Non-Invasive Oxygenation and Ventilation in Acute Critical Illness

Dr. Anthony J Hackett, DO, CPT (P), MC

EMRP Research Director and Chief, Dept. of Clinical Investigation
Department of Emergency Medicine
Carl R. Darnall Army Medical Center
Disclaimer

Information presented in this presentation are solely those of the presenter and do not represent those of the US Army, the DOD, or the US Army Medical Command.
Questions To Answer

• Who does better on CPAP vs. BPAP Vs. HiFlo O2?

• When should we intubate people on NIV?

• Is NIV for Pts with hypoxemic respiratory failure?
## Which Patients Can Get NIV

<table>
<thead>
<tr>
<th>Room</th>
<th>Chief Complaint</th>
<th>Age</th>
<th>Sex</th>
<th>Triage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HTN/CHF/SOB</td>
<td>55</td>
<td>M</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>DNR/DNI SOB from home</td>
<td>82</td>
<td>F</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>FEVER+SOB S/P lung Transplant</td>
<td>66</td>
<td>F</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Fever/cough decreased feeding</td>
<td>8 MO</td>
<td>M</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Fever SOB/CD4 &lt;200</td>
<td>47</td>
<td>M</td>
<td>3</td>
</tr>
<tr>
<td>RESUS1</td>
<td>EMS: COPD/Resp distress</td>
<td>70</td>
<td>M</td>
<td>2</td>
</tr>
<tr>
<td>RESUS2</td>
<td>EMS: Sepsis/Resp distress</td>
<td>72</td>
<td>F</td>
<td>2</td>
</tr>
<tr>
<td>TRAUMA1</td>
<td>SOB multiple Rib fractures</td>
<td>64</td>
<td>M</td>
<td>3</td>
</tr>
</tbody>
</table>
The Physiology

Positive pressure

Oxygenation
NIV Comes in Different Flavors

HiFlowO2

CPAP/Bubble CPAP

BiPAP

OXYGEN

NITROGEN

DANGER

CARBON DIOXIDE
NIV Benefits

• **Prevents:**
  - Ventilator related complications
  - Mortality in pediatrics and adults

• **Improves:**
  - Outcomes in COPD and CHF

• **Hypoxemic RF:**
  - Evidence supports HiFLO O2
CPAP: How it Works

- CPAP = EPAP = PEEP

Stented airways

↑ Recruitment

↑ FRC + Alveolar SA

↑ V/Q + ↓ WOB + ↑ O2
BPAP/Bi-Level vs CPAP

Inspiration

I

E

Nspiratory PAP

Expiratory PAP

(CPAP)

(PSV)

Expiration

IPAP-EPAP = Driving Pressure
What’s different about BPAP/Bi-Level?

• Adds IPAP: pressure above PEEP

• Decreases dead space

• Improves oxygenation and CO2 clearance
Pressure Settings

• **CPAP**
  - Start 1cm H2O/10Kg

• **BPAP**:
  - IPAP: 2X CPAP
  - IPAP Max: 25

• Repeat ABG in 1 hr:
  - + 2CmH2O if PaCO2 > 50

Torres, J and Radeos, M EMCC, 2011
Equipment

Mask

Helmet

Boussignac

Torres, J and Radeos, M EMCC, 2011
CPAP v. BiPAP: Disease Specific Pearls

- **CHF:** CPAP better than BiPAP

- **COPD:** BPAP preferred
NIV IN COPD
How PAP Works in COPD

- Overcomes loss of pulmonary elasticity
- Improved gas exchange
- Less hypercapnia
BPAP in COPD: Decreased WOB

- Reduces WOB via:
  - ↓↓ PaCO2
  - ↑ PaO2
  - ↓↓ RR

Bouchard et Al, NEJM 1995
Intubation in COPD: NIV Vs. O2 + RX

O2 +RX: 74%

PAP+RX: 26%

Brouchard et Al, NEJM 1995. Multicenter RCT
NIV Vs. Usual Care: Metadata

**Treatment Failure** (N=529)
- NNT=5

**Mortality** (N=523)
- NNT=8

**Intubation** (N=546)
- NNT=5
Predictors of Failure on BPAP

• **At Presentation - 1Hr:** $^{(1,2)}$
  - pH < 7.25
  - HR > 120
  - RR > 30

• **Markers at > 1Hr:**
  - Similar
  - Persistent RR > 30$^{(3)}$

• **At any time:**
  - GCS < 14/AMS$^{(3)}$
NIV in COPD

- Prevents
  - Intubation (NNT = 5)
  - Mortality (NNT=8)

