



Non-Invasive Ventilation

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And the Lord God formed man of the dust of the ground and breathed into his nostrils the breath of life, and man became a living soul.

DEFINITION

Noninvasive ventilation is the delivery of ventilatory support without the need for an invasive artificial airway.

HISTORY

- The concept of mechanical ventilation first evolved with negative-pressure ventilation.
- In 1876, Woillez first developed a workable iron lung.
- In 1889, Alexander Graham Bell designed and built a prototype of iron lung for use with a newborn infant.
- In the late 1920s, Drinker introduced negative-pressure ventilation and popularized the iron lung. He maintained an 8-year-old girl with acute poliomyelitis on artificial respiration continuously for 122 hours.
- The polio epidemics of the 1930s, 1940s, and 1950s led to the development of pulmonary medicine as a specialty and the iron lung as a workhorse.
- Ventilators delivering negative-pressure ventilation fell out of favor as the use of invasive positive-pressure ventilation (PPV) increased during the 1960s.
- However, over the past decade and a half, a striking resurgence has been observed in the use of noninvasive ventilation, fueled by the development of PPV delivered through a nasal or face mask.

NIV - MECHANISM OF ACTION

Decreases Work of Breathing

- EPAP / CPAP increases FRC (keeps alveoli open)
- IPAP / PSV adds inspiratory assistance
- In COPD's helps to overcome the added trigger load due to Autopeep (thus helps triggering)

Improves Gas Exchange

- CPAP
- Improves FRC (keep alveoli open)
- EPAP
- Improve V/Q mismatch
- Reverses micro-atelactasis

MECHANISM - BASIC DIFFERENCES

- The expiratory pressure with bilevel pressure support is equivalent to the PEEP, and the inspiratory pressure is

equivalent to the sum of the PEEP and the level of pressure support.

- In **timed mode**, biphasic positive airway pressure ventilation alternates between the inspiratory and expiratory pressures at fixed time intervals, which allows unrestricted breathing at both pressures.
- In **spontaneous mode**, biphasic positive pressure cycles on the basis of the flow rates of the patient's own breathing. In spontaneous mode, upon detection of inspiration, higher pressure is delivered until the flow rate falls below the threshold level.

INDICATIONS

Acute Respiratory failure

- **Obstructive** → *acute exacerbation of COPD*
→ acute exacerbation of OSA
→ asthma / cystic fibrosis
- **Cardiogenic** → *acute pulmonary edema*
- Post-operative respiratory fatigue.
- **Restrictive** → *obesity hypoventilation*
→ neuromuscular diseases
→ chest wall deformities
- Lung Parenchymal
→ *ARDS*
→ *Pneumonias esp. in HIV pts.*
- In DNI patients
→ *Ca / AIDS*

Chronic Hypercapnic respiratory failure

- Nocturnal or partial daytime:
 - *OSA*
 - *CSA*
 - *COPD*
 - *Myasthenia & other neuromuscular disorders*
- Weaning and extubating difficult patients or long term ventilator dependent patients.
“lesser chances of re-intubation”

GOALS OF NIV

- Relieve symptoms of respiratory failure / fatigue.

- Reduce work of breathing rep. in COPD i.e. to decrease PaCO₂ and improve pH.
- Improve gas exchange - resp. oxygenation in acute settings.
- Achieve synchrony.
- Comfort the patient.
- Avoid intubation.
- Improve sleep duration and quality of life in the chronic setting.

