Noninvasive Ventilation in Respiratory Failure

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Definition

- Means of providing ventilatory assistance without an artificial airway

- Augmentation of alveolar ventilation without a direct airway conduit
- Actually used during polio epidemic
- Availability of masks that have spun off of the field of sleep medicine has sparked interest in NIPPV in the critical care setting

Advantages

- Eliminates need for intubation
  - Avoids injury to vocal cords and trachea
  - Reduces risk for VAP
- Sustains normal swallowing, cough, and speech
- Improves patient outcome in some types of respiratory failure

Disadvantages

- Can increase patient discomfort and anxiety
- Can delay time to needed intubation

- Use of NPPV in acute care setting has increased significantly in last 20 years
- Worldwide increased from 4% of all ventilators in 2001 to 11% in 2004

Types

- Negative pressure ventilation
- Bilevel positive pressure ventilation
- Continuous positive airway pressure

Negative Pressure Ventilation

- Inspiration – chest wall is exposed to subatmospheric pressure.
- Expiration – occurs when pressure around the chest wall returns to atmospheric levels.
- Benefits patients with chronic respiratory failure due to chest wall and neuromuscular problems.

Iron Lung

Positive Pressure Ventilation

- Ventilation delivered by a variety of machines via a nasal or full face mask
  - Volume ventilator
    - Delivers a set volume with each breath
    - Poorly tolerated by the patients
  - **Bilevel positive-airway-pressure (bilevel PAP)**
  - Continuous-positive-airway-pressure (CPAP)

CPAP - Operation

- Same pressure throughout the respiratory cycle.
- Effectively delivering PEEP.
- Usually set at 5-15 cm of water pressure.
- Oxygen can be bled into the system.

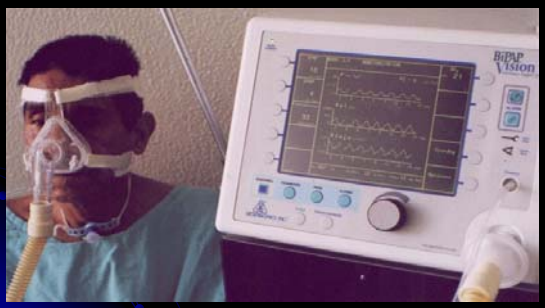
Bilevel PAP – Operation 1

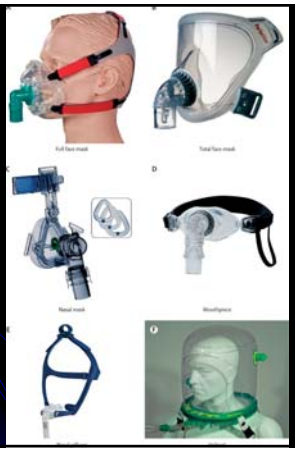
- Continuous high flow PAP that cycles between a high positive pressure during inspiration and a lower positive pressure during expiration.
- Cycles between these pressures by responding to the patient's respiratory efforts and flow rates.
- Conceptually similar to pressure support ventilation with PEEP.

Bilevel PAP – Operation 2

- Supplemental oxygen can be delivered through the same circuit; a higher flow of oxygen may be required (compared to what was needed prior to Bilevel PAP use).
- Settings: Usually inspiratory pressure of 6-15 cm of water and expiratory pressure of 4-8 cm of water; tidal volume is variable.