- BPAP is Best

- Predictors of failure
  - PH < 7.25-7.3
  - AMS
  - RR > 30-28
NIV for Heart Failure
NIV Indirectly Augments SV

↑ Intrathoracic pressure

↓↓ Preload

↓↓ Blood to LV

Optimized Frank-Starling

CPAP
NIV and the Left Heart

- \( \uparrow \text{PEEP} = \uparrow \text{pTM} \)
- \( \uparrow \text{pTM} \) overcomes afterload

Systemic Resistance = 80 mmHg

PEEP: 7.3 mmHg
LV pressure: 80 mmHg

Total Left Ventricular Transmural Pressure = PEEP + LVP = (80 + 7.3) = 87.3 mmHg

http://www.derangedphysiology.com
NIV and Cardiogenic Pulmonary Edema

- Decreased Preload
- Decreased Afterload
- Decreased CV Work
- Decreased PHTN

- Afterload Reduction
- Decreased CV Work
NIPPV Prevents Death in CHF

CPAP

Less Death

BPAP

Less Death

Masip et al. JAMA 2005
NIPPV Prevents Intubation in CHF

Figure 3. Effects of Noninvasive Ventilation on Need to Intubate

- CPAP
- BPAP
- CPAP + BPAP

Masip et al, JAMA 2005
Is CPAP Safer Than BPAP in CHF?

• Increased mortality in B-PAP group 2/2 MI

• Issues in methodology and randomization

Mehta et Al 1997
BiPAP is safe in CHF

- **RCT:** No risk of MI vs. CPAP (1)

- **Meta Analysis:** No mortality difference (2)

1: Belone et al CCM 2004
2: Li et al AMJEM 2013
Conclusions: CHF

• B/CPAP may be used for acute heart failure

• BiPAP = MI have never been replicated in the literature

• CPAP = BiPAP w/ regard to mortality
Other Emergent Indications

• Asthma
• Immunocompromised
• Palliative care
• PNA?
• Kids?
What About Asthma?

• BiPAP V. standard therapy for asthma
  
  • FEV1: 80% vs. 20% Improved
  
  • Hospitalization: 18% vs 63%

• Bottom Line: BiPAP is efficacious and safe but needs more research

Soroksky Et. al, Chest 2003
Reduced Intubation and Death in Immunocompromise

Antonelli Et al. 2000 JAMA

Hilbert Et al. 2001
What About NIV for ARF in kids

- 2 RCT's to date!
- Indications similar to adults
- Major issues:
  - “Mask fear”
  - Patient comfort
Bubble CPAP

- CPAP = tube depth
- “Oscillatory” CPAP
- Useful <12 months

https://www.youtube.com/watch?v=XIMituWYVxQ
BPAP vs. Standard  

- N=50 (0-13 YO)

1. Yanez Ped CCM 2008

BPAP: 32% fewer intubated*
Bubble CPAP vs HiFlo vs. O2 (2)

**N=255 (0-5YO)**

- **Treatment Failure**
  - BCPAP (%): 6
  - O2 (%): 24
  - NNT: 5.6
- **Intubation**
  - BCPAP (%): 6
  - O2 (%): 16
  - NNT: NS
- **Death**
  - BCPAP (%): 4
  - O2 (%): 15
  - NNT: 9


**Bubble CPAP = HiFlo**
In Peds NIV is Superior to Standard O2

• **BPAP** decreases Intubations 1-13 YO

• **Bubble CPAP** <14 months of age Decreased:
  • Intubation
  • Treatment failure: **NNT 5.6**
  • Mortality: **NNT:9**
NIV In Hypoxemic Respiratory Failure?
Is NIV Indicated or Useful In PNA?

• IDSA and ATS:
  • Controversial
  • Avoid:
    • PaO2/FiO2 <150
    • B/L infiltrates

Image courtesy of Jack Ren, Radiopaedia.org, rID: 29090
NIV In Pneumonia: Who Fails

• NIV: 56% failure in CAP (1)

• Who fails at 1 Hr post NIV?
  • PH < 7.35, RR > 28, P:F < 177

• PNA may include 10% ARDS incidence (2)

1. Carron et. AL JCC, 2010
2. Bellani et Al 2016 JAMA
NIV In ARDS/Hypoxemic RF

- NIV Worse: isolated acute resp. failure \(^{(1)}\)
- Failed NIV: 50% mortality \(^{(2)}\)
- Failure \(\propto\) ARDS severity

---

1: Carroll Et al ICM, 2012
2: Argawal et Al: 2010 JRCM
3: ARDS Definition Task force: 2012 JAMA
**ARDS: Who Fails?**

<table>
<thead>
<tr>
<th>ARDS Grade</th>
<th>Mortality (%) + NIV (1)</th>
<th>Mortality (%) Usual care (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild (200-300)</td>
<td>22%</td>
<td>27</td>
</tr>
<tr>
<td>Moderate (100-200)</td>
<td>42%</td>
<td>32</td>
</tr>
<tr>
<td>Severe (&lt;100)</td>
<td>47%</td>
<td>45</td>
</tr>
</tbody>
</table>

**P:F < 150: Highest mortality**

1: Bellani et al: LUNGSAFE ESCIM
2: ARDS Definition Task force: 2012 JAMA
Hypoxemic RF: Predictors of Failure?

