Noninvasive Mechanical Ventilation Outside Intensive Care Unit. Emergency Department Organization

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Marco Antonio Esquivias Campos, María del Pilar Naz Núñez, María del Carmen Martínez Picón, and David Darío Tello Mendiola

Abstract

Noninvasive ventilation (NIV) is an increasingly used technique in emergency and critical care services. It can be applied in both type I and type II acute respiratory failure. By applying this technique, we manage to control hypoxemia and hypercapnia, with the potential to reduce severe complications that can be lifethreatening for the patient, with fewer adverse effects. In recent years, its use in terminal patients or those with Do Not Intubate (DNI) orders has also gained strength, trying to provide optimal patient comfort and understanding the limits of therapeutic effort. Its use is based on evidence, and criteria are established to indicate its initiation. In the emergency department, the use of CPAP, BiPAP, and HFNC to palliate, stabilize, and even transfer patients is essential, according to the pathologies studied. NIV is applicable in pneumonias, COPD, pulmonary edema, near-drowning syndrome, excessive mucus secretions in patients on artificial ventilation, immunosuppressed patients and palliative patients. During the process of mechanical ventilation, it is important to monitor clinical parameters, gasometrical parameters, hemodynamics and ventilation parameters, an indication for its change, if necessary. Finally, for pandemics such as the one generated by SarS-CoV-2, it is the first respiratory support we can use with trained personnel.

Keywords

Noninvasive ventilation (NIV) · Acute respiratory failure · Hypoxemia Hypercapnia · Terminal patients · Do Not Intubate (DNI)

M. A. E. Campos (✉) · M. del Pilar Naz Núñez · M. del Carmen Martínez Picón
D. D. T. Mendiola
Emergency Department, La Mancha Centro General Hospital, Alcazar de San Juan, Spain
e-mail: maesquivias@sescam.jccm.es

A. M. Esquinas et al. (eds.), *Noninvasive Ventilation Outside Intensive Care Unit*, Noninvasive Ventilation. The Essentials,
https://doi.org/10.1007/978-3-031-37796-9_12

Noninvasive Ventilation. Principles in Emergency Medicine

Acute respiratory failure (ARF) is defined as failure of respiratory function, oxygenation, and carbon dioxide release. This results in decreased arterial partial pressure of oxygen (PaO_2) or hypoxemia and/or increased arterial partial pressure of carbon dioxide ($PaCO_2$) or hypercapnia. The establishment period of the ARF is concise, it can be minutes or hours, without giving time for the compensatory mechanisms to be established [1]. Noninvasive mechanical ventilation (NIMV) in type I or type II ARF applied in the emergency department acts in such a way that it improves gas exchange alterations and reduces signs of respiratory effort: dyspnea, accessory respiratory muscle activity, decreased respiratory rate, thus being able to achieve a rapid stabilization of the patient. NIMV is any process that is responsible for covering the flow of a patient, it is any form of ventilatory support that does not use orotracheal intubation (OI), nor any other device that creates artificial ventilation can be used as support ventilation in patients with ARF [2–4]. The principles on which we base ourselves to choose this treatment are:

- The presence of a pathology that responds well to treatment with NIMV.
- The absence of contraindications to its use.
- Patient preferences.
- The use of NIMV compared to the use of the invasive modality reduces many complications that can be life-threatening for the patient. With NIMV it is possible to correct hypoxemia more effectively than with conventional oxygen therapy since it improves the ventilation of the lung fields, and we achieve the so-called alveolar recruitment to improve gas exchange. This allows us to obtain an improvement in respiratory dynamics, with a decrease in respiratory work. The breathing effort increases hypoxemia and hypercapnia, which translates into an increase in lactic acidosis [1].

Indications and Contraindications

Clinical criteria for initiation of NIMV have one or more of the following indications. Moderate-severe dyspnea, with signs of labored breathing or use of accessory muscles

- Tachypnea.
- Blood gas criteria (if available, do not delay NIMV while waiting for the result of a blood gas) [5].
- Need for a fraction of inspired oxygen (FiO_2) greater than 0.4 to achieve adequate oxygenation (88–92% in patients at risk of hypercapnia and greater than 92% in the rest of the patients).
- Acute ventilatory failure (pH < 7.35 with $PaCO_2$ > 45 mmHg, PaO_2/FiO_2 (PaFi) <300 mmHg).

