Domiciliary ventilation

Dr. K T Prasad
Cost per patient:
718.80 $ vs. 235.13 $ per day

HMV: Patients’ perspective

Hospital
• Care by unrelated staff
• Noisy
• Lighted most of the time
• Limited outside view
• Cramped
• Restricted visitors
• Alien surrounding
• Little control over things

Home
• Family care
• Quiet
• Day/night cycles
• Good view
• Roomy
• Supportive visitors encouraged
• Personal objects
• More independence

King AC. Respir Care. 2012 Jun;57(6):921-30
Current status
EuroVent Study

Designed to assess patterns of HMV use
Across 16 countries in Europe
Questionnaire based survey
July 2001 to June 2002

The study was designed to assess the patterns of use of home mechanical ventilation (HMV) for patients with chronic respiratory failure across Europe.

A detailed questionnaire of centre details, HMV user characteristics and equipment choices was sent to carefully identified HMV centres in 16 European countries.

Surveys were sent out by the National Representatives to all centres from July 2001 onwards with a covering letter of explanation. The deadline for receipt of the completed surveys was June 1, 2002.

EuroVent: HMV definition

- Noninvasive ventilation or ventilation via a tracheostomy for ≥3 months on a daily basis carried out mostly in the user's home or other long-term care facility (not a hospital)
- **Excluded patients with obstructive sleep apnoea alone, or patients with a tracheostomy not requiring mechanical ventilation**
- Included negative pressure ventilation, phrenic nerve stimulation and the use of ventilatory adjuncts, such as rocking beds

**EuroVent: HMV prevalence**

<table>
<thead>
<tr>
<th>Estimated</th>
<th>Centres</th>
<th>Users</th>
<th>Prevalence per 100,000 population</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Austria</td>
<td>8</td>
<td>300</td>
<td>3.8</td>
</tr>
<tr>
<td>Belgium</td>
<td>23</td>
<td>500</td>
<td>5</td>
</tr>
<tr>
<td>Denmark</td>
<td>2</td>
<td>500</td>
<td>9.6</td>
</tr>
<tr>
<td>Finland</td>
<td>20</td>
<td>450</td>
<td>8.7</td>
</tr>
<tr>
<td>France</td>
<td>50</td>
<td>10000</td>
<td>17</td>
</tr>
<tr>
<td>Germany</td>
<td>54</td>
<td>5000</td>
<td>6.5</td>
</tr>
<tr>
<td>Greece</td>
<td>12</td>
<td>70</td>
<td>0.6</td>
</tr>
<tr>
<td>Ireland</td>
<td>15</td>
<td>155</td>
<td>3.4</td>
</tr>
<tr>
<td>Italy</td>
<td>70</td>
<td>2200</td>
<td>3.9</td>
</tr>
<tr>
<td>Netherlands</td>
<td>4</td>
<td>900</td>
<td>5.6</td>
</tr>
<tr>
<td>Norway</td>
<td>38</td>
<td>350</td>
<td>7.8</td>
</tr>
<tr>
<td>Poland</td>
<td>8</td>
<td>40</td>
<td>0.1</td>
</tr>
<tr>
<td>Portugal</td>
<td>39</td>
<td>933</td>
<td>9.3</td>
</tr>
<tr>
<td>Spain</td>
<td>35</td>
<td>2500</td>
<td>6.3</td>
</tr>
<tr>
<td>Sweden</td>
<td>65</td>
<td>900</td>
<td>10</td>
</tr>
<tr>
<td>UK</td>
<td>40</td>
<td>2320</td>
<td>4.1</td>
</tr>
<tr>
<td>All countries</td>
<td>483</td>
<td>27118</td>
<td>6.6</td>
</tr>
</tbody>
</table>

EuroVent: Results

- A total of 483 centres treating 27,118 HMV users were identified.
- Of these, 329 centres completed surveys between July 2001 and June 2002, representing up to 21,526 HMV users and a response rate of between 62% and 79%.
- The estimated prevalence of HMV in Europe was 6.6 per 100,000 people.
- The variation in prevalence between countries was only partially related to the median year of starting HMV services. In addition, there were marked differences between countries in the relative proportions of lung and neuromuscular patients using HMV, and the use of tracheostomies in lung and neuromuscular HMV users. Lung users were linked to a HMV duration of <1 yr, thoracic cage users with 6–10 yrs of ventilation and neuromuscular users with a duration of ≥6 yrs.

Asia-Pacific region: Hong Kong

Fig. 1.—New cases (——), withdrawn cases (—-—) and cumulative number of home ventilation (observed (——) and predicted (———)).

Indian data

First report on HMV in 1992...


