NON-INVASIVE VENTILATION

Jason C. Brainard, MD
Assistant Professor
Department of Anesthesiology
Objectives

- Overview of Non-Invasive Ventilation
- Discuss Specific Indications for Non-Invasive Ventilation
History of “Non-Invasive” Ventilation

- 1700s – Reports of bellows-type device used for resuscitation of drowning victims
- 1832 – Dalziel develops prototype negative-pressure tank ventilator
- 1928 – Drinker-Shaw introduces iron lung
- 1931 – Emerson’s modified iron lung becomes standard of care for treatment of polio
Modern Non-Invasive Ventilation

- 1980s – Initial Trials
- Positive pressure ventilation delivered through a non-invasive interface
  - facemask
  - nasal mask
  - nasal cannula
  - helmet
- aka: NIPPV
Modern Non-Invasive Ventilation?

- **New York Times, May 2009**
  - “Martha Mason, who wrote book about her decades in an iron lung, dies at 71”

- **Sydney Morning Herald, November 2009**
  - “A woman who spent more than 60 years in an iron lung to treat polio has died, aged 83”
Goals for NIV

- Improve Oxygenation
- Improve Ventilation
- Stabilize/Improve pH
- Reduce Work of Breathing
Benefits of NIV

- Avoids Intubation
- Decreased Infection
  - Ventilator-Associated Pneumonia (VAP)
  - Sinusitis
  - UTI and CLABSI
- Decreased Need for Sedation/Analgesia
- Decreased Length of Stay
  - ICU
  - Hospital
- Improved Mortality
- Easier to Wean
- Reduce Afterload / Increase Cardiac Output
Risks of NIV

- Delayed Intubation (Emergency Intubation)
- Reduced Clearance of Secretions
- Gastric Distention
- Increased Risk Aspiration
- Skin Breakdown
Physiology of NIV

- Improve Oxygenation
  - Decrease atelectasis (open alveoli)
  - Improve functional residual capacity (FRC)
- Improve Ventilation / Respiratory Acidosis
  - Improve compliance
  - Increase tidal volume
- Decrease Work of Breathing
  - Unload respiratory muscles
  - Improve dyspnea
CPAP vs. BIPAP

- **CPAP** – Continuous Positive Airway Pressure

- **BIPAP** – Biphasic Positive Airway Pressure
  - Multiple programs/settings available
## CPAP vs. BIPAP

<table>
<thead>
<tr>
<th></th>
<th>CPAP</th>
<th>BIPAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>$O_2$</td>
<td>↑↑</td>
<td>↑↑</td>
</tr>
<tr>
<td>$CO_2$</td>
<td>↓</td>
<td>↓↓</td>
</tr>
<tr>
<td>Work of Breathing</td>
<td>↓</td>
<td>↓↓</td>
</tr>
<tr>
<td>Tolerance</td>
<td>↑</td>
<td>↓</td>
</tr>
</tbody>
</table>
Ventilator Interface

**Facemask**
- Improved oxygenation and ventilation
  - Mouth breathers
  - Increased resistance to airflow through nose

**Nasal Mask**
- Improved acceptance
  - Less claustrophobic
  - Better communication
- Improved clearance respiratory secretions

Predictors of Success / Failure

- Improvement in $\text{O}_2/\text{CO}_2$ within 2 hours
- Decreased Respiratory Rate
- Small Air Leak
- Good Coordination / Cooperation
- Low-acuity illness at admission (SAPS < 34)

Contraindications to NIV

- Cardiac or Respiratory Arrest
- Non-Respiratory Organ Failure
  - Severe encephalopathy (GCS < 10)
  - Upper gastrointestinal bleeding
  - Hemodynamic instability or unstable cardiac arrhythmia
- Inability to protect the airway
- Inability to clear respiratory secretions
Contraindications to NIV

- Upper airway obstruction
- Facial surgery, trauma, or deformity
- High risk for aspiration
- Prolonged duration of mechanical ventilation anticipated

“Where should they go?”