Bilevel PAP Device





Features	Conventional Ventilation	NIPPV
Complications of intubation		
Airway trauma	Possible	Absent
Increase resistive work of breathing	Present	Absent
Nosocomial pneumonia	Possible	Absent
Barotrauma	Possible	Absent
Self-extubation	Possible	Absent
Application		
Implementation/removal	Difficult	Easy
Intermittent use	Not possible	Possible
Patient comfort	Average	Excellent
Sedation	Mandatory	Occasionly needed
Paralysis/complications	May be needed/possible	Not needed/absent
Reflexes		
Speech/swallowing/cough	Lost	Preserved
Air humidification/warming	Mandatory	Not needed
Physiotherapy	Cumbersome	Easy
Patient participation in decision making	Not possible	Possible
Weaning	Complex	Easy
Respiratory muscle disuse/atrophy	Possible	Absent
Cost effectiveness	Less	Better
Correction of gas exchange abnormalities	Rapid	Slow
Airway access/protection	Present	Absent
Initial time commitment	Less	More
Patient co-operation	Not needed	Mandatory
Use in very sick patients (coma, hemodynamic unstable, upper abdominal surgery etc.)	Possible	Not possible

COPD Exacerbation

- Marked increase in airway resistance
- Decreased expiratory flow
- Dynamic hyperinflation
- Marked disadvantage for respiratory muscled due shortening and flattening of the diaphragm
- → inefficient position on length-tension curve

COPD Exacerbation

- Load on respiratory muscles also increased by auto-peep
- High O2 cost→ hastens muscle fatigue
- Fatigue→ hypercapnea and acidosis
- NIPPV

→ Respiratory muscle rest theory

→ Restored chemosensitivity

→ Decreased load

COPD Exacerbation

- NIPPV can rest the muscles of respiration
- Thereby decreasing work of breathing
- Allowing time for pharmacological interventions to work
- Numerous uncontrolled studies have shown improvement in gas exchange, respiratory rate and acidosis with NIPPV in copd exacerbations

Noninvasive Ventilation in COPD

TABLE 2
SUMMARY OF RANDOMIZED CONTROLLED STUDIES USING NPPV IN ACUTE RESPIRATORY FAILURE CAUSED BY COPD

Author	Yr	Reference No.	Technique/Mask	Insp/Exp Pressure ($cm\ H_2O$)	Patients (*n*)		Diagnosis	Pa_{CO2} (*mm Hg*)		Pa_{O2} (*mm Hg*)	
					NPPV	Control		B	A	B	A
Bott	1993	128	Volume/nasal		30 (3)	30 (9)	COPD	65	55		
Kramer	1995	129	BiPAP/nasal	8/2	16 (5)	15 (11)	COPD	74	67	67	92
Brochard	1995	130	PSV/oronasal	20	43 (11)	42 (31)	COPD	70	68	41	66
Angus	1996	131	PSV/nasal	14/18	9 (0)	8 (3)	COPD	76	65		
Celikel	1998	132	PSV/oronasal	15/5	15 (1)	15 (6)	COPD	69	64	55	85
Plant	2000	134	VPAP/nasal/oronasal		118 (18)	118 (32)	COPD	66	61	52	56
Barbe	1996	135	BiPAP/nasal	14.8/5	14 (4)	10 (0)	COPD	59		45	
Totals					245 (42)	238 (29)		Means	68	60	54	67
Success rate					83%	61%					

Definition of abbreviations: A = 45 min to 3 h after initiation of NPPV; B = baseline; COPD = chronic obstructive pulmonary disease; Insp/Exp = inspiratory/expiratory; NPPV = noninvasive positive pressure ventilation; PSV = pressure support

Studies are less conclusive regarding NIPPV and stable COPD

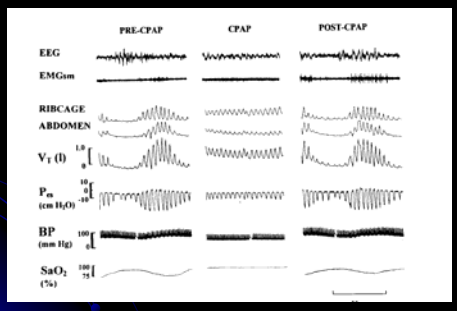
Pt are more likely to tolerate this mode of therapy if they have baseline hypercapnea

NIPPV in CHF

- CPAP augments cardiac output
- Increased intra-thoracic pressures decrease pre-load→ by impeeding cardiac filling
- After-load is reduced by decreasing transmural pressure gradients
- Induces a fall in heart rate