Domiciliary mechanical ventilation in a patient with severe chronic obstructive lung disease and respiratory failure.

Guleria R, Batra YK, Sharma BK, Jindal SK.
Department of Pulmonary Medicine, Postgraduate Institute of Medical Education and Research, Chandigarh.

Abstract
A patient of chronic obstructive pulmonary disease (COPD) with cor-pulmonale and chronic respiratory failure, who was given intermittent positive pressure ventilation at home, is reported. The patient did remarkably well on home mechanical ventilatory support. We believe this to be the first case report of domiciliary mechanical ventilation in a patient of COPD from India.

PMID: 13022224 [PubMed - indexed for MEDLINE]
International Conference on HMV (JIVD 2009)

HMV use had almost doubled in 7 years!

Escarrabill J. Breathe 2009; 6: 36-44
Indications
Gas exchange

- Hypoxic respiratory failure
  - PaO2 ↓↓
  - PaCO2 N/↓
  - LTOT

Ventilation

- Hypercapnic respiratory failure
  - PaO2 ↓
  - PaCO2 ↑↑
  - HMV
Indications for HMV

- Day-time CO2 retention (PaCO2 ≥ 50mmHg)
- Milder CO2 retention with symptoms due to hypoventilation
- Nocturnal hypoventilation/oxygen desaturation

King AC. Respir Care. 2012 Jun;57(6):921-30
Table 1—Indications for Mechanical Ventilation Beyond the ICU

Indications for NIV

- Patient has chronic stable or slowly progressive respiratory failure:
  - Significant daytime CO₂ retention (≥ 50 mm Hg) with appropriately compensated pH or
  - Mild daytime or nocturnal CO₂ retention (45 to 50 mm Hg) with symptoms attributable to hypventilation (eg, morning headaches, restless sleep, nightmares, enuresis, daytime hypersomnolence, etc)
  - Significant nocturnal hypventilation or oxygen desaturation
- The following conditions have been met:
  - Patient has had optimal medical therapy for underlying respiratory disorders
  - Patient is able to protect airway and clear secretions adequately
  - Patient’s reversible contributing factors have been treated (eg, obstructive sleep apnea, hypothyroidism, congestive heart failure, severe electrolyte disturbance).
- The diagnosis is appropriate (see Table 2) and may include the following:
  - Neuromuscular disorders
  - Chest wall deformity
  - Central hypventilation syndrome or obesity hypoventilation
  - Obstructive sleep apnea, and a failure to improve with nasal CPAP
  - COPD, with severe hypercapnia or nocturnal desaturation (tentative indication)*

Indications for invasive ventilation

- Patient meets indications for NIV and has the following:
  - Uncontrollable airway secretions despite use of noninvasive expiratory aids; or
  - Impaired swallowing leading to chronic aspiration and repeated pneumonias
- Patient has persistent symptomatic respiratory insufficiency and fails to tolerate or improve with NIV
- Patient needs round-the-clock (> 20 h) ventilatory support because of severely weakened or paralyzed respiratory muscles (eg, quadriplegia due to high spinal cord lesions or end-stage neuromuscular disease) and patient or provider prefers invasive ventilation.

* However, some conferees strongly prefer NIV, even when the patient has a need for continuous ventilatory support, as long as upper airway function is intact.
Diseases requiring HMV

- Restrictive disorders: Neuromuscular and chest wall disorders
- Obstructive airway disorders: COPD
- Sleep-related breathing disorders: Central/obstructive sleep apnea syndromes, hypoventilation syndromes
- Other: TB sequelae, cystic fibrosis
**Respiratory centre**

**Descending tracts**

**Motor neuron**

**Nerve**

**NM junction**

**Muscles**

**Rib cage**

**Pleura**

**Alveolar pressure**

**Inspiration**

---

**Neuromuscular diseases:**
- Central apnea syndromes
- Cervical cord injury
- Motor neuron disease
- Neuropathies
- Myasthenia gravis
- Muscular dystrophies & myopathies

**Thoracic cage diseases:**
- Chest wall deformities
- Pleural fibrosis

**Lung & airway diseases:**
- Parenchymal fibrosis
- Airway obstruction: COPD, OSA
**Disease treated by HMV: EuroVent 2002**

- **Lung/Airways**: Dark grey
- **Thoracic cage**: Light grey
- **Neuromuscular**: White

EuroVent: Disease categories

- **Lung and airway diseases:** chronic obstructive pulmonary disease (COPD), cystic fibrosis, bronchiectasis, pulmonary fibrosis and paediatric diseases, including bronchopulmonary dysplasia

- **Thoracic cage abnormalities:** early-onset kyphoscoliosis, tuberculosis sequelae such as thoracoplasty, obesity hypoventilation syndrome and sequelae of lung resection

- **Neuromuscular diseases:** muscular dystrophy, motor neurone disease (including amyotrophic lateral sclerosis), post-polio kyphoscoliosis, central hypoventilation, spinal cord damage and phrenic nerve paralysis.

