



# Non-invasive ventilation in COPD exacerbation: how and why

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## Who

Patients with chronic obstructive pulmonary disease (COPD) often experience “exacerbations,” (AECOPD), defined as episodes of increasing respiratory symptoms, particularly dyspnea, cough and sputum production and increased sputum purulence. Many of these patients come to the emergency department (ED) in acute respiratory distress, needing prompt assessment and management. Non-invasive ventilation (NIV) is of paramount importance in the treatment of these patients [1, 2].

## What

NIV consists of the application of a positive pressure to the human respiratory system from outside so that the air inflow to the lung is facilitated. The main characteristic of NIV, compared to invasive ventilation, is that the pressure is applied through a mask, avoiding endotracheal intubation.

The most effective type of NIV in patient with AECOPD gives flow with two different pressures: an inspiratory pressure (IPAP) and an expiratory pressure (EPAP).

## Why

Patients with AECOPD experience an impaired lung emptying because of increased airway resistance (i.e., the airways oppose to the air outflow). Their expiratory time does not last enough to empty the lung, thus leading to a dynamic lung hyperinflation: the patient is obliged to keep breathing

with the lung almost full, not being able to empty it. The consequences of dynamic hyperinflation are:

- The production of a positive pressure within the alveoli created by the air trapped trying to exit the lung (PEEPi).
- The increased effort of breathing because of the diminished compliance of the over-distended thoracic wall and lungs and the over-contracted diaphragm.

To bring some fresh air inside the lung the patient needs:

1. To counterbalance the alveolar positive end-expiratory pressure (iPEEP) to equalize the barometric pressure at the mouth (elastic workload), and then to initiate the ‘true’ inspiration.
2. To overcome the increased airway resistance via extra-work during both inspiration and expiration (dynamic workload).

The role of NIV in AECOPD is the following:

- The IPAP, pushing air inside the lung during inspiration, helps to decrease the dynamic work of breathing (WoB), increasing in this way the amount of air exchanged in every breath (i.e., the tidal volume or  $V_t$ ). This leads to a reduction in the arterial pressure of CO<sub>2</sub> (pCO<sub>2</sub>), and an increase of the arterial O<sub>2</sub> pressure (pO<sub>2</sub>).
- The EPAP helps to counterbalance the PEEPi when starting inspiration. Furthermore, maintaining a lower positive pressure inside the airways helps to keep them open during expiration, reducing the resistance and helping the air to exit the lung.

Many trials have confirmed the benefit of NIV in AECOPD in terms of decreased intubation rate and mortality. For this reason, the most recent guidelines recommend NIV as the first-line therapy for patients with AECOPD with respiratory distress and respiratory acidosis [1–3].

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## When

For the above reason, the benefit of NIV is great in patients with AECOPD when the increased work of breathing exceeds the capacity of the body to face it. Signs of decompensation of the respiratory equilibrium (i.e., indication to NIV, see Fig. 1) are [1, 4]:

- pH < 7.35 with pCO<sub>2</sub> > 45 mmHg.
- Tachypnea (Respiratory rate > 24).
- Respiratory distress defined as the use of accessory muscles.

Despite helping in counterbalancing the derangement brought to the respiratory system by AECOPD, NIV does not address the cause of the exacerbation. Therefore, if the respiratory function of patient is not too compromised, NIV should be started only after a bronchodilator and controlled oxygen therapy has been started [5].

Contraindications to NIV are the conditions where the patient is unable to protect the airway, or to tolerate the mask, or where an intrathoracic positive pressure would worsen a hemodynamic instability [3].

Absolute contraindications: hemodynamic instability, severe facial deformity, facial burns, fixed upper airway obstruction,

Relative contraindications: pH < 7.15, GCS < 8 (however, if the cause of neurological impairment is hypercapnia, this is not a contraindication), confusion/agitation, cognitive impairment.

## Where

Patients starting NIV should be treated and evaluated in a controlled environment that warrants the ability to promptly recognize clinical deterioration (see monitoring).

## How

### Starting

Once the indications for NIV are confirmed, it is time to start to ventilate the patient.