NIPPV in CHF

- Increases heart rate varaiblilty
- Increases LVEF
- Decreases ANP
- Decreases sympathetic tone and NE levelels



Noninvasive Ventilation in CHF

TABLE 1
STUDIES ON THE EFFICACY OF CONTINUOUS POSITIVE AIRWAY PRESSURE IN ACUTE PULMONARY EDEMA

Author	Yr	Reference No.	Technique*	Positive Pressure (cm H_2O)	Patients (n) CPAP	Control	Pa_{CO2} (mm Hg) B	A	Pa_{O2} (mm Hg) B	A
Rasanen	1985	95	CPAP	10	20 (7)	20 (13)	41	39	52	60
Viasanen	1987	96	CPAP	10	40 (7)		36	35	55	79
Lin	1991	97	CPAP	12.5	25 (7)	30 (18)	30	32	326	416
Bersten	1991	98	CPAP	10	19 (0)	20 (7)	58	46	138	206
Lin	1995	99	CPAP	12.5	50 (8)	50 (18)				
Totals					154 (29)	120 (56)	Means	41	38	
Success rate					81%	53%				

Definition of abbreviations: A = 10 min to 3 h after initiation of noninvasive positive pressure ventilation; B = baseline; CPAP = continuous positive airway pressure.
* In all studies, CPAP was administered via oronasal mask.

Numbers in parentheses are numbers of failures, i.e., those who were intubated or who failed to tolerate the mask.

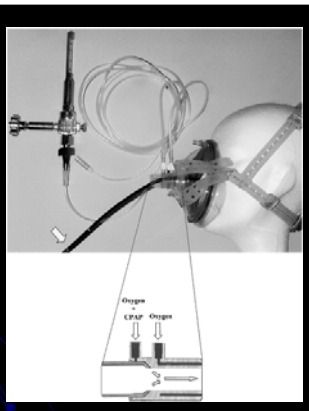
Pa_{O2}/FI_{O2} ratios.

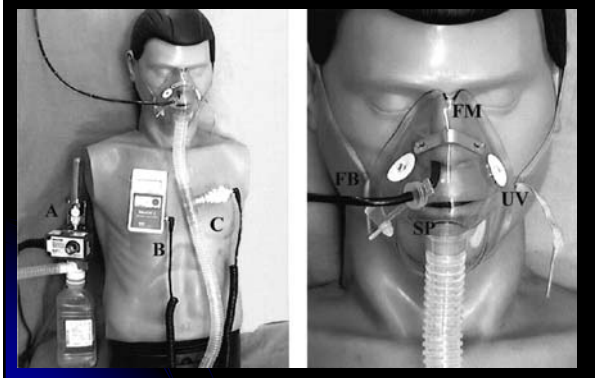
CPAP vs BiPAP

- Meta-analyses
- No difference in intubation or mortality rates
- Some studies showed greater rate of improvement in dyspnea, P_aO_2, and P_aCO_2 with NPPV
- CPAP easier to use

NPPV and Bronchoscopy

- Seems to show may be helpful in avoiding intubation in high risk patients





NPPV *instead* Intubation

- One randomized control trial : NJEM 1998
- Antonelli et al compared NPPV vs immediate intubation for ARDS
- No difference in oxgen improvement
- Only 31% in NPPV group needed intubation
- Intubated patients had increase in complications
- Duration of mechanical ventilation and ICU stay shorter in NPPV

NPPV *instead of* Intubation

- 2007 survey: Antonelli et al
- 3 ICUs, highly skilled in NPPV, real world setting
- 30% fit criteria for NPPV
- 54% avoided intubation, lower M&M
- Approx 15% can be treated successfully

NPPV *to avoid* Reintubation

- Reviewed 4 randomized trials
- 2 showed NPPV reintubation & mortality ↓
- 2 showed no decrease in reintubation and mortality ↑