Contraindications of NIMV [5]

Absolute

- Need to isolate airway/cardiorespiratory arrest.
- Obstruction/severe anatomical alteration in the upper airway.
- Poor control of secretions/high risk of aspiration.
- Threatening hemoptysis.
- Impossibility of adapting any type of interface.
- Rejection/lack of patient collaboration.

Relative

- Uncontrollable hemodynamic instability/shock.
- Decreased level of consciousness (ECG < 8).
- Unresolved pneumothorax.
- Uncontrollable vomiting.
- Uncontrollable hematemesis/epistaxis.
- Pregnancy.
- Severe hypoxemia (PaO_2/FIO_2 < 150 mmHg), hypercapnia ($PaCO_2$ > 70 mmHg), acidemia (pH < 7.15).
- Recent surgery (2 weeks) of the upper airway-upper digestive tract.
- Lack of knowledge of the technique.

Clinical Application in the Emergency Department

NIMV is a technique increasingly used in emergency services, both hospital and outpatient. The main pathologies where we use it are (Table 12.1):

- With more scientific evidence:
  - Acute pulmonary edema (APO) (hypoxemic syndrome or AKI type I).
  - COPD (hypercapnic syndrome or type II ARF).
  - Pneumonia in immunosuppressed patients.
- With less scientific evidence:
  - In patients with a significant respiratory effort but there is an order not to intubate.
  - CO poisoning.
  - near-drowning syndrome,
  - Acute non-cardiogenic pulmonary edema.
  - In patients with restrictive patterns due to underlying diseases such as pulmonary fibrosis, kyphoscoliosis.
  - In patients with asthma.
  - As an aid to weaning in intubated patients.

Table 12.1 Indications for NIMV according to the type of pathology

INDICATIONS FOR NIMV ACCORDING TO TYPE OF PATHOLOGY		
INDICATION	EVIDENCE LEVEL	RECOMMENDATION GRADE
Severe exacerbation of COPD	A	1
Acute Pulmonary Edema	A	1
Immunocompromised patient	B	2
Extubation in patients with COPD or high risk of AKI	B	2
ARF in the postoperative period of abdominal surgery and pulmonary resection	C	2
exacerbated asthma		NR
Community-acquired pneumonia		NR
Bronchoscopy in patients with hypoxemia		NR

NR no recommendation, *COPD* chronic obstructive pulmonary disease, *ARF* acute respiratory failure. Image taken from: Indications, contraindications, advantages, and disadvantages of noninvasive ventilation [4]

Pressure-limited NIMV is the most suitable for acute processes, providing more comfort to the patient. In this mode, pressure is the dependent variable, and the volume will depend on lung mechanics and the value of the pressure programmed in the respirator. We divide NIMV into two main modes: continuous positive airway pressure (CPAP) and double pressure level (BiPAP):

- **Double pressure level (BiPAP):** the ventilator supplies a positive pressure during inspiration (IPAP/PS + PEEP) and maintains another during expiration (EPAP/CPAP/PEEP)
- **Continuous positive airway pressure (CPAP):** increases functional residual capacity and opens collapsed or poorly ventilated alveoli, decreases LV transmural pressure, its main indication is to correct hypoxemia (e.g., EAP), although it also reduces the work of breathing in patients with COPD. The most used pressures are between 5 and 12 cmH_2O [6].

BiPAP, compared to CPAP, can improve vital signs more quickly, being more effective in reducing the work of breathing. High-flow therapy via nasal cannula (HFNCT) should be highlighted; some authors consider it noninvasive therapy, which provides humidified oxygen mixed with ambient air. It allows to reach FiO_2 between 0.21 and 1 and can reach up to a flow of 60 lpm. It manages to reduce the anatomical dead space since it generates a positive pressure at the end of expiration and increases alveolar recruitment, lung compliance, and tidal volume. All this leads to a decrease in the effort of breathing [1]. Among its multiple indications is the transition from invasive mechanical ventilation (IMV) to noninvasive, treatment of decompensated heart failure and its benefits have recently been seen in COPD patients with a mild-moderate exacerbation (pH between 7.30 and 7.35 and pCO_2 <55–60) [7].