# Diseases treated by HMV: Hong Kong

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Restrictive thoracic disorders</strong></td>
<td></td>
</tr>
<tr>
<td>Thoracic cage disorders</td>
<td>38 (15.3)</td>
</tr>
<tr>
<td>Post-tuberculous fibrothorax</td>
<td>9 (3.6)</td>
</tr>
<tr>
<td>Neuromuscular disorder</td>
<td>30 (12.0)</td>
</tr>
<tr>
<td>Mixed pathologies and miscellaneous</td>
<td>8 (3.2)</td>
</tr>
<tr>
<td><strong>Complicated OSA/OHS</strong></td>
<td></td>
</tr>
<tr>
<td>OHS</td>
<td>11 (4.4)</td>
</tr>
<tr>
<td>COPD: OSA overlap syndrome</td>
<td>22 (8.8)</td>
</tr>
<tr>
<td>Severe OSA, intolerant to CPAP</td>
<td>10 (4.0)</td>
</tr>
<tr>
<td><strong>COPD</strong></td>
<td>121 (48.6)</td>
</tr>
</tbody>
</table>

Changing trends...

[Graph showing changing trends in respiratory issues over years, with categories for Neuromuscular Disorders, Obesity - Hypoventilation, Post - TB, Post - Polio, Kyphoscoliosis, and COPD.]
Goals of HMV

- To improve blood gases
- To correct hypoventilation and associated symptoms
- To improve quality of sleep
- To improve QoL
- To improve survival
FIGURE 2. a) Summary score of Severe Respiratory Insufficiency (SRI) Questionnaire, b) physical component summary (PCS) of the Medical Outcome Survey 36-Item Short-form Health Survey (SF-36), and c) mental component summary (MCS) of the SF-36 in patients with chronic hypercapnic respiratory failure prior (T0) to home mechanical ventilation (HMV), and 1 month (T1) and 12 months (T12) following the institution of HMV (n=85). Higher values indicate better health-related quality of life (HRQL).

*: nonsignificant; *: p<0.05; ***: p<0.001.

Windisch W. Eur Respir J. 2008 Nov;32(5):1328-36
Duchenne’s MD: Impact of NIV on ABG

Duchenne’s MD: Impact of NIV on survival

Median survival in hypercapnic Duchenne’s MD without NIV

Can patients with chronic hypoventilation be managed with oxygen alone?

Do they really require HMV?
Kyphoscoliosis: Oxygen vs. ventilation

Buyse B, Meersseman W, Demedts M. Eur Respir J. 2003 Sep;22(3):525-8
Thoracic restriction: HMV & Sleep quality

Fifteen consecutive patients (13 women) of mean (SD) age 57.9 (12.0) years with CRF due to thoracic restriction were included in the study.

During the one year observation period four polysomnographic studies were performed: three during spontaneous breathing without NMV-
  ➢ before initiation of NMV (T0) and
  ➢ after withdrawing NMV for one night
    • at six months (T6) and
    • 12 months (T12-)-and
  ➢ the fourth during NMV after 12 months (T12+).
# Indications for NIV in restrictive diseases

<table>
<thead>
<tr>
<th>Clinical Criteria</th>
<th>Physiologic Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe, irreversible disease</td>
<td>Vital capacity &lt;25% predicted</td>
</tr>
<tr>
<td>Symptoms of nocturnal hypoventilation</td>
<td>Pimax &gt; -50 cmH2O (COPD), or &gt; -25 cmH2O (restrictive disorder)</td>
</tr>
<tr>
<td>Dyspnea at rest or sleep</td>
<td>PaCO2 &gt;45 mmHg</td>
</tr>
<tr>
<td>Refractory cor pulmonale</td>
<td>Nocturnal SaO2 &lt;88% despite supplemental O2</td>
</tr>
</tbody>
</table>

*Patients must satisfy at least two clinical criteria and two physiologic criteria

Criner GJ et al. Chest. 1999 Sep;116(3):667-75
SRBDs

- CPAP is indicated for the treatment of moderate to severe OSA (STANDARD)

- CPAP therapy targeted to normalize the apnea-hypopnea index (AHI) is indicated for the initial treatment of CSAS related to CHF (STANDARD)

AASM practice parameters.
Kushida CA et al. Sleep. 2006 Mar;29(3):375-80

AASM practice parameters.
Failure of weaning from invasive mechanical ventilation is one of the major clinical problems in COPD patients. In one study these “chronically critically ill” patients, representing only 3% of the total number of patients admitted to the ICU, used almost 40% of the total patient days of care.

