A Man dead in Appearance, recovered by distending the Lungs with Air; by Mr. William Tossach Surgeon in Alloa.

Medical Essays
AND
Observations,
Revised and Published by
A Society in Edinburgh.

Medical Essays and Observations, 1744; 5(2):605-608
Positive pressure ventilation by mouth/bellows
Positive pressure ventilation by mouth/bellows

Fig. 1.

Fig. 2.

Noninvasive Face Mask Ventilation in Patients with Acute Respiratory Failure*

Gianfranco Umberto Meduri, M.D., F.C.C.P.;†
Craig C. Conoscenti, M.D.; §Phillip Menashe, M.D.;§
and Sreedhar Nair, M.D., F.C.C.P.‖

(Chest 1989; 95:865-70)
Advantages of Non-invasive ventilation

- Avoids complications of intubation
  - effects of sedation, anesthetic
  - upper airway trauma
  - nosocomial infections
- Patient comfort
- May allow eating, talking, coughing
- Easy removal & reapplication
Disadvantages of NIPPV

- Facial pressure necrosis
- Delay in definitive treatment
- Difficult transport
- Risk of aspiration
- Poor tolerance
- Poor tracheal toilet
- Hypoxemia if disconnect
- Local barotrauma
Disadvantages of NIPPV

- Facial pressure necrosis
- Delay in definitive treatment
- Difficult transport
- Risk of aspiration
- Poor tolerance
- Poor tracheal toilet
- Hypoxemia if disconnect
- Local barotrauma
Consider:
- COPD
- pulmonary edema
- facilitate weaning
- asthma
- post-extubation
- cystic fibrosis
- ARDS
- upper airway obstruction
- immunocompromised
RCT - COPD

- 85 COPD patients

Outcome

- reduced intubation 74% vs 26%
- reduced mortality 29% vs 9%
- reduced hospital stay 35 vs 23 days

Criticisms

- highly selected patients: 85 out of 275
- Uncontrolled oxygen therapy in controls
- High mortality in control group
- Underutilization of medical therapy

COPD – Cochrane systematic review

8 studies

Results:
- lower mortality (RR 0.41, 95% CI 0.26 – 0.64)
- lower intubation (RR 0.42, 95% CI 0.31 – 0.59)
- shorter hospital stay (-3.2d, 95% CI -4.4 - -2d)

BMJ 2003; 326:177-178
Results:

- lower mortality (risk reduction 10%)
- lower intubation (risk reduction 28%)
- shorter hospital stay (reduction 4.5 d)
- benefits appear in patients with severe exacerbations, not mild exacerbations

Keenan et al, Ann Intern Med 2003
Cardiogenic Pulmonary Edema

Physiology of positive pressure

Positive pressure:
- redistributes lung water
- decreases work of breathing
- decreases afterload
- decreases preload
Physiology of positive pressure

Positive pressure:
- redistributes lung water
- decreases work of breathing
- decreases afterload
- decreases preload
Cardiogenic Pulmonary Edema

  - CPAP v conventional Rx
  - reduced intubation rate, no effect on mortality

- **Mehta, 1997** *Crit Care Med* 25:620-628
  - CPAP v NIPPV
  - more rapid improvement in PaCO$_2$
  - no difference in intubations, mortality
  - increased myocardial infarction rate?
<table>
<thead>
<tr>
<th>Authors</th>
<th>Groups</th>
<th>n</th>
<th>Oxygenation</th>
<th>HR, RR</th>
<th>Intubation</th>
<th>Mortality diff</th>
<th>Incr MI</th>
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<tr>
<td>Masip</td>
<td>O₂ NIPPV</td>
<td>37</td>
<td>+</td>
<td>+</td>
<td>33%</td>
<td>5%</td>
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<tr>
<td>Park</td>
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<td>42%</td>
<td>7%</td>
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<td>(Crit Care Med 2004; 32:2407)</td>
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<tr>
<td>Nava</td>
<td>O₂ NIPPV</td>
<td>130</td>
<td>+</td>
<td>+</td>
<td>25% NS</td>
<td>20%</td>
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<tr>
<td>(Am J Respir Crit Care Med 2003; 168:143 (in ER))</td>
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<tr>
<td>Bellone</td>
<td>CPAP NIPPV</td>
<td>36</td>
<td>-</td>
<td>-</td>
<td>5.5% NS</td>
<td>11%</td>
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<tr>
<td>(Intensive Care Med 2005 31:807 (hypercapnic))</td>
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</tbody>
</table>