1. Decide (involving the patient whenever possible) what is the alternative plan in the event of NIV failure (i.e., NIV is ceiling therapy or not).
2. Explain to the patient what you are going to do.
3. Choose a ventilator, either turbine or compressed air-driven, with a specific software for NIV, and a display for pressure and flow curve.
4. Choose a mask. Oro-nasal or full-face with the right measure to fit the patient face. The perfect fit of the mask will allow use high pressures with low discomfort for the patient and lower air leaks.
5. Choose a ventilator setting. The main ventilation modality in AECOPD is pressure support ventilation (PSV). Remember to set a backup ventilation (see point 11) [4].
6. Choose a PEEP. The PEEP (or EPAP) is meant to counterbalance the iPEEP, and should be kept below it. Since iPEEP cannot be measured non-invasively, it should be started in the low range, 4–6 cm H<sub>2</sub>O maximum.
7. Choose a pressure support (PS). The PS is the amount of pressure added to the PEEP during inspiration: PEEP + PS = IPAP. You need a PS just enough to obtain a V<sub>t</sub> of 6–8 ml/kg (use ideal body weight). Start with 8–10 cm H<sub>2</sub>O and increase 2 cm H<sub>2</sub>O at a time until you get the right V<sub>t</sub>. Higher IPAP will lead to higher air leaks around the mask.
8. Choose an FiO<sub>2</sub>. Start with the same FiO<sub>2</sub> the patient needs to have peripheral oxygen saturation (SpO<sub>2</sub>) of

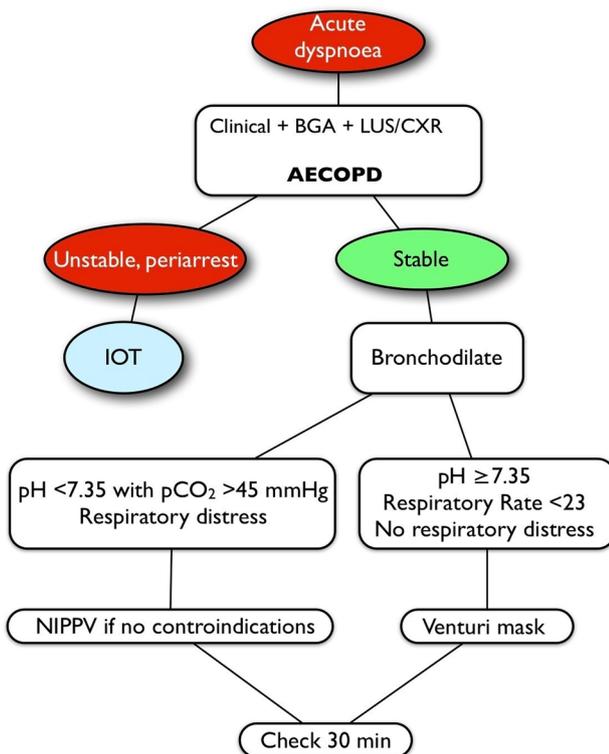


Fig. 1 Flowchart of NIV application in COPD exacerbation

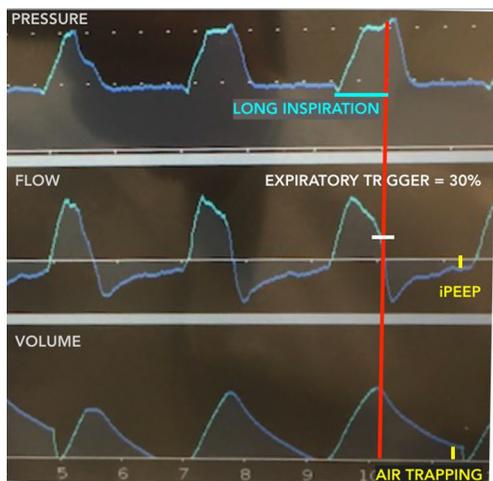
88–92% on spontaneous breathing, and then tune it to have the same value during NIV.