Long-term NIV produced no improvement in QoL or dyspnoea (MRC scale)

Indications for home NIPPV in COPD

- Symptoms: Fatigue, dyspnea, morning headache
- Physiological criteria
  - PaCO2 ≥ 55mmHg
  - PaCO2 = 50-54mmHg with nocturnal desaturation (SaO2 ≤ 88% for 5 continuous minutes while receiving oxygen therapy ≥ 2L/min)
  - PaCO2 = 50-54mmHg with history of hospitalization (>1 episode in a year) related to recurrent episodes of hypercapnic respiratory failure

Chest. 1999 Aug;116(2):521-34. PMID: 10453883
Antoniadis A. Pneumon 2009; 22(Suppl 2):103-111
## Stable COPD: (NIV + LTOT) vs. (LTOT alone)

<table>
<thead>
<tr>
<th>Study</th>
<th>n</th>
<th>IPAP/EPAP (cmH2O)</th>
<th>ΔPaCO2 (mmHg)</th>
<th>Survival</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casanova 2000</td>
<td>52</td>
<td>12/4</td>
<td>NIV: +0.4</td>
<td>No benefit (at 1 year)</td>
<td>- Improved dyspnoea and psychomotor coordination</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LTOT: -0.9</td>
<td></td>
<td>- No improvement in exacerbations</td>
</tr>
<tr>
<td>Clini 2002</td>
<td>90</td>
<td>14/2</td>
<td>No difference* (at 2 years)</td>
<td>No benefit (at 2 years)</td>
<td>- Improved dyspnoea and HRQoL</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- No improvement in lung function, 6MWD, sleep quality, exacerbations</td>
</tr>
<tr>
<td>McEvoy 2009</td>
<td>144</td>
<td>12.9/5.1</td>
<td>NIV: -0.9</td>
<td>No benefit** (2.2 years)</td>
<td>- No improvement in lung function, HRQoL***, exacerbations</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LTOT: -2.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


*There was no difference in PaCO2 between both the groups when breathing room air. However, PaCO2 was 5 mmHg lower (already 1mmHg lower at baseline) in the NIV group while breathing usual oxygen.

**Adjusted HR 0.63, 95% CI 0.40 to 0.99, p = 0.045; Unadjusted HR 0.82, 95% CI 0.53 to 1.25, p = NS

***Patients treated with NIV had poorer general and mental health and reported less vigour and more confusion and bewilderment.
Baseline differences in McEvoy’s study

<table>
<thead>
<tr>
<th></th>
<th>LTOT (n = 72)</th>
<th>NIV+LTOT (n = 72)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>68.8 (67.1 to 70.5)</td>
<td>67.2 (65.3 to 69.1)</td>
</tr>
<tr>
<td>Gender (% male)</td>
<td>61%</td>
<td>69%</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>25.4 (24.0 to 26.8)</td>
<td>25.5 (24.3 to 26.7)</td>
</tr>
<tr>
<td>FEV₁₀ (litres)</td>
<td>0.55 (0.51 to 0.59)</td>
<td>0.63 (0.57 to 0.69)</td>
</tr>
<tr>
<td>FEV₁₀ (% predicted)</td>
<td>23.1 (21.4 to 24.8)</td>
<td>25 (22.4 to 27.6)</td>
</tr>
<tr>
<td>FVC (litres)</td>
<td>1.76 (1.60 to 1.92)</td>
<td>1.98 (1.80 to 2.16)</td>
</tr>
<tr>
<td>FVC (% predicted)</td>
<td>54.8 (51.0 to 58.6)</td>
<td>57.5 (53.9 to 61.1)</td>
</tr>
<tr>
<td>FEV₁₀/FVC (%)</td>
<td>32.9 (30.9 to 34.9)</td>
<td>32.9 (30.3 to 35.5)</td>
</tr>
<tr>
<td>TLCO (ml/min/mmHg)</td>
<td>6.76 (5.96 to 7.56)</td>
<td>8.61 (7.49 to 9.73)</td>
</tr>
<tr>
<td>TLCO (% predicted)</td>
<td>30.7 (27.9 to 33.5)</td>
<td>37.2 (33.2 to 41.2)</td>
</tr>
<tr>
<td>Oxygen treatment (h/day)</td>
<td>20.5 (19.5 to 21.5)</td>
<td>20 (18.8 to 21.2)</td>
</tr>
<tr>
<td>Pao₂ (mm Hg, air)</td>
<td>52.5 (50.1 to 54.9) (n = 62)</td>
<td>54.8 (52.4 to 57.2) (n = 61)</td>
</tr>
<tr>
<td>Paco₂ (mm Hg, air)</td>
<td>54.4 (52.6 to 56.2) (n = 62)</td>
<td>52.6 (51.0 to 54.2) (n = 61)</td>
</tr>
<tr>
<td>SGRQ</td>
<td>64.1 (49.9–70.8)*</td>
<td>69 (57.2–77.2)*</td>
</tr>
</tbody>
</table>