There are different interfaces to connect to the different ventilators in NIMV. In the emergency department, the most used is the oronasal or oropharyngeal mask, since it is the most effective in acute pathology. However, it prevents the patient from speaking, eating, or coughing, so its tolerability is limited [1].

In hypoxemic or type I respiratory failure (e.g., heart failure, APO, pneumonia, SarS-CoV-2 infection) with RR greater than 28–32 rpm, with use of accessory muscles, O_2Sat<90%, moderate-severe dyspnea, medical treatment would be indicated together with the use of NIMV.

- Suspected hypercapnia or chronic respiratory disease: use of NIMV in BiPAP mode.
  - We started with IPAP 10–12 cmH_2O and EPAP 5–8 cmH_2O,
  - Fast ramp at the start,
  - Rescue respiratory rate (RR) at 12–15 rpm,
  - I:E ratio 1:1–2.
  - Minimum FiO_2 is necessary to achieve a saturation of around 88–90%.
  - It is necessary to re-evaluate at 60 min to assess the clinical and/or gasometric improvement. One of the best indicators of clinical improvement is a reduction in respiratory rate. If we do not see improvement, assess OI, or change the ventilation mode. See Annex I.
  - Without suspicion of chronic disease or hypercapnia: the use of CPAP and HFNC would be indicated.
  - In CPAP mode:

We started with an EPAP of 5 and a minimum FiO_2 to achieve saturation of around 92%.
We will increase the EPAP 2 by 2 cmH_2O until effective values, ideally between 7 and 10 cmH_2O.
If there is no improvement after 60 min, increase EPAP and be careful with values greater than 15–20 cmH_2O. If despite this there is no improvement, assess OI.

- As for HFNCT, start with flows around 50–60 bpm and, as always, use the minimum FiO_2 necessary to maintain saturation around 92%.
- If the patient has an order not to OI or intolerance to NIMV, it is recommended to take breaks from it with cycles of HFNC and rotational therapy.
- In case of an acute hypercapnic or type II respiratory failure (e.g., COPD exacerbation (gold standard)) with a RR greater than 25 rpm, with the use of accessory muscles, $O_2Sat<90\%$, moderate-severe dyspnea, a Ph between 7.25 and 7.35 and a pCO_2 >45 mmHg, medical treatment would be indicated along with the use of NIMV.
- NIMV in BiPAP mode:
  IPAP 10–12 cmH_2O.
  EPAP between 4 and 5 cmH_2O,
  Target expiratory tidal volume 6–8 mL/kg of ideal weight.
  Starts with medium-fast ramp.
  Safety FR 12–15.
  I:E ratio 1:3–4.
  FiO_2 is necessary to maintain a saturation between 88 and 90%.

- In the case of moderate COPD exacerbation (pH 7.30–7.35 and pCO_2 between 45 and 55 mmHg), HFNC can be started with a flow of 60 lpm and a minimum FiO_2 to maintain oxygen saturation between 88 and 90 %. This therapy can also be used when there is intolerance to NIMV as rotational therapy. See Annex II.

Monitoring and Surveillance

When faced with a patient to whom NIMV has been applied, it is necessary to conduct control and follow-up to verify that it is being effective (Table 12.2). The best indicator for monitoring NIMV is the decrease in respiratory rate and the decrease in dyspnea or the patient's feeling of anxiety:

- Clinical monitoring: check that the patient adapts well to the interface and to the ventilator, check for leaks, control of dyspnea, decrease in diaphoresis and/or signs of hypoxemia-hypercapnia (e.g., cyanosis), decrease in tachypnea, respiratory work, the use of accessory muscles, improvement of the level of consciousness, control of possible complications such as skin lesions due to interface pressure, conjunctivitis, gastric distension, nausea, etc.