- ICU
  - NIV for OSA is different than NIV for Acute Respiratory Failure
Indications for NIV

“A trial of NIPPV is worthwhile in most patients who do not require emergent intubation and have a disease known to respond to NIPPV and have features that predict success using NIPPV, assuming that they lack contraindications”

Bauman KA, Hyzy RC. UpToDate.com.
Indications for NIV

- COPD exacerbations
  - Best evidence to date (multiple large RCTs)
  - Avoids intubation and improves mortality

**THE LANCET**

Early use of non-invasive ventilation for acute exacerbations of chronic obstructive pulmonary disease on general respiratory wards: a multicentre randomised controlled trial

- Intubation Rate: 27% vs. 15%
- Mortality Rate: 20% vs. 10%

Indications for NIV

- Acute Cardiogenic Pulmonary Edema
  - High quality evidence (multiple small RCTs, MAs)
  - Avoids intubation and improves mortality

Intubation Rate Reduced by 57% (RR 0.43)
Mortality Reduced by 45% (RR 0.55)
No Difference Between CPAP and BIPAP

NIV for Acute Cardiogenic Pulmonary Edema

- 1069 Patients Enrolled (More Than Meta-Analysis)
- No Statistical Effect on Intubation Rates or Mortality
- Pt’s. Requiring Emergency Intervention Excluded
- DNR not discussed
- Extremely Low Intubation Rate (<3%) in Both Groups
- Significant Crossover from Conventional $O_2$ to NIV

Indications for NIV

- **Pneumonia**
  - Moderate level evidence (few RCTs, many observational)
  - Few specific to hospital acquired PNA (mostly CAP)
  - Results conflicting (possible harm)
  - Like related to volume, viscosity, and ability to clear secretions

- **Aspiration Pneumonitis / Pneumonia**
  - No Studies
Indications for NIV

- **Asthma**
  - Limited evidence
  - May be beneficial in avoiding ARF and intubation

- **DNI**
  - Good evidence
  - Improves survival and discharge vs. conventional $O_2$ therapy

Hilbert G et al. NEJM. 2001;344:481-487.
Indications for NIV

- Post-Extubation
  - Prevention vs. Treatment
Indications for NIV

- Post-Extubation
  1. Prevention of ARF
     - Moderate Evidence (2 RCTs)
     - Prevents re-intubation and may improve mortality

  Re-intubation rate: 8% vs. 24%
  Mortality: 6% vs. 18% (p=.064)
  60% Increased risk mortality w/ re-intubation

Indications for NIV

- **Post-Extubation**

2. Treatment of Post-Extubation ARF
   - Moderate Evidence (2 RCTs)
   - No reduction in re-intubation
   - May increase mortality

- [Link to Original Article](NEJM.pdf)
  - Noninvasive Positive-Pressure Ventilation for Respiratory Failure after Extubation
    - No Difference in Rate of Re-Intubation
    - Mortality: 25% (NIV) vs. 14% (p=.05)

Indications for NIV

- Post-op Respiratory Failure
Indications for NIV

- Post-op Respiratory Failure
  - Reported to occur in 5-10% patients after major thoracic or abdominal surgery
  - Most Important Morbid Postoperative Pulmonary Complication → Atelectasis
    - Poor post-operative coughing (Pain)
    - Shallow inspiration (Pain)
    - Increased interstitial lung water
    - Significantly increases risk for pneumonia and ARF

Indications for NIV

- Post-op Respiratory Failure

Nasal Continuous Positive Airway Pressure: A Method to Avoid Endotracheal Reintubation in Postoperative High-risk Patients With Severe Nonhypercapnic Oxygenation Failure

- Heterogeneous Surgical Patient Population
- CPAP is safe, easy to apply, and effective

Post-op Respiratory Failure

“But what about my patients?”
NIV – Cardiac Surgery

- Diaphragm dysfunction
- Lung collapse during bypass
- Trauma to lung during operation
- Post-op Pneumonia in up to 6.5% patients

Prevention
- 6 RCTs identified

Treatment
- No studies

Cardiac Surgery – ARF Prevention

- 4 Studies (Matte, Pasquina, Zarbock, Kindgen-Milles)
  - Improved pulmonary function
  - Decreased incidence of pulmonary complications

- 2 Studies (Jousela, Pinilla)
  - +/- Improved pulmonary function
  - No reduction in pulmonary complications

Cardiac Surgery – ARF Prevention

- 468 Patients Randomized
- CABG and Valve Surgery
- 1º Endpoints: Hypoxemia, PNA, Re-intubation
- Excluded pts. with COPD and LV Dysfxn.