Values are mean (95% CI) or *median (interquartile range).

Meta-analysis: Nocturnal NIV for stable COPD

- **Population:** Hypercapnic patients with stable COPD
- **Intervention:** Nocturnal-NIPPV at home for at least 3 months
- **7 studies, 245 people**
- **Meta-analysis of individual patient data**
- **Outcome measures:** PaCO2, PaO2, 6MWD, SGRQ, FEV1, FVC, PImax, sleep efficiency
- **Result:** No consistent clinically or statistically significant effect on any parameter (95% CI of all outcomes included zero)

Overlap syndrome (COPD + OSA)

Marin JM et al. Am J Respir Crit Care Med. 2010 Aug 1;182(3):325-31
Tracheostomy IPPV at home (Palermo, Italy 1995-2004)

Equipment selection
Closed circuit

• Usually has 2 limbs
• Exhalation via ‘valves’
• Allows higher level of support
• Allows more extensive monitoring
• Tighter control of ventilator variables

Open circuit

• Single limb
• Exhalation via ‘ports’
• Lesser level of support
• Lesser/less accurate monitoring options
• Poorer control of ventilator variables

King AC. Respir Care. 2012 Jun;57(6):921-30. PMID: 22663967
Blurring boundaries…

RAD = Respiratory assist device

King AC. Respir Care. 2012 Jun;57(6):921-30. PMID: 22663967
Open circuit

Interface selection
Invasive

- Reduced risk of aspiration
- Better clearance of secretions
- Better for long durations (>20h/d)

Non-invasive

- More comfortable & aesthetic
- Less speech alterations
- No complications related to artificial airway

King AC. Respir Care. 2012 Jun;57(6):921-30. PMID: 22663967
Duration of ventilation required per day

- Individual preferences
- Amount of secretions
- Facial dysmorphisms
- Adequacy of swallowing

IMV vs. NIV

King AC. Respir Care. 2012 Jun;57(6):921-30. PMID: 22663967
# Medicare Ventilator Support Claims Data 2010

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total all forms ventilation (RAD and all forms of mechanical ventilator)</td>
<td>47,981</td>
</tr>
<tr>
<td>Total invasive mechanical ventilator</td>
<td>3,172</td>
</tr>
<tr>
<td>Total noninvasive mechanical ventilator</td>
<td>899</td>
</tr>
<tr>
<td>Total noninvasive RAD</td>
<td>43,910</td>
</tr>
</tbody>
</table>

### Invasive Ventilator Support by Region (%)

<table>
<thead>
<tr>
<th>Region</th>
<th>Support (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States (total all invasive/total all forms)</td>
<td>6.6</td>
</tr>
<tr>
<td>Europe (EuroVent survey data)‡</td>
<td>13</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Oral*</th>
<th>Nasal masks</th>
<th>Nasal pillows</th>
<th>Oronasal</th>
<th>Full-face</th>
<th>Helmet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air leak</td>
<td>Mouth, nose leaks</td>
<td>In mouth-breathers</td>
<td>In mouth-breathers</td>
<td>Less</td>
<td>Less</td>
<td>Less</td>
</tr>
<tr>
<td>Influence by dental status</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Dead space and CO₂ rebreathing</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td>Difficulty in communication &amp; feeding</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Patient comfort</td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Risk of aerophagia</td>
<td>+</td>
<td>Less</td>
<td>Less</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Risk of skin damage</td>
<td>-</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Claustrophobia</td>
<td>+</td>
<td>Less</td>
<td>Less</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
</tbody>
</table>

*Excessive salivation, gag reflex and vomiting & orthodontic deformities (with long-term use)
EuroVent 2002: Interface preference

Nasal mask is the most widely used NIV interface for HMV

Dark grey: Nasal mask
Light grey: Facial mask
White: Tracheostomy

Humidification
Nasal CPAP with mouth leak resulted in nearly three-fold increase in nasal airway resistance.

This was substantially attenuated by effective humidification.