Practical Approach to the Use of NPPV in the Postextubation Setting

- NPPV in Patients At Risk for Postextubation Respiratory Failure
- (Preferred approach for the use of NPPV in the postextubation
- setting)
- Identify high-risk features
- Elderly patients (age 65 y)
- More than one consecutive failure of weaning trial
- Chronic heart failure
- $PaCO_2$ 45 mm Hg after extubation
- More than one medical/surgical co-morbid illness
- Poor cough reflex

- Upper-airways stridor at extubation that does not require
- immediate reintubation
- APACHE II score 12 on the day of extubation
- Severely obese patients (body mass index 35 kg/m2)
- NPPV in Established Postextubation Respiratory Failure

NPPV in Established Postextubation Respiratory Failure

- Use judiciously
- Likely to benefit selected patients →eg, acute COPD, hypercapnic
- pulmonary edema
- Trial of NPPV for 2 hours
- Close monitoring of respiratory, cardiovascular and arterial blood
- gas variables
- Facilities for intubation and invasive ventilation readily available

	Reducing mortality	Decreasing intubation
COPD exacerbation[41]	+++	+++
[redacted]	[redacted]	[redacted]
Weaning COPD patients[107]*	+++	WMD −6·32
[redacted]	[redacted]	[redacted]

Recommendations for NIV to treat acute respiratory failure

Recommendations based on levels of evidence

Level 1 evidence:
Systematic reviews (with homogeneity) of RCTs and individual RCTs (with narrow CIs)

Evidence of use (favourable)
- **COPD exacerbations**
- **Facilitation of weaning/extubation in patients with COPD**
- **Cardiogenic pulmonary oedema**
- **Immunosuppressed patients**

Evidence of use (caution)
- **None**

Level 2
Systematic reviews (with homogeneity) of cohort studies—individual cohort studies (including low quality RCTs; eg, <80% follow-up)
Evidence of use (favourable)
- **Do-not-intubate status**
- **End-stage patients as palliative measure**
- **Extubation failure (COPD or congestive heart failure) (prevention)**
- **Community-acquired pneumonia in COPD**
- **Postoperative respiratory failure (prevention and treatment)**
- **Prevention of acute respiratory failure in asthma**

Evidence of use (caution)
- **Severe community acquired pneumonia**
- **Extubation failure (prevention)**

Level 3
Systematic reviews (with homogeneity) of case–control studies, individual case-control study
Evidence of use (favourable)
- **Neuromuscular disease/kyphoscoliosis**
- **Upper airway obstruction (partial)**
- **Thoracic trauma**
- **Treatment of acute respiratory failure in asthma**

Evidence of use (caution)
- **Severe acute respiratory syndrome**

Level 4
Case series (and poor quality cohort and case-control studies)
Evidence of use (favourable)
- **Very old age, older than age 75 years**
- **Cystic fibrosis**
- **Obesity hypoventilation**

Evidence of use (caution)
- **Idiopathic pulmonary fibrosis**

Selection Guidelines

- Appropriate Dx w/ potential reversibilty
  - COPD exacerbation
  - cardiogenic pulmonary edema

- Establish need for ventilatory assistance
  - Moderate to severe respiratory distress
  - Tachypnea, accessory muscle use, abdominal paradox
  - ABG derangement (pH<7.35, PaCO2>45 or PaO2/FiO2<200)

Contraindications

- Cardiorespiratory Instability
- • Cardiac or respiratory arrest.
- • Hypotension with high inotropes
- • Recent Myocardial infarction with pulmonary
- edema
- • Serious arrhythmia.
- • Undrained pneumothorax.
- . Unable to protect airways
- • Severe encephalopathy
- • Poor Bulbar Function
- • Comatose state
- • Cerebrovascular Accident

- Unable to fix Interface mask
- • Recent Facial, Esophageal, or Craniofacial
- Trauma.
- • Fixed Anatomic Abnormalities of the nasopharynx
- d. Copious Secretions

