

Artificial ventilatory support has become an integral component in the management of critically ill patients in the intensive care units. Concept of mechanical ventilation evolved in the middle half of the last century with the use of negative pressure ventilators, commonly known as tank ventilators. Invasive positive pressure ventilators became popular after the Copenhagen polio epidemic. Currently ventilatory support can be provided in two ways; Invasive ventilation and Non-invasive ventilation.

Non-invasive ventilation (NIV) is defined as ventilatory assistance to the lungs without an invasive artificial airway.

RATIONALE

Non invasive ventilation has several advantages over invasive ventilation. These include;

- Leaves upper airway intact, avoiding direct upper airway trauma, thereby preserving airway defenses.
- Reduction of infectious complications eg, sinusitis, nosocomial pneumonia and sepsis.
- Allows patients to eat orally, vocalize normally, expectorate secretions and communicate normally.

Further, accumulated evidence over the past decade has shown that proper patient selection has lowered the morbidity and mortality rates, length of hospital stay and thereby cost of hospitalization.

MECHANISM OF ACTION

Non-invasive ventilation helps in improving the pulmonary mechanics and oxygenation.

Studies have shown that NIV augments ventilation and allows oxygenation without raising the PaCO₂. There is partial unloading of respiratory muscles leading

to an increase in tidal volume, decrease in respiratory rate and increase in minute ventilation thereby causing resetting of respiratory center ventilatory responses to PaCO₂.

Non-invasive ventilation is most commonly applied in acute respiratory failure associated with COPD, where the ventilatory response to raised PaCO₂ is decreased.

Administering of NIV in patients with COPD with respiratory failure helps to increase the neural output to the diaphragm and other respiratory muscles and thus resets the respiratory control center making it more responsive to an increased PaCO₂. These patients are then able to maintain normal PaCO₂ throughout the daylight hours without need for mechanical ventilation.

Evidence level	Definition
Level A (High)	Multiple randomized, control trials—Recommended.
Level B	Atleast one randomized, controlled trial—Weaker Recommendation.
Level C	Case series or reports—can be tried, but with close monitoring

INDICATIONS

- Type 1: Respiratory failure or hypoxemic respiratory failure.
- Type 2: Respiratory failure or hypercapnic respiratory failure.
- Both

Hypercapnic Respiratory Failure

COPD and facilitating weaning in COPD (A).

Asthma (B).

Cystic fibrosis (C).

Obstructive sleep apnea syndrome (C).
Upper airway obstruction (C).
Extubation failure in COPD (C).

COPD

The use of non invasive ventilation in patients with acute exacerbations of COPD is considered the ventilatory mode of choice. It helps by reducing the rate of endotracheal intubation. It also improves the vital signs, gas exchange, thereby reducing dyspnea.

There is also reduction in the in-hospital mortality, with reduction in the complications like nosocomial pneumonia.

Recommendations

Standard medical therapy + NIV.

NIV Recommendations

- Acute exacerbation of COPD ($\text{pH} < 7.35$, $\text{PaCO}_2 > 45$ mm Hg). (A).
- Mild exacerbation of COPD ($\text{pH} > 7.35$) may not benefit from NIV. (B). However, it may not cause harm to these patients.
- NIV can be used both in ICU and wards though in acute exacerbation ($\text{pH} < 7.30$) are better managed in ICU. (B).

Acute Asthma

Uncontrolled studies have reported improvements in gas exchange and low rates of intubation after the initiation of NIV in patients with severe asthma. In another randomized trial no benefit of NIV in asthma was demonstrated.

Although use of NIV in asthma is inconclusive, a trial of NIV in selected patients is justified, particularly in patients who fail to respond promptly to medical treatment and have no contraindications.

It has been also suggested that aerosolized medicines may be delivered more effectively by NIV. However, NIV is not recommended for routine use of asthma exacerbation. (C).

NIV may be tried in ICU in patients of acute severe asthma who fail to respond quickly to medical treatment and have no contraindication. (B).

Cystic Fibrosis

Uncontrolled studies have shown that NIV may be useful as rescue therapy to stabilize gas exchange in the

treatment of acute episodes of respiratory failure in end-stage cystic fibrosis, providing a bridge to lung transplantation. (C).