Mode selection
Controlled vs. Spontaneous

- Spontaneous: Better synchrony and comfort
- Controlled/Mandatory: Safer when patient’s breathing is erratic

Chatburn RL. Respir Care. 2009 Jan;54(1):85-101. PMID: 19111109
Stable VT despite varying patient effort, airway resistance, chest wall compliance

Poor performance during leak

Better patient synchrony and comfort

Stable ventilation despite leak
VCV vs. PCV during leak

Chatburn RL. Respir Care. 2009 Jan;54(1):85-101
EuroVent: Pressure vs. Volume

Dark grey: Pressure preset
Light grey: Volume preset

Major NIV modes

- **Continuous positive airway pressure (CPAP):** Similar to PEEP in IMV
  - With or without auto-titration feature (APAP)

- **Bi-level positive airway pressure (BPAP):**
  - **BPAP-S:** Patient-triggered, flow-cycled; Similar to PSV in IMV
  - **BPAP-T:** Time-triggered, time-cycled; Similar to PCV in IMV
  - **BPAP-ST:** Additional time-triggered, but flow-cycled breaths delivered when patients’ spontaneous rate falls below the set rate; Similar to PSV with PCV backup in IMV

- **Newer modes**
  - **Adaptive servo ventilation (ASV):** Similar to PRVC, Adaptive support ventilation (ASV) in IMV
  - **Averaged volume assured pressure support (AVAPS):** Similar to volume assured PSV in IMV

Chatburn RL. Respir Care. 2009 Jan;54(1):85-101. PMID: 19111109
Pressure controlled inspiration (with variable pressure limit) to achieve a volume target
Adaptive Servo Ventilation (ASV)

- Closed-loop mechanical ventilation, pressure preset, and volume or flow cycled
- Breath-by-breath adjustment of inspiratory pressure support with a back-up rate to normalize breathing patterns relative to a predetermined target

Examples

- **ResMed ASV** (ASV, iVAPS, AdaptSV) targets 90% of the calculated **minute volume** and adjusts IPAP and ventilator rate accordingly
- **Respironics ASV** (AutoSV) targets an **average peak flow** and adjusts IPAP accordingly

Use: Central sleep apnea
ASV/iVAPS (ResMed)

- Targets Minute Ventilation (MV) and adjusts pressure support and back-up rate accordingly

- Settings
  - Height
  - Target Ve
  - EPAP
  - Minimum pressure support
Table 1. Commercial names for Modes That Use Adaptive Control

<table>
<thead>
<tr>
<th>Ventilator</th>
<th>Adaptive Control Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dräger Evita 4 and XL</td>
<td>AutoFlow</td>
</tr>
<tr>
<td>Hamilton Galileo</td>
<td>Adaptive Pressure Ventilation</td>
</tr>
<tr>
<td></td>
<td>Adaptive Support Ventilation*</td>
</tr>
<tr>
<td>Maquette Servo-i</td>
<td>Pressure Regulated Volume Control</td>
</tr>
<tr>
<td></td>
<td>Volume Support</td>
</tr>
<tr>
<td>Puritan Bennett 840</td>
<td>Volume Control +</td>
</tr>
<tr>
<td>Newport E500</td>
<td>Volume Target Pressure Control</td>
</tr>
<tr>
<td>Viasys/Pulmonetics PalmTop Ventilator</td>
<td>Pressure Regulated Volume Control</td>
</tr>
<tr>
<td>Viasys Avea</td>
<td>Pressure Regulated Volume Control</td>
</tr>
</tbody>
</table>

*Adaptive support ventilation uses optimal control, an advanced form of adaptive control.
n/M/SD” = “number/mean/standard deviation
MD = Mean difference

“While there is no survival or long-term data available for ASV at this time, there is a sufficient amount of data consistently demonstrating improvement in both the AHI and LVEF”

AASM practice parameters.
AVAPS (Average Volume Assured Pressure Support) is similar to VAPSV (Volume assured pressure support ventilation) in invasive MV

Automatically adjusts the pressure support level (IPAP) to maintain a consistent tidal volume

Settings:
- Set target tidal volume to 110% of displayed patient tidal volume in the S/T mode or 8 cc per kg of ideal body weight.
- IPAP Max = 25-30 cm H2O
- IPAP Min = EPAP + 4 cm H2O

Candidates: Patients with risk of hypoventilation due to respiratory muscle weakness, restrictive disorders (kyphoscoliosis, obesity hypoventilation), obstructive lung diseases (COPD, CF)
Auto-titration

- Use: Titration of CPAP/EPAP/IPAP according to airway resistance

- Nomenclature
  - ResMed: APAP, AutoSet
  - Respironics: Auto CPAP

- Principle: **Forced oscillation technique**

- Involves the production of high frequency, low amplitude pressure waves during apneas, and the measurement of the changes in flow (If airway is open, flow increases with increase in pressure)
Patient requiring NIV

Possibility of significant hypoventilation

Yes

Auto BPAP or AVAPS

Variable VT

BPAP-S

High CPAP req.

