>
<td>Increased median time to first exacerbation by 95%</td>
<td>27 days</td>
<td>52 days</td>
<td>0.049</td>
</tr>
<tr>
<td>Decreased antibiotic use by 40%</td>
<td>38.5% of days</td>
<td>22.8% of days</td>
<td>0.008</td>
</tr>
<tr>
<td>Increased Forced Expiratory Volume (FEV1) by 10%</td>
<td>Increased by 110 mL (10%)</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>Increased Forced Vital Capacity (FVC) by 15%</td>
<td>Increased by 330 mL (15%)</td>
<td>0.006</td>
<td></td>
</tr>
<tr>
<td>Improved Quality of Life Scores (Total)</td>
<td>Baseline</td>
<td>6.8 units above baseline</td>
<td></td>
</tr>
</tbody>
</table>
Hasani et al. 2008 used a radio-aerosol technique to measure mucociliary clearance before and after 7 days of humidification.

**METHOD**

- 10 bronchiectasis patients
- Delivered optimally humidified flow of 20 - 25 L/min through nasal cannula

**RESULTS**

- Following humidification, mucociliary clearance was considerably improved
- Improved mucociliary clearance may slow the rate of disease progression


DEVICES USED:
F&P MR880 and F&P Optiflow
Further studies are underway to establish the role of NHF in the home and preliminarily data is promising.
Increasing Research...
Maggiore et al. 2014
American Journal of Respiratory and Critical Care Medicine

STUDY
Maggiore et al. 2014 compared the efficacy of nasal high flow (NHF) to Venturi mask. Primary outcome PaO$_2$/FiO$_2$SET

METHOD
- 105 patients, post-extubation randomized to receive NHF or a Venturi mask

RESULTS
- Significant reductions in the requirement for reintubation from 21% to 4% and any other form of ventilatory support from 35% to 7% in the NHF group
- Improved oxygenation
- Fewer desaturations and interface displacement
- Improved comfort and airway dryness


DEVICE USED: F&P Optiflow™
Stephan et al. 2015
Journal of the American Medical Association

STUDY

A 6 centre randomized non-inferiority trial comparing high flow nasal oxygen (HFNO) with Bi-PAP in hypoxemic patients, post cardiothoracic surgery. The primary outcome was treatment failure.

METHOD

- 830 post-operative patients
- Randomized to receive either HFNO or Bi-PAP
- Non-inferiority was demonstrated if the lower boundary of the 95% CI less than 9%.

RESULTS

- HFNO was not inferior to Bi-PAP. Treatment failed in 21% of HFNO patients and 21.9% of BiPAP patients.
- Significantly less skin breakdown with HFNO.
- Reduced nurse workload; interface displacement 6 times per 24 hours with BiPAP compared with 1 per 24 hours with HFNO.
**Frat et al. 2015**
The New England Journal of Medicine

**STUDY**
A 23 centre RCT comparing high flow oxygen (HFO) to both non-rebreather mask and NIV. The primary outcome was the proportion of patients intubated at day 28.

**METHOD**
- 310 patients pre-intubation in acute hypoxemic respiratory failure (PaO₂:FiO₂ ≤ 300 mm Hg) were randomized to receive HFO, non-rebreather mask or NIV.

**RESULTS**

- **Significant reduction in intubation rate**
  (PaO₂:FiO₂ ≤200 mm Hg)
  - Hazard ratio for death at 90 days:
    - Standard oxygen versus HFO: 2.01 (P=0.046)
    - Noninvasive ventilation versus HFO 2.50 (P=0.006)

- **Significant increase in ventilator-free days**

- **Significantly reduced intensity of respiratory discomfort and dyspnea**
Case Studies...
CASE STUDY: ESCALATION

BON SECOURS ST. FRANCIS HEALTH SYSTEM,
GREENVILLE, SC
Joseph Whitten, Director Respiratory Care Services

SITUATION
Bon Secours St. Francis Health System was looking to identify ways to reduce cost and improve patient outcomes within their hospitals as part of a system-wide transformation program.

SOLUTION
After learning about heated humidification and nasal high flow they introduced it to their 15-bed ICU (and other critical care areas), then measured and managed data for 12+ months.

Disclaimer: Any clinical opinions in this Case Study are the opinions of the contributing author and are given for information purposes only. The clinical opinions are not intended as and do not substitute medical advice.
CASE STUDY: ESCALATION

BON SECOURS ST. FRANCIS HEALTH SYSTEM, GREENVILLE, SC
Joseph Whitten, Director Respiratory Care Services

RESULTS

<table>
<thead>
<tr>
<th>Average hospital length of stay 2011 (days)</th>
<th>Bilevel utilization (%)</th>
<th>Hospital ventilator use (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>After</td>
<td>Before</td>
</tr>
<tr>
<td>16</td>
<td>12</td>
<td>102</td>
</tr>
<tr>
<td>-4.5 DAYS</td>
<td>-45%</td>
<td>-9%</td>
</tr>
</tbody>
</table>

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CONCLUSION

Proactive use of nasal high flow delivered results:

- Reduced Bilevel patient days by 1320 days
- Reduced mechanical ventilation patient days by 641 days
SITUATION
As an academic facility, OU Medical Center attempts to stay at the forefront of new medical developments and from their review of potential patient and economic benefits they established a nasal high flow evaluation with three aims:

- Reduce Bilevel usage to reduce Bilevel rental costs
- Increase patient comfort and improve patient care
- Provide better patient outcomes

SOLUTION
OU Medical Center instigated a three-month evaluation of nasal high flow in their 28-bed MICU.

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RESULTS

Initial analysis after the three-month evaluation found:

- **Bilevel rental savings per month of $1,500 to $4,000**
- **Potential increase in patient comfort compared to Bilevel**
- **Patients found nasal high flow less stressful to wear than Bilevel mask**
- **RNs, RTs and MDs found it easy to get patients setup with nasal high flow**
- **Early intervention [with nasal high flow] in patients with respiratory distress may prevent escalation**
High Flow O2 Therapy

- Reduced respiratory rate vs. face masks\(^1\)\(^-\)\(^5\)
- Improved oxygenation vs. low flow oxygen\(^2\) and face mask\(^3,6\)
- Increased tidal volume vs. low flow oxygen\(^2\)
- Improved subjective dyspnea vs. low flow oxygen\(^2\) and face mask\(^3\)
- Reduced mortality vs. std. oxygen and NIV\(^3\)
- Greater overall comfort than face mask\(^8,3,4\)
- Less skin breakdown than BiPAP\(^8\)
- Significantly less nurse workload than BiPAP\(^8\)
- Non-inferior to BiPAP\(^8\)
Summary

• Existing O2 delivery methods today are limited
• Non-pharma therapies for managing COPD in the home are few
• Increasing evidence that during an acute respiratory event, e.g. COPD exacerbation, HFNC has a role to play and is equal to bi-level in terms of outcome, yet preferred by the user
• Studies are underway to establish the role of HFNC for long-term use in the home, e.g. COPD; preliminarily data promising
Questions
REFERENCES


REFERENCES


Rittayamai N, Tscheikuna J, Praphruetkit N, Kipinyochai S. Use of high-flow nasal cannula for acute dyspnea and hypoxemia in the emergency department. Respir Care. Published online June 9, 2015: (DO: 10.4187/respcare.03837).