- 1069 patients, 3 groups (O₂, CPAP, NIV)
- More rapid improvement with NIV
- No difference in short term mortality

Meta-analysis (Ann Intern Med 2010; 152:590)

- NIV associated with
  - Reduced intubation rate
  - Improved mortality, particularly in pts. With ACS
Cardiogenic Pulmonary Edema

<table>
<thead>
<tr>
<th>Study, Year (Reference)</th>
<th>CPAP</th>
<th>Standard Therapy</th>
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<tbody>
<tr>
<td><strong>Random-effects model</strong></td>
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<td>Events, $n$</td>
<td>Patients, $n$</td>
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<td>Wallen et al., 1985 (24)</td>
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<td>Berdon et al., 1991 (25)</td>
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<td>Lin et al., 1995 (26)</td>
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<td>Tabata et al., 1998 (28)</td>
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<td>Delmonico et al., 2000 (29)</td>
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<th>Standard Therapy</th>
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Ann Intern Med 2010; 152:590
# Cardiogenic Pulmonary Edema

<table>
<thead>
<tr>
<th>Study, Year (Reference)</th>
<th>CPAP Standard Therapy</th>
<th>RR (95% CI) W (random), %</th>
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<td>Random-effects model</td>
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<tr>
<td>44</td>
<td>741</td>
<td>0.44 (0.32–0.60) 100</td>
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<tr>
<td>Study, Year (Reference)</td>
<td>Bilevel Ventilation Standard Therapy</td>
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<tr>
<td>Random-effects model</td>
<td>31</td>
<td>0.54 (0.33–0.86) 100</td>
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<tr>
<td>Study, Year (Reference)</td>
<td>Bilevel Ventilation CPAP</td>
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<tr>
<td>Random-effects model</td>
<td>31</td>
<td>1.23 (0.72–2.10) 100</td>
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</tbody>
</table>
RCT - Hypoxemic Respiratory Failure


- 64 patients with hypoxemia
- Randomized to NIV or intubation

Outcome
- equivalent to conventional ventilation
- fewer nosocomial infections
- shorter ICU and hospital stay

Criticisms
- small study, inadequate power
- delayed SIMV wean in conventional ventilation arm
- only 77 of 486 patients screened were eligible
105 patients with hypoxemia
Randomized to NIV or high O₂

Outcome
- Decreased intubation rate (25% vs 52%)
- Decreased septic shock (12% vs 31%)
- Decreased ICU mortality (18% vs 39%)

Criticisms
- 30 patients with cardiogenic pulmonary edema
- High mortality rate
Acute hypoxic respiratory failure

- Systematic review – excluded cardiogenic pulmonary edema

- Results:
  - reduced intubation rate – by 23% (95% CI: 10 – 35%)
  - reduced ICU LOS – by 2 d (95% CI: 1 – 3 d)
  - reduced ICU mortality – by 17% (95% CI: 8 – 26%)

- but, significant heterogeneity in trial results
- NIV cannot be broadly recommended for all patients

Keenan et al, Crit Care Med 2004; 32:2516
56 patients with severe CAP and respiratory failure

Randomized to standard therapy or NPPV

Significant reductions in:
- intubation rate (21% vs. 50%)
- ICU days (2 vs. 6)

Improved 2-month survival in those with COPD + CAP (90% vs. 38%)

Confalonieri et al, AJRCCM 1999; 160:1585
56 patients with severe CAP and respiratory failure

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(90% vs. 38%)

Confalonieri et al, AJRCCM 1999; 160:1585
52 immunosuppressed patients with fever, bilat infiltrates, hypoxia:
- conventional Rx
- intermittent NIPPV

Significant reductions in:
- intubation rate (46% vs. 77%)
- mortality (50% v 81%)

Criticisms:
- Excluded pH < 7.30
- Intubation for PaO\textsubscript{2}/FiO\textsubscript{2} < 85