Fails

BPAP-ST

Fails

ASV

No

CPAP trial

Variable CPAP req.

Auto CPAP

Need back-up?

CSA?
Monitoring
Monitoring

- Day-time ABG
- Nocturnal pulse oximetry
- Transcutaneous CO2
- Data from NIV machine
- Polysomnography
Monitoring

- Day-time ABG
- Nocturnal pulse oximetry
- Transcutaneous CO2
- Data from NIV machine
- Polysomnography
Pulse oximetry - Advantages & disadvantages

- Advantages
  - Simple
  - Short set-up time
  - Short response time
  - Sensitive

- Disadvantages
  - Motion artefacts
  - Perfusion dependence
  - Poor accuracy when oxygen saturation <80%
  - Poor specificity

Pulse oximetry

- If normal, cannot exclude alveolar hypoventilation (especially in patients on LTOT)
- Does not identify the mechanisms of SpO2 abnormalities (apneas, leaks, etc.)
Visual inspection of oximetry tracing

Recurrent oscillations in SpO2

Central/obstructive apneas
Intermittent leaks

Prolonged desaturation

Inadequate pressure support
Prolonged leaks

PWA/PTT

Requirements: ECG + Pulse oximetry

Smith RP et al. Thorax 1999;54:452-457
Inspiratory effort

Fall in BP (Pulsus paradoxus)

Lengthening of PTT

PTT $\propto 1/\text{BP}$

Non-invasive marker of inspiratory muscle effort
Obstructive apnoea

Swings of Poes become increasingly negative during an obstructive event, with simultaneous increase in oscillations of PTT between inspiration and expiration.

For both Poes and PTT signals, respiratory oscillations are markedly reduced.

Transcutaneous CO2

Severinghaus electrode
PtcCO2 during HMV

Limitations

- Slow response time: Usually < 2 minutes
- Drift: typically ≤5% per hour (requires calibration q8-12h)
- Membrane needs change every 2-6 weeks
- Can be continuously used at one site for only up to 8 hours
- Cost
PtcCO2 drift

No significant drift in 8h

Correlation with arterial CO2

Data from NIV machine

Synthesis data: Periodic trend

Detailed data: Cycle-by-cycle

Polygraphic data: With HR, SpO2

Thorax. 2011 May;66(5):438-45
Built-in software

- Compliance
- Tidal volume
- Minute ventilation
- RR
- Number of triggered breaths
- Leaks
- AHI
Pattern of ventilator use: Good compliance

Pattern of ventilator use: Poor compliance

Problems with data from NIV machines

Reliability of data?

Discrepancy between devices

‘Normal’ values?
### Unintentional leak, 0 L/min

<table>
<thead>
<tr>
<th>Device</th>
<th>Vt Bench, mL</th>
<th>Vt Software, mL</th>
<th>[Vt Bench] – [Vt Software], mL</th>
<th>Leaks on Bench, L/min</th>
<th>Leaks from Software, L/min</th>
<th>[Leaks on Bench] – [Leaks from Software], L/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>912</td>
<td>711</td>
<td>201</td>
<td>52.8</td>
<td>45.0</td>
<td>7.8</td>
</tr>
<tr>
<td>B</td>
<td>968</td>
<td>840</td>
<td>128</td>
<td>40.1</td>
<td>35.0</td>
<td>5.1</td>
</tr>
<tr>
<td>C</td>
<td>886</td>
<td>797</td>
<td>89</td>
<td>44.8</td>
<td>46.0</td>
<td>2.0</td>
</tr>
<tr>
<td>D</td>
<td>1,033</td>
<td>705</td>
<td>328</td>
<td>38.1</td>
<td>26.2</td>
<td>11.9</td>
</tr>
<tr>
<td>E</td>
<td>809</td>
<td>690</td>
<td>119</td>
<td>40.5</td>
<td>20.2</td>
<td>20.3</td>
</tr>
<tr>
<td>F</td>
<td>1,015</td>
<td>750</td>
<td>265</td>
<td>0.0</td>
<td>1.2</td>
<td>-1.2</td>
</tr>
<tr>
<td>G</td>
<td>1,032</td>
<td>820</td>
<td>212</td>
<td>0.0</td>
<td>2.4</td>
<td>-2.4</td>
</tr>
</tbody>
</table>