9. Choose the inspiratory trigger. You want the ventilator to be the most sensible as possible without auto triggering itself. Thus, start with 1 l/min or  $-1$  cm  $H_2O$  and increase it if autotriggering develops [4].
10. Choose the rise time. The dyspneic AECOPD patient wants as much air as possible in the littlest time possible. Start with a short rise time, and then increase it when the patient gets better [4].
11. Choose the expiratory trigger (Fig. 2). The AECOPD patient needs more time to exhale than a normal subject. The higher the expiratory trigger value, the sooner the ventilator will end up supporting inspiration, giving time to the patient to exhale. Therefore, use an expiratory trigger greater than 50%.
12. Choose a backup respiratory rate. The patient chooses his own respiratory rate during NIV, not the ventilator. Hence, the backup respiratory rate should be lower

than the patient respiratory rate: start with 10–12 breaths/min [4].

## Monitoring

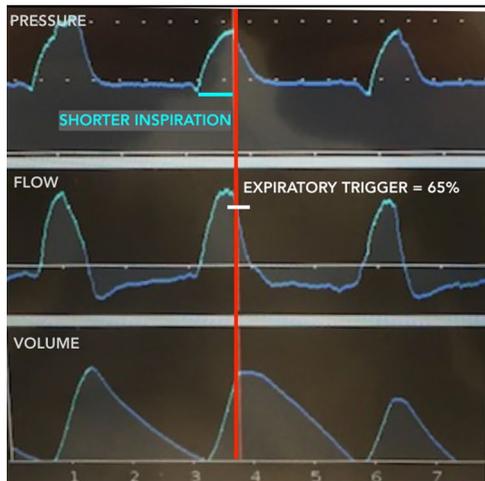
1. Look at the patient: you want to see within the first minutes, a reduction of the respiratory distress with neurologic improvement, avoiding discomfort and high air leaks (Table 1).
2. Look at the monitor: the goal is a reduction in respiratory rate with an increase of  $SpO_2$ , avoiding dysrhythmias (frequent during hypoxia) and hypotension.
3. Repeat the arterial blood gas analysis (ABG) within 1 h, and then every hour until stabilization, or sooner if clinical parameters are worsening.
4. Look at the ventilator:  $V_t$ , peak pressure, alarms.



### EXPIRATORY TRIGGER: WRONG SETTING

The Expiratory Trigger is set too late (30% of PIF)

In this way, the ventilator does not allow the patient to fully expire before the next breath starts; this leads to further air trapping and iPEEP increase



### EXPIRATORY TRIGGER: CORRECT SETTING

The Expiratory Trigger is correctly set earlier (65% of PIF)

This allows the patient to have a shorter inspiration with a longer expiration

**Fig. 2** The setting of expiratory trigger in COPD patients

**Table 1** How to monitor COPD patients on NIV

Monitoring during NIV	
Always monitor neurological status	
After minutes	Evaluate comfort, compliance and leaks
5'	Is the respiratory rate decreasing? Is SpO <sub>2</sub> increasing?
15'	Repeat ABG
30'	Repeat ABG
60'	Repeat ABG
180'	Repeat ABG anytime there is a clinical worsening or if vital signs are not improving

- Look at the pressure and flow waveforms to recognize asynchrony to optimize ventilation and avoid intolerance [3].
- Monitor for complications (aspiration, hypotension, pneumothorax).

### When to stop

NIV can be gradually discontinued when there has been normalization of pH and pCO<sub>2</sub>, and a general improvement in the patient's condition: improvement in the dyspnea, RR < 25, pH > 7.35, SpO<sub>2</sub> > 90% with FiO<sub>2</sub> < 35%.

Discontinue NIV and consider endotracheal intubation if:

- Imminent respiratory arrest.
- Persistence of severe respiratory distress.

- Deterioration of pH or persistence of respiratory acidosis despite NIV.
- Worsening of neurologic status.
- Intolerance to NIV.
- Hemodynamic instability.

### Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

**Statement of human and animal rights** This article does not contain any studies with human participants or animals performed by any of the authors.

**Informed consent** For this type of study formal consent is not required.

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