Obstructive Sleep Apnea Syndrome or Obesity Hypoventilation

NIV is recommended for obstructive sleep apnea presenting as acute respiratory failure. (C). NIV is also recommended for patients of obesity hypoventilation syndrome with acute respiratory failure. (B).

Upper Airway Obstruction

NIV can be used to treat patients with upper airway obstruction caused by glottic edema following extubation along with aerosolized medications. (C).

Hypoxemic Respiratory Failure

ARDS. (C).

Community acquired pneumonia. (C).

Cardiogenic pulmonary edema. (A).

Trauma/Burns. (C).

Transplant and immunocompromised patients. (C).

Postoperative patients. (B).

Do not intubate patients. (C).

Data on successful application of NIV in patients with acute hypoxemic respiratory failure is less and conflicting. This is mainly due to varied etiologies in subgroups of patients causing respiratory failure. Recently a few studies have focused on some of the individual diagnoses within the large category. It has been found to be very effective in cardiogenic pulmonary edema. NIV may also be efficient when some components or degree of cardiac decompensation participates in the clinical feature, even if it is not the main or only cause of episode of respiratory failure.

It should be noted that patients with hypoxemic respiratory failure should preferably be ventilated with a full face mask during acute phase and may be shifted to nasal mask once condition stabilizes.

NIV should be discontinued if there is;

- a. No improvement in gas exchange and dyspnea,
- b. Significant mouth leak,
- c. Severe mask intolerance, or
- d. No improvement in mental status within 30 minutes of the application of NIV in an agitated hypoxemic patient.

ARDS

In ARDS there is limited literature on use of NIV. However, NIV may be used with great caution in cases of ALI and that to in ICU. (C). The application should be reserved for hemodynamically stable patients who can be closely monitored in an ICU where facilities for invasive ventilation are present.

Acute Cardiogenic Pulmonary Edema

Various studies have shown the success of NIV + conventional medical therapy in treatment of cardiogenic pulmonary edema (A). Improvement of PaO₂/FiO₂ ratio, respiratory rate and dyspnea occurred significantly faster with above treatment and reduced the rate of intubation. Studies have also shown that NIV did not increase myocardial infarction rates.

Trauma and Burns

Trauma patients develop respiratory failure for a multitude of reasons, but some have chest wall injuries such as flail chest or mild acute lung injury that might respond favorably to NIV. Patients with burns respond poorly to NIV (C).

Transplant and Immunocompromised Patients

Studies have shown that NIV has been a preferred mode to invasive ventilation due to decreased rate of nosocomial infection. Neutropenic patients with pulmonary infiltrates and acute hypoxemic respiratory failure (randomized trials), NIV reduced the rate for intubation, occurrence of nosocomial infection, ICU and hospital mortality rates (80 to 46%).

More recently NIV has been reported to yield similar benefits in AIDS patients with PCP v/s invasive ventilation. NIV is therefore recommended early in the course of hypoxemic respiratory failure in immunocompromised patients. (A).

Community Acquired Pneumonia

Conflicting reports have emerged regarding use of NIV in CAP, from various studies with no apparent benefit in non-COPD patients with severe pneumonia. 2/3rds of these patients eventually required intubation. A subgroup analysis showed that benefit occurred only in patients with underlying COPD.

NIV may be used in the ICU with caution in selected patients with CAP particularly in those with associated COPD. (B).

Postoperative Patients

Controlled trials have shown that NIV improves oxygenation, reduces the need for re-intubation and lowers the mortality rate after lung resection surgery and enhances pulmonary function after gastroplasty.

Studies have shown that use of NIV avoids intubation in 67% of patients who develop respiratory failure after abdominal surgery. It also resulted in lower length of ICU stay and lower mortality rate. NIV therefore may be used in patients who develop respiratory distress or respiratory failure after lung resection or abdominal surgery. (B).

Do Not Intubate Patients

NIV may be useful tool in patients with acute respiratory failure who donot wish to be intubated. NIV provides good outcomes in such patients with underlying COPD and CCF. NIV also reduces dyspnea, preserves patient's autonomy and provide time for finalization of affairs for some terminal patients (C).