CONTRAINDICATIONS

- Respiratory arrest
- Unable to protect the airway
 - poor cough
 - poor gag
- Excessive thick secretions
- Restless / Uncooperative patient
- Medically unstable
 - acute MI / arrhythmias
 - shock
 - hypotension
- Unconscious / drowsy patient
- Faciomaxillary injuries, burns and abdominal surgery
- Need for continuous or near continuous ventilatory assistance

SELECTION GUIDELINES

Acute use

- | | |
|------------|---|
| | - RR > 24 but < 50 |
| | - Use of accessory muscles |
| CLINICAL | - Paradoxical breathing |
| | - Moderate dyspnoea |
| | - Impending respiratory fatigue |
| | - PaCO ₂ > 45 |
| LABORATORY | - pH < 7.30 - 7.35 |
| | - PaO ₂ / FiO ₂ < 200 |

Chronic use

COPD/OSA/Restrictive Lung Disease

- **Clinical:**
 - Fatigue
 - Morning headache
 - Nightmares
 - Dyspnoea
 - Excessive sleep
- **Laboratory:**
 - Daytime PaCO₂ > 45 < 55
 - Night time SpO₂ < 90% for 5 min.
- Failure to respond to optimal medical treatment

EQUIPMENT & MODES

Ventilators

Conventional

- Pressure Limited (PSV) ~ 25 - 35 cm H₂O

- Volume Limited (VC) ~ 15 ml/kg (twice that of intubated patients to compensate for leaks)

Commonest is PSV (IPAP) with PEEP (EPAP)

Specialised

- Wall mounted CPAP (high pressure flow generator)
- CPAP → via a compressor
- BIPAP purely spontaneous (IPAP + EPAP)
- A/C → spontaneous trigger
- Time triggered
- Volume / Pressure limited modes

Newer

- PAV (Proportional Assist Device)

Interfaces

Nasal Masks

- Mainly for chronic application
- Less claustrophobic
- Allows patient to eat & drink and also sometimes talk
- May need chin straps for mouth breathers
- **Disadvantage:** Increased chances of leak

Face Mask

- Mainly for acute application where patients are mouth breathers
- **Better for patients with air leaks**

Disadvantage

- Causes claustrophobia
- Interferes with speech / eating
- Interferes with expectoration
- Increased chances of aspiration

Nasal Pillows

- Nose bridge erosions are eliminated
- Less claustrophobic

Mouth Pieces with Lip Seals

Tents / Helmets

Advantages of Specialized Ventilators over Conventional

- Can compensate for leaks by increasing flow rates.
- Can have very sensitive flow / pressure triggers.
- Simple / Cheaper.
- Portable.
- Convenient for home ventilation and out of ICU ventilation therefore saves ICU cost.

Disadvantages of Specialized Over Conventional Ventilators

- Does not have O₂ blenders therefore high FIO₂ not guaranteed (gives O₂ separately)
- Uses single tubing and thus has a increased chance of hypercarbia

- Cannot reach very high inflation pressures therefore not useful in acutely breathless patients
- Does not have monitoring facilities?

Advantages of NIV over Conventional Ventilation

- Can eat and talk
- Decreases chance of VAP
- Decreases all risks of intubation
- May decrease LOS
- May decrease mortality
- Maintains natural humidification

Disadvantages of NIV over conventional ventilators

- Risk of aspiration
- Risk of inadequate ventilation
- Needs specialized experts for the initial 1hour, thus more manpower
- Complications related to NIV
- Risk of re-breathing (single tubing) and thus hypercarbia

PREDICTORS OF SUCCESS

- Younger age
- Less severe illness
- Cooperative patient / Willing patient
- Awake patient
- Can co-ordinate breathing with the ventilator
- Patient who develops less air leaks
- Intact dentition
- PaCO₂ between 45 - 90
- pH between 7.1 - 7.35
- Those that improve gas exchange and RR within the first 2 hours

PROTOCOL FOR INITIATION

- Choose an appropriate location with monitoring facilities i.e. Oximetry / Hemodynamics / ABG.
- Position the patient 30 - 45° propped up.
- Select the correct sized interface.
- Select the ventilator
- Encourage patient to hold the mask.
- When patient adapts to the mask, then strap it up (allow 1-2 fingers under the strap).
- Connect the interface to the ventilator and turn the ventilator on.
- Choose the mode and settings.
Spont - Timed (backup facilities). Start with low setting and build up.
i.e. PSV / IPAP of 8 - 12cm H₂O
CPAP / EPAP of 2 - 5 cm H₂O.
Volume of 10 ml / kg
- Check other settings - Ramp / Rise time / Sensitivity / Flow Rate etc.
- Gradually increase inspiratory pressure by increments of 2 cm until

max 20 - 25 cm or TV reaches 15 ml / kg.