Table 12.2 Monitoring and surveillance in NIMV

		Start	1 h	2 h	4 h	6 h
Gasometric results	pH					
	PaO_2					
	$PaCO_2$					
	HCO_3					
	PAFI					
	SAFI					
	FiO_2					
Hemodynamic monitoring	HR					
	SAP					
	ADT					
Respiratory monitoring	RF					
	O_2Sat					
	Musculature accessory (Y/N)					
	Paradoxical breathing (Y/N)					
Ventilator monitoring	PEEP/EPAP					
	PS/IPAP					
	TV					
	Trigger					
Neurological monitoring	Glasgow					
	Tolerance					

- Blood gas monitoring:
  - Arterial blood gas analysis is essential at the beginning of ventilation and in the first hour since it will verify the evolution of ventilation. The following controls will be conducted at the discretion of the physician with venous blood gases. According to the literature, it would be indicated at 60–120 min, at 4–6 h, and at 12 and 24 h.
  - oxygen saturation,
  - expiratory capnography: can offer a wide gradient with respect to arterial pCO_2 due to alterations in the patient's ventilation-perfusion relationship and leaks.
- Hemodynamic monitoring: respiratory rate, continuous electrocardiographic, and blood pressure [8].

NIMV Application in the Palliative Patient in the Emergency

When we work in an emergency service, it is common for many of our patients to be elderly patients, patients with multiple pathologies, fragile elderly patients, or patients who, whether they fulfill these characteristics, are being followed up by the palliative care unit. One of the great challenges in medicine is knowing when to limit therapeutic effort and prioritize patient comfort.

Dyspnea is one of the most common symptoms faced by patients near the end of life. Traditionally, the treatment of dyspnea in palliative patients has been based on opiates, benzodiazepines, and conventional oxygen therapy. NIMV has recently been proposed as an effective tool for the treatment of dyspnea in palliative patients [1]. Four cases have been described in which this therapeutic alternative could be useful:

1. A palliative situation with potentially curable superimposed pathology.
2. A palliative situation without curative intent, relief of symptoms.
3. A palliative situation pending decisions.
4. A palliative situation waiting to say goodbye to family or friends.

However, this therapeutic alternative has a series of limitations, one must be cautious when using it, as it can pointlessly prolong the moment of death, cause inconvenience and discomfort, create false expectations for the patient and relatives, as well as being able to limit the communication and intimacy at the end of life [9].

Likewise, the effectiveness of HFNCT has been described as a useful treatment option in patients with a no-intubation or no-resuscitation order, compared with others such as NIMV, the use of opiates, and conventional oxygen therapy presenting better tolerability and fewer adverse effects [10].

Noninvasive Therapy in SARS-COV-2 Infection in the Emergency

In the SarS-Cov-2 infection, it is a respiratory infection in which we can use NIT as an adjuvant treatment to the doctor.

The first therapeutic step would be a conventional oxygen therapy, followed by HFNC (starting with high flows, 60 lpm, and maximum FiO_2 of 1). The next step is NIMV, and the last is IMV that requires OI (Fig. 12.1) [11].

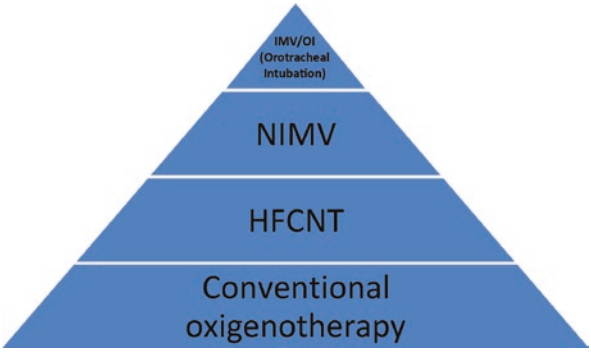


Fig. 12.1 Therapeutic steps of ventilation in the SarS-Cov-2 infection

Criteria for Starting Ventilatory Support in ARF Secondary to Covid-19 (Fig. 12.2) [11]

– Clinical criteria.
  Moderate-to-severe dyspnea with signs of labored breathing and use of accessory muscles and paradoxical abdominal movement.
  Tachypnea >30 rpm.
– Gasometric criteria.
  PAFI<200 (or need $FiO_2 > 0.4$ to maintain $O_2Sat > 92\%$).
  pH < 7.35 with $pCO_2 > 45$ mmHg.

