High Velocity Nasal Insufflation (Hi-VNI™)
Emergency Medicine Application

Kansas Society for Respiratory Care
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Disclosure & Background

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  Area Clinical Manager
  St. Louis Territory

• Employee of Vapotherm, Inc.,
  Exeter, NH
Learning Objectives

• Discuss the Emergency Medicine application of High Velocity Nasal Insufflation

• Understand High Velocity Nasal Insufflation Mechanisms of Action

• Learn how to implement a High Velocity Nasal Insufflation Protocol – including identify the appropriate patients

• Review current supporting clinical data
Can’t Breathe!
Continuum of Care

- **High Flow Nasal Cannula**
  - Oxygen therapy that delivers high flows through a nasal cannula.

- **High Velocity Nasal Insufflation**
  - High Flow and High Velocity
    - Refined form of HFNC
  - Improves ventilation efficiency
  - Reduces work of breathing
  - Delivers a specific FIO2
Patient Example: Congestive Heart Failure

66 year old CHF Patient

15 L/min from the wall oxygen supply initiated. An ABG & clinical observation that this therapy did not alleviate dyspnea or hypoxemia. The patient was switched from the Salter cannula to Vapotherm (25 L/min and 100% oxygen).
Patient Example: COPD Exacerbation

A 60 year-old patient with history of COPD, having been intubated in the past month for a COPD exacerbation, arrived in the Emergency Department at Athens Regional Medical Center. Initial assessment noted tachypnea with nasal flaring and purse lipped breathing, as well as bilateral wheezing and wet cough.

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<th>pH</th>
<th>PaCO₂</th>
<th>PaO₂</th>
<th>HCO₃</th>
<th>SaO₂</th>
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<td>74</td>
<td>78</td>
<td>34</td>
<td>93</td>
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What therapy would you typically initiate?

A. Non-rebreather  
B. Bi-level  
C. Mechanical Ventilation  
D. High Flow Support
Patient Response

<table>
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<tr>
<th>Time</th>
<th>HR</th>
<th>RR</th>
<th>pH</th>
<th>PaCO₂</th>
<th>PaO₂</th>
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<td>68</td>
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Hi-VNI avoided an ICU admission and more invasive respiratory modalities
Mechanisms of Action
Respiratory Physiology and Ventilation

- At least 30% of inspired tidal volume is anatomical dead space.
- At start of inspiration anatomical dead space is filled with expiratory CO₂.
- Dead-space volume and gas composition impact breathing efficiency and ventilation.
High Velocity Nasal Insufflation (Hi-VNI)

Optimally heated & humidified gas via a small-bore nasal cannula flushes dead space of expiratory gas, creating a reservoir that facilitates oxygenation & alveolar ventilation.
Minute Ventilation = Tidal Volume x Respiratory Rate

Alveolar Ventilation = (Tidal Volume – Dead Space) x Respiratory Rate

Alveolar ventilation improves with a reduction in dead space volume independent of tidal volume and respiratory rate.
Requirements for Effective Therapy

• Nares are not obstructed
• Adequate flow and velocity to flush dead space
• Patient is spontaneously breathing

Facilitates CO₂ ventilation by reduction of dead space
Velocity, at a constant volume of flow, varies inversely with the cross sectional area of a tube.

\[
\text{Velocity} = \frac{\text{Distance}}{\text{Time}}
\]

Volume of Flow = 5 L/min → 5 L/min → 5 L/min

Velocity = 16.4 cm/sec
A = 5.08 cm²

Velocity = 32.8 cm/sec
A = 2.54 cm²

Adult Cannula Flow Velocity Comparison

- Small-Prong
- Large-Bore

Volumetric Flow (L·min⁻¹)

Velocity (m·sec⁻¹)
Prong Size Also Dictates Efficiency of Expiratory Gas Egress

The small-bore cannula allows greater opening for expiratory gas egress.
Prong Size Dictates Flow Velocity

Gas velocity impacts efficiency of expiratory gas flush from the dead space.

Note: CFD model assumes an open mouth.
Time to Flush is a Function of Respiratory Rate

Expiratory Phase (seconds)

Respiratory Rate

Adult Respiratory Distress
Optimal Gas Conditioning

High Flow Requires Optimal Humidity & Temperature
What is Humidity?

- The given amount of water vapor in the air at a specific temperature
- As the temperature increases, so does the amount of water vapor a given volume of air can hold, also called saturated capacity

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Saturated Capacity</th>
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<tr>
<td>22º C</td>
<td>18 mg/L</td>
</tr>
<tr>
<td>30º C</td>
<td>32 mg/L</td>
</tr>
<tr>
<td>37º C</td>
<td>44 mg/L</td>
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What is Absolute Humidity?

Absolute Humidity is the actual water vapor content of a given volume of air.

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What is Relative Humidity?

Relative humidity is the percent of water vapor content of the saturated capacity at a given temperature.