### Unintentional leak, 60 L/min

<table>
<thead>
<tr>
<th>Device</th>
<th>Vt Bench, mL</th>
<th>Vt Software, mL</th>
<th>[Vt Bench] – [Vt Software], mL</th>
<th>Leaks on Bench, L/min</th>
<th>Leaks from Software, L/min</th>
<th>[Leaks on Bench] – [Leaks from Software], L/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>668</td>
<td>547</td>
<td>121</td>
<td>76.8</td>
<td>62.0</td>
<td>14.8</td>
</tr>
<tr>
<td>B</td>
<td>800</td>
<td>700</td>
<td>100</td>
<td>65.5</td>
<td>60.0</td>
<td>5.5</td>
</tr>
<tr>
<td>C</td>
<td>923</td>
<td>826</td>
<td>97</td>
<td>74.3</td>
<td>75.0</td>
<td>-0.7</td>
</tr>
<tr>
<td>D</td>
<td>1,116</td>
<td>712</td>
<td>404</td>
<td>96.2</td>
<td>68.2</td>
<td>28.0</td>
</tr>
<tr>
<td>E</td>
<td>763</td>
<td>580</td>
<td>183</td>
<td>91.3</td>
<td>38.2</td>
<td>53.1</td>
</tr>
<tr>
<td>F</td>
<td>1,062</td>
<td>900</td>
<td>162</td>
<td>30.4</td>
<td>31.2</td>
<td>-0.8</td>
</tr>
<tr>
<td>G</td>
<td>1,228</td>
<td>1,100</td>
<td>128</td>
<td>32.5</td>
<td>33.6</td>
<td>-1.1</td>
</tr>
</tbody>
</table>

- Underestimation of VT by all devices
- Poor leak assessment by most of the devices
- Non-uniformity in methods used for leak assessment

Goals to achieve in a patient treated by NIV:
- Clinical improvement and reduction in daytime PaCO₂
- Mean nocturnal SpO₂ > 90% more than 90% of recording time, without residual SaO₂ oscillations
- 'Synthesis report' from NIV software: showing more than 4h/night of use, without discomfort (i.e.: fragmented use or multiple short periods of ventilator use).

Detection of non intentional leaks (clinically and/or by NIV software):
- Optimize mask fitting
- Disappearance of SpO₂ abnormalities, discomfort & non-compliance

Suspect upper airway instability
- Increase EPAP
- Resolution of SpO₂ abnormalities, discomfort and/or non-compliance
- Pursue home-based nocturnal NIV with same ventilator settings

Suspect persistent nocturnal hypoventilation (documented by PtcCO₂)
- Increase IPAP or Vₜ
- Resolution of SpO₂ abnormalities, discomfort and/or non-compliance

Asynchrony? Central events?
- PSG

Transition to home care & follow-up
Transition from hospital to home

- Patient assessment: Fitness for discharge (clinical stability, secretions, etc.)
- Community assessment: finances, home conditions (power-cuts, battery-backup, access to hospitals, etc.)
- Equipment preparation: procuring ventilator, humidifier, nebuliser, suction device, oxygen source
- Care-giver training: suction, device operation, troubleshooting
What can go wrong?

<table>
<thead>
<tr>
<th>Causes of Home Ventilator Failure Reports</th>
<th>No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defective equipment or mechanical failure</td>
<td>73 (39)</td>
</tr>
<tr>
<td>Improper care, damage, or tampering by caregivers</td>
<td>25 (13)</td>
</tr>
<tr>
<td>Functional equipment improperly used by caregivers</td>
<td>56 (30)</td>
</tr>
<tr>
<td>Functional equipment with change in patient’s condition mimicking ventilator failure</td>
<td>5 (3)</td>
</tr>
<tr>
<td>No problem identified</td>
<td>30 (16)</td>
</tr>
</tbody>
</table>
Results

- Compared with controls, the TA group experienced significantly fewer hospitalisations (-36%), urgent GP calls (-65%) and acute exacerbations (-71%)

- After deduction of TA costs, the average overall cost for each patient was 33% less than that for usual care

Conclusion

- HMV use has increased markedly over the years and is bound to increase further
- Changing trends in usage: Neuromuscular disorders → Sleep-disordered breathing, COPD
- NIV (with nasal masks) is more widely used compared to IMV
- Major improvements in NIV devices/modes: data on clinical impact evolving
- More sophisticated ventilators/modes only add to the cost (and may even be harmful) when used in unnecessary situations
- Proper interface selection, humidification, caregiver education and periodic monitoring are essential for success