- Decide the correct settings to target clinical goals.
 - i.e. relief of dyspnoea
 - improved pattern / rate of breathing
 - improve SpO₂ /gases
 - patient - ventilator synchrony
- Provide O₂ to keep SpO₂ 90 - 94%.
- Add humidifier if NIV used for more than 24 hours.
- If agitated by very mild sedation, talk to the patient & encourage him or her.
- Monitor gases within 1 - 2 hours to see response.

EVIDENCE OF USEFULNESS OF NIV

- Decreases incidence of intubation.
- Decreases incidence of infection and other complication.
- Decreases incidence of mortality.
- Decreases LOS.
- Decreases cost of hospitalisation.
- Decreases duration of ventilation.
- **USEFUL in:**
 - COPD exacerbation
 - DNI
 - Acute pulmonary edema
 - OSA
 - Restrictive neuromuscular lung disease

The use of NPPV in patients with COPD exacerbation

- Recent prospective randomized studies strongly support the use of noninvasive mechanical ventilation in patients with severe exacerbations of COPD.
- In a large randomized trial (**Brochard, 1995**) comparing NPPV with a standard ICU approach, the use of NPPV was shown to reduce complications, the duration of ICU stay, and mortality. Patients in whom NPPV failed had a similar mortality rate compared to the intubated group (25% vs 30%).
- **Plant and colleagues** published the largest prospective randomized study comparing NPPV to standard treatment in patients with COPD exacerbation. NPPV was administered in the wards where the nurses were trained for 8 hours in the preceding 3 months. Treatment failed in significantly more patients compared to the control group (27% vs 15%) but the in-hospital mortality rates were significantly reduced from the use of NPPV (20% to 10%).
- In addition, **3 Italian cohort studies** with historical or matched control groups have suggested that long-term outcome of patients treated with NPPV, is much better than that of patients treated with medical therapy and/or with endotracheal intubation.

Severe but stable COPD

- Evidence for the use of NPPV in patients with severe but stable COPD is less convincing.
- Of the four controlled studies using NPPV for severe but stable COPD, only one has shown favorable results.

This crossover study by **Meecham Jones** used a nasal BIPAP system nocturnally, and improvements were observed in daytime and nocturnal PaCO₂, total sleep time, and quality-of-life scores after 3 months of NPPV use.

- A trial of nocturnal NPPV is recommended in patients with COPD with severe hypercapnia (PaCO₂ >55 mm Hg), nocturnal oxygen desaturation, coexisting sleep disordered breathing, and possibly patients with frequent panic attacks, which may be relieved by using NPPV.

Hypoxemic respiratory failure

- Studies on the use of NPPV in hypoxemic respiratory failure, defined as PaO₂-to-FIO₂ ratio of less than 200 in the absence of carbon dioxide retention, have yielded conflicting results.

Patients with a variety of diagnoses (e.g., pneumonia, congestive heart failure, acute respiratory distress syndrome) had been included in this category.

Uncontrolled studies have suggested that some patients with hypoxemic respiratory failure may respond favorably to NPPV.

In one study of NPPV for hypoxemic respiratory failure, only 30% of NPPV-treated patients required intubation. The mortality rate was 22%, compared to the predicted mortality rate of 40%.

- In a trial of 64 patients with hypoxemic respiratory failure randomized to receive NPPV or intubation, only 31% of NPPV-treated patients required intubation. Improvements in oxygenation were comparable in the two groups, but the NPPV-treated patients had significantly fewer infectious complications.