- P:F <150, shock/MOSF \(^{(1)}\)

- High Expired Tidal Vol: \(^{(2)}\)
  - ETV > 9.5 ml/kg
  - >85% sens/spec

- High Driving Pressures \(^{(3)}\)
  - PPLAT-PEEP

1: Chawala Et Al: JCC 2016
2: Carteaux Et Al: CCM 2016
3: Tucci Et Al: JTD 2016
Hypoxemic RF: Are We Doing it Wrong?

We use ARDSNET for MV why not for NIV?
Intubations: Facemask vs. Helmet

FM (n=44)
- Intubation: 61.5%*
- NNT: 2.3

Helmet (n=39)
- Intubation: 18.2%*

Patel, B Et al, JAMA 2016

*P<0.005
Mortality: Facemask vs. Helmet

In Hospital:
- 90 Day: 48.7%
- 90 Day: 27.3%*

90 Day:
- 56.4%
- 34.1%*

Patel, B Et al, JAMA 2016  *P<0.005
Recruitment to Improve P:F

• Apply ARDSNET thinking…

• 40 cm H2O PSV X 40 s

• 50 % pts: >20% P:F improvement

Lovas: Front Med 2015
NIV In PNA and ARDS

• Not for: P:F <150 or B/L infiltrates

• 1 Hr Predictors of failure:
  • Higher RR
  • pH <7.35
  • P:F < 200

• Data shows that patients who fail do far worse
NIV in ARDS Toward an NIV Open Lung Model?

• Helmets? (1)

• If ETV > 9 intubate (2)

• Keep driving pressures low (3)

• Lung recruitment maneuvers (4)

Is it Wrong to Try NIV in PNA/ARDS?

• Most trials involve **prolonged NIV use**

• Monitor closely + **0hr/1hr ABG**

• **Know who fails**

• Think of NIV as a **Pre-oxygenation method for intubation**
Is there A Better Answer for Hypoxemic Respiratory Failure?
Hi Flow Nasal Canula (HFNC)

- Heated/Humidified
- FIO2: 20-100%
- Decreases air entrainment
- Flows: 20-60 LPM
Hi Flow Equipment

flow meter

air-oxygen blender

O₂ (%)

heated inspiratory circuit

active humidifier

nasal cannula

Nishimura Journal of Intensive Care 2015
Hi Flow O2: How it works

- Deadspace washout
- Decreased nasal resistance
- PEEP to 3cm
- Decreased WOB

https://emcrit.org/pulmcrit/high-flow-nasal-cannula-for-apneic-oxyventilation/
Hi Flow O2 Indications

- Pediatric respiratory distress
- Adult hypoxic respiratory failure
- Pre-oxygenation for RSI

PNEUMONIA
FLORALI(1)

HFNC in Acute Hypoxemic Resp. failure

NRB >10 LPM  
N=94

NIV SpO2 92  
N=110

HFNC 50 LPM  
N=106

Frat, M Et al, NEJM 2015

*P<0.005
Intubated at 28 Days

**HFNC**
- All Pt’s: 38%
- P:F <200: 35%*

**NRB**
- All Pt’s: 47%
- P:F <200: 53%

**NIV**
- All Pt’s: 50%
- P:F <200: 58%

Frat, M et al, NEJM 2015

*P<0.005
Mortality at 90D

- HFNC: 12%*
- NRB: 23%
- NIV: 28%

All Pt's: 12%*

Frat, M Et al, NEJM 2015

*P<0.005
Why Does HFNC Improve Outcome?