RCT - Immunosuppressed patients
Retrospective analysis of 1302 patients with hematological malignancy requiring ventilatory support

- 21% received NIV, 46% went on to need intubation
- Propensity matched

Mortality:
- Initial NIV: 42%
- NIV then IMV: 69%
- Initial IMV: 77%

This analysis revealed that, on the whole, an initial NIMV trial significantly reduced mortality by 27%.
30 asthmatics in ER
- NIPPV x 3hr
- Sham NIPPV (subtherapeutic pressure)

Improvement in:
- increase in FeV1
- Rate of hospitalization (17% v 62%)

Criticisms:
- “Sham” NIPPV
- Small study
- Severity of illness

Cochrane review (2005): need more studies
42 asthmatics in ER
- NIPPV vs standard therapy
- No significant difference in:
  - increase in FeV1, O2, CO2

Significant benefits of NIV:
- Shorter ICU and hospital stay
- Reduced dose of inhaled bronchodilator
- 4 control patients required NIV
- 2 NIV patients required intubation
Facilitating Weaning

Early extubation on to noninvasive ventilation

Patients who fail trial of spontaneous breathing:
- extubated onto NIPPV
- conventional PSV wean
Facilitating Weaning

- **Nava, 1998** *Ann Intern Med 128:721*
  - 50 patients with COPD exacerbation
  - reduced duration of ventilation & ICU
  - decreased pneumonia & mortality (28% to 8%)

- **Girault, 1999** *Am J Respir Crit Care Med 160:86-92*
  - 33 patients with acute on chronic resp failure
  - no increased risk, no difference in re-intubation
  - no other benefit over PSV wean
Facilitating Weaning

- **Cochrane review**
  - 12 studies, 530 patients, predominantly COPD
  - Decreased mortality RR 0.55 (95% CI 0.38-0.79)
  - Decreased ICU LOS 6.2 d (95% CI 3.78-8.77d)
  - Decreased VAP RR 0.29 (95% CI 0.19 – 0.45)

*Burns et al, Cochrane Database Syst Rev. 2010(8):CD004127*
Extubation Failure

- **Esteban et al**  
  - NIPPV for extubation failure  
  - 221 patients  
  - no difference in the re-intubation rate  
  - higher mortality in NIPPV group (25% v 14%)  
  
- **Keenan et al**  
  - NIPPV for respiratory distress <48h of extubation  
  - 81 patients  
  - no difference in reintubation  
  - no difference in mortality (31%)
Extubation Failure

- **Esteban et al**  
  *N Engl J Med 2004; 350:2452*
  - NIPPV for extubation failure
  - 221 patients
  - No difference in the re-intubation rate
  - Higher mortality in NIPPV group (25% v 14%)

- **Keenan et al**  
  *JAMA 2002, 288:2540*
  - NIPPV for respiratory distress <48h of extubation
  - 81 patients
  - No difference in reintubation
  - No difference in mortality (31%)
Unplanned extubation?

- Small prospective study:
  - If in the weaning process, can consider NIPPV
    - 91% success (10/11 patients)
  - If not weaning, reintubate.
    - 100% (4/4 patients) failed NIPPV

- COPD
- Cardiogenic pulmonary edema
- Hypoxemic respiratory failure
- To facilitate weaning
- Community acquired pneumonia (+COPD ?)
- Immunosuppressed patients (not very ill) ?
- Asthma ?
Appropriate patient

- Alert, co-operative & compliant
- Spontaneous respiration
- Appropriate underlying disease
- No contraindications
Appropriate patient

- Alert, co-operative & compliant
- Spontaneous respiration
- Appropriate underlying disease
- No contraindications
Appropriate patient

- Alert, co-operative & compliant

Exception:
COPD with hypercapnia and mild altered LOC.