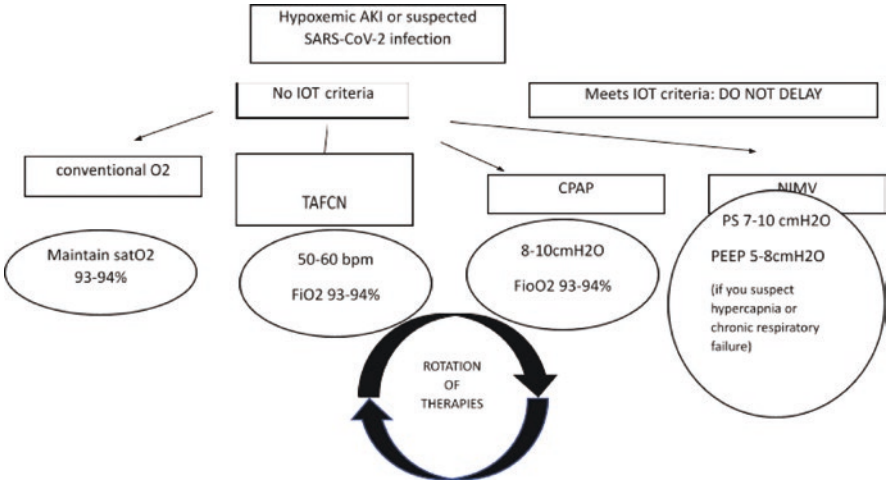
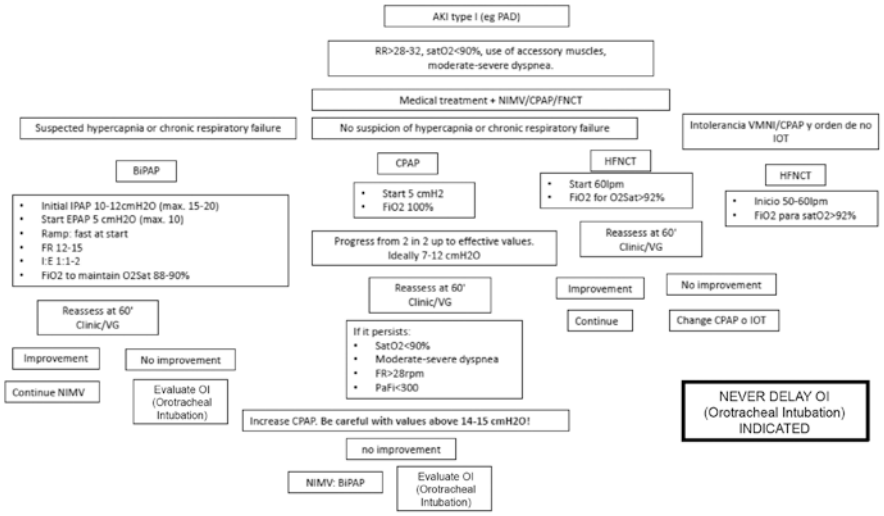


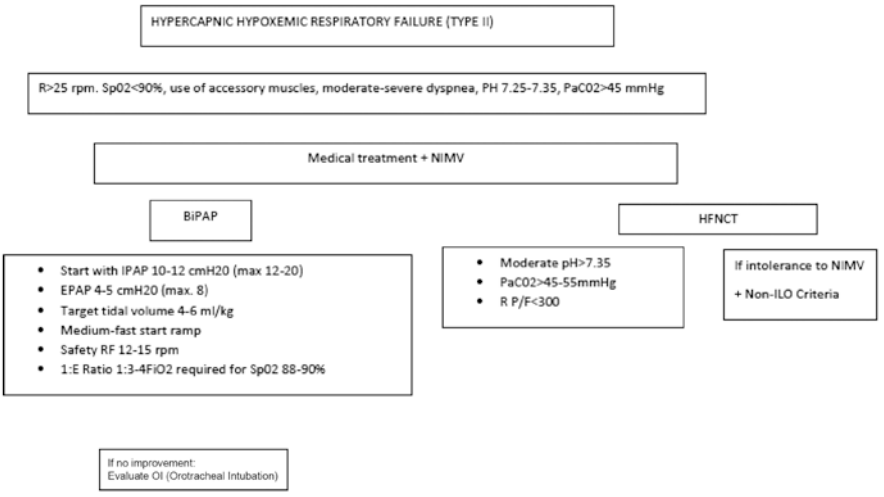
Fig. 12.2 Criteria for starting ventilatory support in ARF secondary to covid-19

Annexes

Annex I: Acute Respiratory Failure Type I



Annex II: Acute Respiratory Failure Type II



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