Cardiac Surgery – ARF Prevention

### Cardiac Surgery – ARF Prevention

![Table 2 — Pulmonary and Cardiac Complication and Resumption on the ICU or IMCU in the Study and Control Groups*](image)

*See Table 1 for abbreviation not used in the text.*

Cardiac Surgery – ARF Prevention

- Pulmonary Complications – 5% vs. 11%
  - (Hypoxemia, Pneumonia, Re-intubation)
- Readmission Rate – 3% vs. 6%

NIV – Thoracic Surgery

- High-incidence baseline severe pulmonary disease
- Resection of viable lung
- Lung collapse during surgery
- Severe pain with thoracotomy incision
- Pulmonary Complications in 25%

- Prevention
  - 2 studies identified
- Treatment
  - 4 studies identified

NIV – Thoracic Surgery

- All Studies Positive
  - Prevention and Treatment
Thoracic Surgery – ARF Treatment

- Followed 690 “high-risk” pts. after lung resection
- 16% of patients developed ARF
- 21% patients immediately intubated
- Remaining treated with NIV

Noninvasive ventilation for acute respiratory failure after lung resection: an observational study

Thoracic Surgery – ARF Treatment

Thoracic Surgery – ARF Treatment

- 85% successfully treated with NIV
- 20% patients receiving NIV developed PNA
- Factors associated with NIV failure –
  - Cardiac comorbidities
  - No initial response to NIV

NIV – Abdominal Surgery

- Highest rate of atelectasis
- Abdominal distention
- Severe pain and splinting
- 30-50% post-operative hypoxemia
- 8-10% w/ hypoxemia require re-intubation

- Prevention
  - 5 Studies Identified
- Treatment
  - 6 Studies Identified

NIV – Abdominal Surgery

- Prevention
  - 4/5 Studies Positive

- Treatment
  - 5/6 Studies Positive
Abdominal Surgery – ARF Treatment

- Laparotomy + 90min. viscera exposure
- Developed severe post-op hypoxemia
- 209 Patients Randomized
- 1º Endpoint: Re-intubation
- Excluded pts with COPD, OSA, CHF, Post-op PCO2 > 50

Abdominal Surgery – ARF Treatment

### Abdominal Surgery – ARF Treatment

<table>
<thead>
<tr>
<th></th>
<th>Control (n = 104)</th>
<th>CPAP (n = 105)</th>
<th>Difference of Means (95% CI)</th>
<th>P Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICU length of stay, mean, d</td>
<td>2.6</td>
<td>1.4</td>
<td>−1.2 (−2.0 to −0.3)</td>
<td>.09</td>
</tr>
<tr>
<td></td>
<td>Median (95% CI), d</td>
<td>1 (1-11)</td>
<td>1 (1-4)</td>
<td></td>
</tr>
<tr>
<td>Hospital length of stay, mean (SD), d</td>
<td>17 (15)</td>
<td>15 (13)</td>
<td>−2 (−6 to 2)</td>
<td>.10</td>
</tr>
<tr>
<td></td>
<td>Median (95% CI)</td>
<td>12 (7-47)</td>
<td>11 (6-35)</td>
<td></td>
</tr>
<tr>
<td>Relative Risk (95% CI)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pneumonia, No. (%)†</td>
<td>10 (10)</td>
<td>2 (2)</td>
<td>0.19 (0.04 to 0.88)</td>
<td>.02</td>
</tr>
<tr>
<td>Infection, No. (%)‡</td>
<td>11 (10)</td>
<td>3 (3)</td>
<td>0.27 (0.07 to 0.94)</td>
<td>.03</td>
</tr>
<tr>
<td>Sepsis, No. (%)§</td>
<td>9 (9)</td>
<td>2 (2)</td>
<td>0.22 (0.04 to 0.99)</td>
<td>.03</td>
</tr>
<tr>
<td>Anastomotic leakage, No.</td>
<td>6</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pneumonia, No.</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deaths, No. (%)</td>
<td>3 (3)</td>
<td>0 (0)</td>
<td></td>
<td>.12</td>
</tr>
</tbody>
</table>