Hypoxemic respiratory failure

- In another study of patients with severe community-acquired pneumonia and hypoxemic/hypercapnic respiratory failure, NPPV use was associated with reduced intubation rates (21% vs 50%) and a reduced duration of ICU stay (1.8 d vs 6 d) compared with standard treatment.
- Controlled studies are generally lacking in the support of using NPPV for other types of acute respiratory failure. However, several case series, report successful NPPV use in:
 - acute asthma
 - cystic fibrosis
 - respiratory deterioration following extubation in the postoperative phase
 - acute pulmonary edema
 - as a method of weaning patients from invasive ventilation.

Acute Pulmonary Edema

- Noninvasive CPAP has been shown in randomized controlled trials to be an effective therapy for acute pulmonary edema, improving oxygenation and hypercapnia, decreasing respiratory work, and reducing the rate of endotracheal intubation.

- In a controlled study, nasal BIPAP improved the PaCO₂ levels, pH, respiratory rate, and dyspnea more rapidly than nasal CPAP in patients with acute pulmonary edema. Therefore, CPAP alone seems a logical first choice in the treatment of patients with acute pulmonary edema. However, patients with hypercapnia or patients with continued respiratory distress on CPAP should be switched to BIPAP

Acute Asthma

- No randomized trials have evaluated NPPV to treat acute asthma.
- In the largest uncontrolled trial, 17 patients with asthma who had an average initial pH of 7.25 and a PaCO₂ of 65 mm Hg were treated with NPPV. Only two patients required intubation for hypercapnia. The average duration of ventilation was 16 hours, and no complications occurred.
- Therefore, NPPV appears to be an effective ventilatory modality in correcting gas exchange abnormalities in patients with severe asthma exacerbation.

Cystic Fibrosis

- One study described the use of NPPV to treat six patients with end-stage cystic fibrosis with forced expiratory volumes in one second (FEV₁) ranging from 350-800 mL with severe acute or chronic carbon dioxide retention. Patients were supported for 3-36 days. Four of these patients survived until a heart or lung transplant could be performed.
- Therefore, NPPV could be used as a rescue therapy in supporting patients with acute and deteriorating cystic fibrosis to provide a bridge to transplantation.

Facilitation of Weaning

- NPPV has been used to accelerate and facilitate weaning in patients who do not meet the standard criteria for extubation. Patients in whom weaning is difficult have been placed on **NPPV following extubation**. Although the selection criteria have not been well defined, they include a patient who is fully alert and cooperative, an airway that is easy to reintubate, and a patient with respiratory muscle strength sufficient to clear secretions.
- Patients who have developed acute and chronic respiratory failure because of **obesity hypoventilation syndrome** may often be switched from invasive ventilation to NPPV support. Because these patients require ongoing ventilatory support initially 24 h/d and subsequently through the nights, weaning via NPPV appears to be the best option. NPPV weaning has been used in these patients, tracheostomy notwithstanding.
- Another use of NPPV is in **the treatment of extubation failures**. Most benefit appears to be in patients with COPD exacerbations, acute pulmonary edema, and postextubation upper airway obstruction secondary to glottic swelling.

Restrictive thoracic disorders

- Several uncontrolled studies, including those by Ellis et al, Kerby et al, and Bach et al, demonstrated that even patients with severe carbon dioxide retention and symptoms such as morning headache and daytime hypersomnolence could undergo remarkable reversal after several weeks of nocturnal nasal ventilation.
- Uncontrolled trials have consistently demonstrated the efficacy of NPPV in restrictive thoracic disorders, but no randomized trial has ever been conducted.

- The long-term survival of patients with restrictive thoracic diseases who use NPPV for chronic respiratory failure is comparable to those who use invasive PPV.

OTHER UNCOMMON WAYS OF NIV

- Negative pressure ventilation.
- Cuirass
- Iron lung
- Jackets
- Rocking belt.
- Diaphragmatic pacing.