Most common reason for failure of NIV is interface intolerance
Nasal mask

- comfortable, better tolerated
- fewer skin problems
- less dead space
- allows coughing, eating, talking
- less concern about vomiting

-Disadvantages:  mouth leak
                 mouth breathing
                 nasal obstruction

Navalesi et al, Crit Care Med 2000, 28:1785
Face (oro-nasal) mask

- less leak
- Less resistance, higher peak inspiratory flow
- improved minute ventilation and $\text{PaCO}_2$

- Disadvantages:
  - increase dead space
  - unable to expectorate, talk
  - claustrophobia
  - vomiting
  - gastric distension

Navalesi et al, Crit Care Med 2000, 28:1785
Equipment - The Mask

Full face mask
- No trauma to bridge of nose
- reduced resistance to airflow
- more comfortable

Disadvantages: claustraphobia
CO$_2$ clearance reduced
gastric distension

Navalesi et al, Crit Care Med 2000, 28:1785
RCT of nasal versus face mask
- 90 patients with chronic lung disease, acute respiratory failure
- Clinical benefit similar
- Higher failure rate with nasal mask (leaks)
**RCT of nasal versus face mask**
- 90 patients with chronic lung dis, acute resp failure
- Clinical benefit similar
- Higher failure rate with nasal mask (leaks)

**Conclusion:**
- Use **Facemask** as first line
- Nasal masks can be used effectively as an alternative

*Girault et al, Crit Care Med 2009; 37:124*
Physiological comparison of 4 interfaces, with varying internal volumes (14 patients)

- **INSPIRAID**
  - Integral mask with the largest internal volume (977 ml)
- **FULL FACE**
  - Large oro-nasal mask with a large internal volume (163 ml)
- **AIRVIE**
  - Small oro-nasal mask with a moderate internal volume (84 ml)
- **ORACLE**
  - Mouth piece without internal volume

Fraticelli et al, Crit Care Med 2009; 37:939
Physiological comparison of 4 interfaces, with varying internal volumes (14 patients)

- No differences in - minute ventilation
  - work of breathing
  - CO$_2$ reduction

- Mouthpiece: more leaks, more asynchrony and less comfortable

Fraticelli et al, Crit Care Med 2009; 37:939
Equipment - The Mask

Helmet

- transparent PVC helmet
- secured by 2 armpit braces and soft collar
- High bias flow (>30 L/min)
- well tolerated
- avoids facial problems
- CO₂ rebreathing

Antonelli et al, Crit Care Med 2002; 30:602
Helmet

Less effective than standard interfaces in situations of resistive load.

Asynchrony, worse CO$_2$ clearance

Racca et al. J Appl Physiol 2005
Problems

- Air Leaks
  - inadequate tidal volume
  - breath cycle termination
  - conjunctivitis

- Edentulous patient

- Nasogastric tubes

- Intolerance

Equipment - The Mask
Non-invasive ventilators: Gas exchange

**Single circuit: CO$_2$ excretion**

- No exhalation valve
Non-invasive ventilators: Gas exchange

**Single circuit: CO\textsubscript{2} excretion**

- No exhalation valve
Non-invasive ventilators: Gas exchange

**Single circuit: CO₂ excretion**

- No exhalation valve
Non-invasive ventilators: Gas exchange

Single circuit: CO$_2$ excretion

• No exhalation valve
Non-invasive ventilators: Gas exchange

**Single circuit: CO$_2$ excretion**

- No exhalation valve
- Flushed out - deliberate leak
- Dependent on
  - flow rate $\equiv$ PEEP
  - dead space
  - leak
Non-invasive ventilators: Gas exchange

**Single circuit: CO₂ excretion**

- No exhalation valve
- Flushed out - deliberate leak
- Dependent on
  - flow rate $\equiv$ PEEP
  - dead space
  - leak
Excessive Air Leaks

 Prevent by

- Correct mask and headgear
- Hydrogel or foam seals
- Chin strap?

 Consequences

- Inadequate ventilation
- Dyssynchrony
  - Failure to trigger
  - Failure to cycle off
Monitoring NIV

- Initial period may be labor intensive
- Facilities to intubate always available
- Consider intubation if:
  - no improvement in first hour
  - deterioration in level of consciousness
  - NIV poorly tolerated
  - inadequate secretion clearance
International Ventilation Survey:
- March 1998
- >15,000 admission; 361 ICU’s
- 5% NIV, 32% needed intubation

Repeat study
- March 2004
- >19,000 admissions, 349 ICU’s
- 11% NIV, 35% needed intubation

Esteban et al, JAMA 2002;287:345
Am J Respir Crit Care Med. 2008; 15;177(2):170