NIV IN WEANING FROM MECHANICAL VENTILATION

Patients who require invasive mechanical ventilation initially and fail to wean promptly are potential candidates for NIV to facilitate extubation, thereby reducing the complications related to prolonged intubation. Several randomized, controlled trials have demonstrated that NIV significantly shortens the duration of invasive mechanical ventilation, reduces the length of ICU stay and improves the survival compared with patients weaned in the routine manner. Studies have also shown that use of NIV to facilitate weaning and extubation appears to benefit patients with COPD.

CONTRAINDICATIONS

There are no absolute contraindications. Contraindications have been determined by the fact that they were the exclusion criteria in many studies.

- Inability to protect the airways, e.g. comatose patients, patients with CVA, confused or agitated patients.
- Homodynamic instability, e.g. uncontrolled arrhythmias, patient on very high doses of inotropes, recent MI.
- Severe GI symptoms, e.g. vomiting, obstructed bowel, recent GI surgery.
- Copious secretions.
- Life threatening hypoxemia.
- Non-availability of trained personnel.

PREDICTORS OF SUCCESS WITH NIV

Studies have shown that not all patients with respiratory failure may be suitable for the successful application of NIV with failure rates of 7-50%. It should be realized that NIV is not a substitute for invasive mechanical ventilation, but only a way to prevent it by providing support early enough, before severe derangements take place.

Understanding the determinants of success will help in accurate patient selection for NIV and a timely switchover to invasive ventilation.

Factors which Influence Immediate Failure with NIV Application

As stated earlier NIV is not a substitute for invasive ventilation. Awareness of factors which influence failure of NIV places a very important role in successful outcomes. These include;

- Baseline respiratory abnormalities at admission like respiratory rate, heart rate, pH and PaCO₂.
- Severity of illness as assessed by the APACHE or SAPS score.
- Degree of encephalopathy as assessed by the GCS score.
- Preadmission functional status as reflected by FVC.
- Inability to clear secretions.
- Associated diseases such as pneumonia.
- Response to NIV after initiation.
- Technical factors related to interface, mode and device use for ventilation, patient-ventilator synchrony, humidification.
- Non availability of trained medical and nursing personnel.

INITIATION OF NIV

After appropriate patient selection is done, select a suitable ventilator, including a suitable patient-ventilator interface. Thereafter, explain the patient the entire process, thereby gaining the patient's confidence. Select initial settings and monitor patient closely.

VENTILATOR SELECTION

Selection of a ventilator is based largely on the availability, practitioner experience, and patient comfort.

Both conventional critical care ICU ventilators and portable non invasive ventilators are available. The advantages of typical ICU ventilators are the presence of full alarm systems, their ability to deliver a precise/high FiO₂ and the ability to separate inspiratory and expiratory gas mixtures thereby preventing the complications of rebreathing. Newer NIV incorporate many of these above features, however they are costly. Now portable NIV ventilators providing bilevel ventilation are most popular and cost effective. These machines deliver two treatment pressures. ie IPAP applied when the patient inhales, and lower pressure is applied when the patient exhales called the EPAP. EPAP is equivalent to applying PEEP in a spontaneous breathing subject.

Portable NIV ventilators have single tubing with a potential for rebreathing expired gas. The application of EPAP flushes dead space CO₂ and prevents rebreathing. EPAP also helps in alveolar recruitment, prevent atelectasis and stabilizes the upper airway during sleep. Supplemental oxygen administration can be done by connecting O₂ directly to a port on the mask or to a T-connector in the ventilator circuit. However precise O₂ delivery cannot be controlled as in critical care ventilators, since the FiO₂ will vary according to the patient's respiratory pattern. The best way to monitor O₂ administration is by pulse oxymeter.

HUMIDIFICATION

As physiological humidification mechanisms are unaltered in NIV and much of the air being breathed is ambient and consequently better humidified, humidification is not routinely needed. However humidification can be used under following situations;

- Dryness of mouth.
- Nasal stuffiness and congestion.
- Patient has thick secretions.
- Nasal stuffiness and dryness.

INTERFACES

These are devices that connect the ventilator tubing to the patient and facilitate the entry of pressurized gas into the upper airways during NIV. These include:

- Nasal masks,
- Full face mask,
- Total face helmets. (Hockey goalies mask)

MASK SELECTION ADVT AND DISADVANTAGE OF NASAL V/S FULL FACIAL MASK

Variable	Nasal	Full face mask
Comfort	+++	++
Claustrophobia	+	++
Rebreathing	+	++
Lower CO ₂	+	++
Permits expectoration	++	+
Permits speech	++	+
Permits eating	+	-
Functions if nose is obstructed	-	+
+ Possible	++ Likely	+++ Most likely-not possible

Both nasal and full face masks can be used for providing NIV successfully. However, in acute setting full-face masks appear to be advantageous. (A). A unit should be equipped with a range of masks and accessories since the interface is crucial to the success of NIV.