- Exclude Patients with contraindications
  - Respiratory or cardiac arrest
  - Homodynamic instability
  - Unable to protect airway
  - Unable to fit mask
  - Untreated Ptx
  - Recent upper airway or esophageal surgery
  - Excessive secretions
  - Uncooperative or agitated

Noninvasive Ventilation Complications

FREQUENCY OF ADVERSE SIDE EFFECTS AND COMPLICATIONS OF NPPV WITH POSSIBLE REMEDIES

	Occurrence (%)*	Possible Remedy
Mask-related		
Discomfort	30-50	Check fit, adjust strap, new mask type
Facial skin erythema	20-34	Loosen straps, apply artificial skin
Claustrophobia	5-10	Smaller mask, sedation
Nasal bridge ulceration	5-10	Loosen straps, artificial skin, change mask type
Acneiform rash	5-10	Topical steroids or antibiotics
Air Pressure or Flow-related		
Nasal congestion	20-50	Nasal steroiids, decongestant/antihistamines
Sinus/ear pain	10-30	Reduce pressure if intolerable
Nasal/oral dryness	10-20	Nasal saline/emollients, add humidifier, decrease leak
Eye irritation	10-20	Check mask fit, readjust straps
Gastric insufflation	5-10	Reassure, simethacone, reduce pressure if intolerable
Air Leaks	80-100	Encourage mouth closure, try chin straps, oronasal mask if using nasal mask, reduce pressures slightly
Major Complications		
Aspiration pneumonia	< 5	Careful patient selection
Hypotension	< 5	Reduce inflation pressure
Pneumothorax	< 5	Stop ventilation if possible, reduce airway pressure if not Thoracostomy tube if indicated

Best Predictors of Success

- Good Response in 1-2 hours
  - Reduction of respiratory rate
  - Improvement in pH
  - Improvement in oxygenation
  - Reduction in PaCO2

Appropriately monitored location; oximetry, respiratory impedance, vital signs as clinically indicated

↓

Patient in bed or chair sitting at ≥ 30-degree angle

↓

Select and fit interface

↓

Select ventilator

↓

Apply headgear; avoid excessive strap tension (one or two fingers under strap); encourage patient to hold mask

↓

Connect interface to ventilator tubing and turn on ventilator

Start with low pressures/volumes in spontaneously triggered mode with backup rate; pressure-limited: 8 to 12 cm H2O inspiratory; 3 to 5 cm H2O expiratory volume-limited: 10 ml/kg

↓

Gradually increase inspiratory pressure (10 to 20 cm H2O) or tidal volume (10 to 15 ml/kg) as tolerated to achieve alleviation of dyspnea, decreased respiratory rate, increased tidal volume (if being monitored), and good patient-ventilator synchrony

↓

Provide O2 supplementation as needed to keep O2 sat > 90%

Check for air leaks, readjust straps as needed

↓

Add humidifier as indicated

↓

Consider mild sedation (i.e., intravenously administered lorazepam 0.5 mg) in ↓↓agitated patients

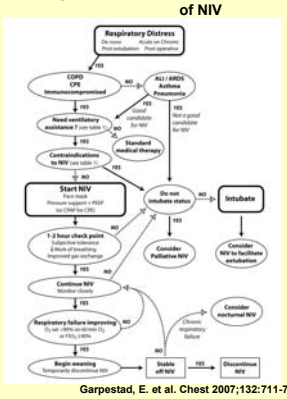
↓

Encouragement, reassurance, and frequent checks and adjustments as needed

↓

Monitor occasional blood gases (within 1 to 2 h and then as needed)

Algorithm illustrating the principles of patient selection and practical application of NIV



Garpestad, E. et al. Chest 2007;132:711-720

Conclusion

- Start NIV early (but not too early)
- Select correct patient in correct clinical setting
- Monitor closely
- If no improvement in 1-2 hours consider intubation