Abdominal Surgery - ARF Treatment

- Re-intubation rate: 10% vs. 1%
- Decreased Pneumonia/Infection/Sepsis
- Trial stopped prematurely 2/2 efficacy

NIV for Esophagectomy

Case-control study, 36 matched patients
Respiratory failure due to Pneumonia

Non-invasive ventilation for treatment of postoperative respiratory failure after oesophagectomy

NIV for Esophagectomy

NIV for Esophagectomy

<table>
<thead>
<tr>
<th></th>
<th>NPPV (n = 36)</th>
<th>Control (n = 36)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumonia</td>
<td>13</td>
<td>12</td>
<td>1.000†</td>
</tr>
<tr>
<td>Infectious</td>
<td>23</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Aspiration</td>
<td>27(6)</td>
<td>28(7)</td>
<td>0.317‡</td>
</tr>
<tr>
<td>Postoperative SAPS II*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reintubation</td>
<td>9</td>
<td>23</td>
<td>0.008†</td>
</tr>
<tr>
<td>ARDS</td>
<td>8</td>
<td>19</td>
<td>0.015†</td>
</tr>
<tr>
<td>Septic shock</td>
<td>7</td>
<td>16</td>
<td>0.043†</td>
</tr>
<tr>
<td>Anastomotic leakage</td>
<td>2</td>
<td>10</td>
<td>0.027§</td>
</tr>
<tr>
<td>ICU stay (days)*</td>
<td>14(13)</td>
<td>22(18)</td>
<td>0.034‡</td>
</tr>
<tr>
<td>Hospital stay (days)*</td>
<td>34(19)</td>
<td>40(21)</td>
<td>0.208‡</td>
</tr>
<tr>
<td>Postoperative death</td>
<td>4</td>
<td>7</td>
<td>0.512§</td>
</tr>
</tbody>
</table>

NIV for Esophagectomy

- Re-intubation rate: 25% vs. 64%
- Anastamotic leak: 6% vs. 28%

Indicators of Failed NIV

- No improvement or stabilization of O₂/CO₂ in 2 hours
- Worsening tachypnea or inc. WOB
- Declining mental status or agitation
- Inability to clear secretions
- Inability to tolerate mask or ventilator

Indications for Emergent Intubation

- Challenging to define
- Indications based on accepted practice
- No data to support specific recommendations
- “I know it when I see it”

Absolute Indications

1) Conditions requiring immediate intubation
   - surgery/heavy-sedation/paralysis

2) Contraindicated/Failed NIV
Review

- Non-Invasive Ventilation
  - CPAP – ? Better Tolerated
  - BIPAP – Improved Ventilation and ↓ WOB
- COPD, Cardiogenic Pulm Edema – Strong Evidence
- Pneumonia – Limited Evidence
- Post-Extubation ARF
  - Prevention – Mod. Evidence
  - Treatment – No Benefit, Possible Harm
Review

- NIV for Post-Op Resp. Failure
  - Cardiac/Thoracic/GI Surgery/Transplant
  - All Mod. Level of Evidence for Efficacy
    - Both Prevention and Treatment

- Indicators of Failed NIV
  - No improvement O2/CO2 w/in 2 hours
  - Worsening mental status
  - Inability to clear secretions
  - Must monitor closely for (re)intubation
References

- Bauman KA, Hyzy RC. UpToDate.com.
References

References

References