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<td>18 mg/L</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>100%</td>
<td>54%</td>
<td>39%</td>
</tr>
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</table>
Proper Gas Conditioning is Critical to Hi-VNI Tolerance & Airway Health

Physiologic state of gas in the lungs:

- 37°C
- 100% Relative Humidity

Or

(44 mg H₂O/L)

Suboptimal Humidification Results in Mucociliary Dysfunction

Mucosal Function vs. Inspired Humidity

Delivery of Optimal Humidification

**Average Absolute Humidity (mg H₂O/L)**

- **Optiflow**
  - 30 L/min: 35 mg H₂O/L
  - 40 L/min: 35 mg H₂O/L

- **Airvo 2**
  - 30 L/min: 35 mg H₂O/L
  - 40 L/min: 35 mg H₂O/L

- **Vapotherm**
  - 5 L/min: 40 mg H₂O/L
  - 10 L/min: 45 mg H₂O/L
  - 20 L/min: 40 mg H₂O/L
  - 30 L/min: 45 mg H₂O/L
  - 40 L/min: 45 mg H₂O/L

Flows Tested:
- **Vapotherm**
  - 5 L/min, 10 L/min, 20 L/min, 30 L/min, 40 L/min
- **F & P**
  - 20 L/min, 40 L/min, 50 L/min

References:
Mitigating Rainout

Heated Wire

Water Jacket
IS IT HUMID TODAY?

IT FEELS A BIT HUMID TO ME
Patient Selection & Protocol Implementation
Who are the right Patients?

• **Symptoms**
  - General Dyspnea
  - Bi-level intolerant
  - Hypercapnia
  - Refractory Hypoxemia
  - Increased cardiac workload
  - Increased Work of Breathing

• **Conditions**
  - Acute COPD Exacerbation
  - Mild/Moderate Congestive Heart Failure
  - Asthma
  - Pneumonia
  - Bronchitis
  - Bronchiolitis (RSV)
  - Influenza
Keep in mind...

- Patients must be:
  - Spontaneously Breathing
  - Alert & Oriented
  - Able to Protect Airway
Choose the Appropriate Interface

• Cannula should be sized not to occlude greater than 50% of the nares
• Cannula prongs should be spread enough not to pinch the nasal septum
• Allow the system to reach at least 33°C before connecting delivery tube to the cannula
Patient Application Guidelines

Start flow high and go low - Hi-VNI is a de-escalation therapy

Clinical Use Guidelines
Assess these parameters to determine therapy initiation:
• \( \text{PaO}_2 < 80 \text{ mmHg} \)
• \( \text{SaO}_2 < 90\% \)
• \( \text{PaCO}_2 > 45 \text{ mmHg} \)
• Tachycardia
• Tachypnea

<table>
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<tr>
<th>Hypercarbia (increased WOB)</th>
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<td>( \text{FLOW} ) 40 L/min</td>
<td></td>
<td>Titrator to effect comfort/ventilatory effect</td>
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<tr>
<td>( \text{FIO}_2 ) 35%</td>
<td></td>
<td>Desired ( \text{SpO}_2 )</td>
</tr>
<tr>
<td>( \text{TEMP.} ) 37°C</td>
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<td>Comfort/secreton mobilization</td>
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IF YOU COULD CHECK IF THE CANNULA IS CONNECTED BEFORE CALLING ME...

YEAH...THAT BE GREAT
High-Flow Oxygen Adult Study


<table>
<thead>
<tr>
<th>Group</th>
<th>Flow / Pressure</th>
<th>FiO₂</th>
<th>Duration / Application</th>
<th>Outcome: Intubation Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mask</td>
<td>13 L/min 100% O₂</td>
<td>&gt; 0.80</td>
<td>Continuous or until recovery or intubation</td>
<td>47%</td>
</tr>
<tr>
<td>HFNC</td>
<td>48 L/min</td>
<td>0.82</td>
<td>Continuously for at least 2 days</td>
<td>38%</td>
</tr>
<tr>
<td>NIPPV</td>
<td>PIP/PEEP 8/5 cmH₂O</td>
<td>0.67</td>
<td>8 hr /day for at least 2 days; HFNC between applications</td>
<td>50%</td>
</tr>
</tbody>
</table>

- Patients admitted to the ICU in respiratory distress: 4,777
- Patients excluded for hypercapnia: 582
- Underwent randomization: 313
Memorial Herman Poster Data

High Flow Therapy In The Emergency Department - A Paradigm Shift?

R. Graham RRT1, B Melton RRT1, S Croft RRT1, T Green RRT1, O Easton RRT1, B Bauer RRT1, P Doshi MD2

1Memorial Hermann Healthcare System, Houston, TX
2UT Houston Medical School, Houston, TX

Abstract

Methylene Blue-reversed mouse model for treatment of respiratory disease, especially related to COPD. RRTs in this ED have been recently trained. A number of patients may ultimately be managed through inhalation therapy, including nebulizer treatments.