• Benefits of O2 w/ Hypoxia

• NIPPV may cause barotrauma

• HFNC allows secretion clearance

Frat, M Et al, NEJM 2015
Setting the Flow

- Neonate: 2 LPM
- Infant: 6 LPM
- Child: 20 LPM
- Adult: 60 LPM
Titration Tips

• Start at the max and decrease
• Avoid hyperoxia
• Infants: RR/HR is a good surrogate
• Beware the 60LPM/100%
Other Hi Flow Outcomes

• Immunocompromised Adults:
  • Reduced mortality and intubation

• Kids:
  • 68% less intubations vs. standard in bronchiolitis over 1 yr period

• 30% reduction in intubation over 5 yr

1. Huang, B Et Al JCC 2018
2. McKiernan J Peds 2010
3. Schibler Int. care Med 2011
Who To Beware of

• COPD/CHF

• Increasing RR/WOB

• Dropping PO2

• Max LPM/Sats

• Organ Dysfunction in PNA and PCP

Kim W Et al. JTD 2016
Conclusions
Conclusions: Benefits of NIV

- **Highest benefit:**
  - CHF
  - COPD
  - ARF in Immunocompromised

- **Moderate benefit:** Asthma

- **No benefit/may be harmful:**
  - Pneumonia ➔ Hi flow O2 is better
  - Severe ARDS
Conclusions: Selecting Candidates

• What modality:
  • CPAP for O2
  • BPAP for CO2

• Know who fails:
  • Acidotic, High RR
  • No improvement at 1 Hr

• Kids:
  • Ages 1-13: standard NIV
  • < 14 MO: Bubble CPAP
Conclusions: NIV in ARDS

- Only for P:F >200
- Hi Flo or Helmets are best (1)
- Keep Driving Pressures Low (3)
- Lung recruitment maneuvers (4)
- **Intubate If:** ETV > 9, P:F < 200 (2)

1: Chawala Et Al: JCC 2016
2: Carteaux Et Al: CCM 2016
3: Tucci Et Al: JID 2016
4: Lovas: Front Med 2015
Conclusions: High Flow O2

• Improved outcomes in adults and children

• Best for hypoxemic respiratory failure vs NIV
  • Less intubation: $NNT = 4.3$
  • Less mortality: $NNT = 6.2$
  • Most dramatic in P:F <200 group

• Start high, titrate down
## Conclusions: Just Remember This

### Non-Invasive Ventilation Methods and Disease Specific Indications

<table>
<thead>
<tr>
<th></th>
<th>CPAP</th>
<th>BPAP</th>
<th>NIV Helmet</th>
<th>Bubble CPAP</th>
<th>Hi Flow O2</th>
<th>Intubation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHF</td>
<td>☑</td>
<td>☑</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COPD</td>
<td>☑</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asthma</td>
<td>☑</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Immunocompromise</td>
<td>☑</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ARF Peds &gt; 1YO</td>
<td></td>
<td>☑</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ARF Peds &lt;1 YO</td>
<td></td>
<td></td>
<td></td>
<td>☑</td>
<td>☑*</td>
<td></td>
</tr>
<tr>
<td>PNA Any P:F (no MOSF)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>☑</td>
<td></td>
</tr>
<tr>
<td>ARDS P:F &gt;200</td>
<td></td>
<td></td>
<td></td>
<td>☑</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ARDS P:F &lt;200</td>
<td></td>
<td>☑</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ARDS +MOSF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>☑</td>
</tr>
<tr>
<td>PNA +MOSF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>☑</td>
<td></td>
</tr>
</tbody>
</table>

© AJ Hackett, 2018
Contact Information

CPT(P) Anthony J. Hackett, DO
Dept. of Emergency Medicine
Carl R Darnall Army Medical Center
Ft Hood, Texas 76544

Ahackett@NYIT.Edu
Anthony.J.Hackett4.mil@mail.mil
References

References


3. Acute respiratory distress syndrome: Predictors of noninvasive ventilation failure and intensive care unit mortality in clinical practice. Chawla R1, Mansuriya J2, Modi N3, Pandey A4, Juneja D5, Chawla A6, Kansal S7

4. Noninvasive ventilation for acute respiratory distress syndrome: the importance of ventilator settings. Mauro R. Tucci, corresponding author1 Eduardo L. V. Costa,1,2 Maria A. M. Nakamura,1 and Caio C. A. Morais1

5. Lung Recruitment Can Improve Oxygenation in Patients Ventilated in Continuous Positive Airway Pressure/Pressure Support Mode. András Lovas,1 Márton Ferenc Németh,1 Domonkos Trásy,1 and Zsolt Molnár1,*
So What do We do With PNA?

• Initial and 1 hr re-assessment are key!
  • Initial acidosis, AMS, Failure to improve \(\rightarrow\) Intubate

• Know who fails: Low pH, High RR, Sicker patients

• Consider Hi Flow first instead of standard NIV unless:
  • Pre-existing COPD or pulmonary disease
  • Need for intubation
  • Shock