INITIATION OF NIV

Portable pressure ventilators.

- Choose the correct interface.
- Explain therapy and its benefit to the patient in detail. Also discuss the possibility of intubation.
- Set the mode in spontaneous mode.
- Start with very low settings. IPAP of 6-8 cm of H₂O with 2-4 cm of H₂O of EPAP. The difference between IPAP and EPAP should be at least 4 cm of H₂O.
- Administer O₂ at 2 liters/min.
- Hold the mask with the hand over the patient's face. Do not fix it.
- Increase EPAP by 1-2 cm increments till all the patient's inspiratory efforts are able to trigger the ventilator. Most patients require EPAP of about 4-6 cm of H₂O. Patients who are obese or have obstructive sleep apnea require higher EPAP.
- At this time increase EPAP and IPAP in the same proportion, keeping the difference of 4.
- When all the patient's efforts are triggering the ventilator, leave EPAP at that level.
- Now start increasing IPAP in increments of 1 – 2 cm upto a maximum pressure which the patient can tolerate without discomfort and there is no major mouth or air leaks.

- Now secure interface with head straps. Avoid excessive tightness. If the patient has a NG tube put a seal connector in the dome of the mask to minimize air leakage.
- After titrating the pressure, increase O₂ to bring O₂ saturation to around 90%.
- As the settings may be different in wakefulness and sleep, readjust them accordingly.

CAUTION

When NIV is being initiated for acute respiratory failure, close monitoring and the capability to initiate endotracheal intubation and other resuscitation measures should be available in the same set up. Start NIV preferably in the ICU or in the emergency room in acute respiratory failure.

MONITORING

Careful monitoring of patient is essential, when patient is on NIV. It is recommended that the patient is monitored for dyspnea, mask comfort, anxiety, asynchrony or leaks. Monitor vital parameters e.g. Pulse, R/R, BP, ECG, SpO₂. Do ABG (baseline after 1-2 hours and as clinically indicated).

ADVERSE EFFECTS AND COMPLICATIONS

These are subdivided into three categories;

Related to Mask

- Discomfort
- Erythema
- Skin ulcers usually on the bridge of the nose, related to pressure from the mask seal.

These can be avoided by using mask with proper fitting and attachment over the nose and face; newer masks with softer silicone seals help minimize these problems.

Related to Airflow (Leakage) or Pressure

- Conjunctival irritation.
- Ear pain.
- Nasal dryness or oral dryness.
- Gastric insufflation (Responds to simethicone).

These can be prevented by refitting the mask snugly over the face or nose or lowering inspiratory pressure may ameliorate these problems.

Patient—Ventilator Asynchrony

- Due to agitation
- Due leaks
- Inadequate ventilator triggering.

CONCLUSION

NIV is an important addition in critical care units, if properly applied. The efficacy of NIV has been demonstrated for in patients with acute exacerbations of COPD, acute pulmonary edema, respiratory failure in Immunocompromised patients and to facilitate extubation in COPD patients.

Interplay of several factors, i.e. proper patient selection, monitoring of patient, proper selection of interface, and presence of trained personnel are essential for success of NIV. Use of NIV has greatly improved the outcomes in appropriately selected patients.

SUGGESTED READING

1. Frederic S Bongard, Darryl Y Sue. *Current Critical Care Diagnosis and Treatment*, 2nd Edition, Chapter 12, pp 296-8.
2. Mitchell P Fink, Edward Abraham, JL Vincent. *Textbook of Critical Care Medicine*, Vth Edition, Chapter 68, pp 519-26.
3. NIV Guidelines - Indian Society of Critical Care Medicine.
4. Use of Continuous Positive Airway Pressure in Critically Ill Patients, by SM Maggiore A Arcangeli, M Antonelli 392-9.
5. *Yearbook of Intensive Care and Emergency Medicine* by J.L.Vincent. 2006.