Methods

Results

A table of 10 Technical Assessment Forms was compiled for these facilities. The data collected include: (Figure 3):

- COPD (25.5%)
- Asthma (5.5%)
- Other (25.5%)
- N/A (25.5%)

Discussion

Our work has recognized limitations, and was not intended to formulate definitive clinical conclusions. Rather, it is intended to determine whether or not adoption of HFT in this ED was feasible. We envision a technical protocol that will be developed and reported by the research team.

Conclusions

There appears to be sound evidence to support application of HFT in the setting of COPD exacerbation, especially for those patients who require mechanical ventilation. Our group is currently in the process of designing a protocol aimed at improving the overall experience and utilization of HFT in the ED. We have demonstrated the feasibility of this approach.
Initial Presumed Diagnosis

- COPD: 31%
- CHF: 29%
- Asthma: 14%
- General Dyspnea: 11%
- Pneumonia: 6%
- Pulmonary Fibrosis: 3%
- Sarcoidosis: 3%
- Other: 3%
Known Disposition %

- Discharged Home: 12%
- ICU Admission: 32%
- Floor Admission: 56%
Multicenter Emergency Dept. Experience

- Data from 6 centers compiled in publication with 128 forms
  - Athens Regional Medical Center, Athens GA
  - Memorial Hermann – TMC, Houston TX
  - Memorial Hermann – Northeast, Humble TX
  - Memorial Hermann – The Woodlands, TX
  - Erlanger Health System, Chattanooga, TN
  - Missions Hospital, Asheville, NC

- Demonstrated clinical & economic benefits
- Expertise and clinical pathways for use (protocol developed)

Assessment of High Flow Nasal Cannula Therapy use in the Emergency Department Setting: Observations of Practice Across Four Systems

Sheldon Spry, BRT, Terti Alake, RRT-NPS, Rose Deneen, RPA, RT, KC Russell Graham, BRT, RRT, CPS, Bob Mele Anderson, RRT, Suzanne Crotte, MHS, RRT, Terry Emen, EJ, REY, Todd McCullh, MBA, RRT, Judy Miller, ERT, RRT, Bryan Anderson, MHS, RRT, Tracy Greens, RRT, Charles Dunlap, BRT, RRT-NPS, Mark Koinkeng, MBA, CFM, CPH, TH, Thomas L. Miller, PhD

Abstract

Objective: Recent evidence suggests that high flow nasal cannula (HFNC) may have a meaningful impact on care, workflow and economics in the Emergency Department (ED) setting. The goal of the current project was to better understand how utilization of HFNC as a front line respiratory support would impact workflow within the ED and to define hypotheses for future research related to patient outcomes.

Methods: A multicenter study was designed to assess the utilization and value of HFNC in the ED setting using a real-time, case by case assessment of staff perceptions and decisions making around the utilization of HFNC. From May of 2015 through March of 2016, six hospitals in four states across four facilities participated in the project. HFNC was utilized as a front line therapy in place of other oxygen therapy modalities, and used based on clinician discretion. For each individual use of HFNC, attending staff responded to questions regarding the decision to utilize HFNC, perceptions on how the therapy performed, and decisions on patient disposition. The respondents were instructed to record their intervention at the time of therapeutic intervention.

Results: A total of 128 assessments were completed. Clinical objective pulmonary disease (COPD), ground-level and community-acquired (COP) represented the majority of working diagnoses treated with HFNC. 41%, 48% and 18%, respectively. Severity scores of HFNC interventions were documented with hypoxemia or of them involved elevated arterial carbon dioxide levels. Respondents indicated excellent respiratory responses as well as high ease of use and patient tolerance. Disposition decisions were to admit 36% of cases to the ICU, 56% to the medical floor and 8% to discharge.

Conclusion: HFNC may be useful in the ED to rapidly stabilize patients in significant respiratory distress with accurately tolerated respiratory support modality. Clinical use guidelines were established that were effective and accepted by clinical staff. The use of the therapy may have utility in reducing ICU admissions associated with the use of NIV from primary respiratory support.

About the authors:
- 130 Editors, Regional Medical Center, Athens GA
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- 16 Erlanger Health System, Chattanooga, TN
- 17 Mission Hospital, Asheville, NC
- 18 Memorial Hermann-Long Beach Medical Center, Houston, TX

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Initial Respiratory Assessment

- Increased WOB
- Combined Failure
- Hypercapnia
- Hypoxemia
Known Disposition

- ICU: 41%
- General Care Floor: 54%
- Discharged Home: 5%
Summary

• HiVNI is able to flush expiratory gas from the dead space to facilitate oxygenation and alveolar ventilation

• HFNC is primarily an oxygen therapy

• Patient comfort and adherence are optimal with Hi-VNI when compared to conventional respiratory modalities

• HiVNI may be used in the Emergency Department with patients in respiratory distress and/or impending respiratory failure