Journal of
Pulmonology and
Intensive Care

Review

DOI: 10.51271/JOPIC-0027

Noninvasive mechanical ventilation

Derya Hoşgün[1], Berçem Afşar Karatepe[2]

[1]Deparment of Chest Disease and Intensive Care Unit, Atatürk Sanatorium Training and Research Hospital,University of Health Sciences, Ankara, Turkiye
[2]Deparment of Internal Medicine, Elazığ Fethi Sekin City Hospital, Elazığ, Turkiye

Cite this article: Hoşgün D, Afşar Karatepe B. Noninvasive mechanical ventilation. *J Pulmonol Intens Care.* 2024;2(1):14-16.

Corresponding Author: Derya Hoşgün, drbercem@hotmail.com

Received: 30/11/2023 ◆ **Accepted**: 13/01/2024 ◆ **Published**: 13/02/2024

ABSTRACT

Noninvasive mechanical ventilation (NIMV) is positive pressure ventilation applied through a mask without an artificial airway and is frequently used in acute and chronic respiratory failure. It is the first choice in the weaning process for patients with acute exacerbations of chronic obstructive pulmonary disease (COPD) and acute cardiogenic pulmonary edema. The choice of device, mode, and mask is important to the application and success of NIMV. In appropriate diagnosis and indication, NIMV should be the first choice in patients who are cooperative, able to protect their airways, clinically stable, and to whom the mask can be applied. In this review the NIMV application especially in acute respiratory failure is summarized.

Keywords: Noninvasive mechanical ventilation, positive pressure ventilation, acute respiratory failure

INTRODUCTION

Noninvasive mechanical ventilation (NIMV) is a type of positive pressure ventilation applied with a mask without an artificial airway. The most important advantage is the reduction of complications such as ventilator-associated pneumonia and nasocomial infections associated with invasive mechanical ventilation. Physiologically, it prevents collapse in the airways and alveoli, reduces the afterload of the heart with increased intrathoracic pressure, workload on the diaphragm and respiratory muscles, and interstitial edema, and increases gas exchange and functional residual capacity.[1,2] Respiratory failure is defined as the inability to provide the oxygen required by tissues or to excrete carbon dioxide, which is a product of metabolism. Acute respiratory failure develops within minutes, hours, or days. A partial oxygen pressure (PaO_2) below 60 mmHg in room air in arterial blood gas is defined as type 1 respiratory failure (hypoxemic respiratory failure). Type 2 respiratory failure is defined as $PaCO_2$ (arterial partial carbon dioxide pressure) >45 mmHg in addition to hypoxemia.[1-3]

INDICATIONS, CONTRAINDICATIONS AND APPROPRIATE PATIENT SELECTION

It is frequently used in acute or chronic respiratory failure. According to the ERS/ATS guidelines, there are strong, less strong, and weak evidence-level recommendations for NIMV in acute respiratory failure. Chronic obstructive pulmonary disease (COPD) exacerbations, acute cardiogenic pulmonary edema, the weaning process in COPD and immunodeficient patients are recommended at a strong level of evidence. Asthma attacks, postoperative and acute hypoxemic respiratory failure, and extubation failure are recommended at a less strong level of evidence. Upper airway obstruction, trauma, ARDS (acute respiratory distress syndrome), OSAS (obstructive sleep apnea syndrome), and OHS (obesity hypoventilation syndrome) are recommended as indications for NIMV at a weak level of evidence.[2,4] International guidelines do not recommend the use of NIMV in COPD patients with normo- or mild hypercapnic acute respiratory failure without acidosis. In emergency departments, it is recommended for acute decompensated CAP, cardiogenic pulmonary edema, and right heart failure. Recommendations for the use of NIMV in ARDS without chronic respiratory failure and de novo acute hypoxemic respiratory failure due to pneumonia are not clear, and it is recommended not to delay invasive mechanical ventilation to reduce mortality and morbidity.[1-3,5]

Appropriate patient selection includes tachypnea (>25/min), use of auxiliary respiratory muscles, abdominal breathing, mask-face compliance, clear consciousness, adequate cough reflex, swallowing reflex, respiratory acidosis in arterial blood gas ($pH<7.35$-$PaCO_2>45$ mmHg), and $PaO_2/FiO_2<200$ mmHg (ratio of partial arterial oxygen pressure to inspired oxygen concentration). As a result, patients with appropriate diagnosis and indication, preserved airway reflexes, and communicable and hemodynamically stable patients are the most suitable candidates for NIMV.[5,6] **Table 1** presents the failure indicators of NIMV.[2,5,6]

Table 1. Failure indicators of noninvasive mechanical ventilation[2,5,6]

- Advanced age
- Multiorgan failure
- High APACHE II , SAPS and SOFA scores
- No clinical improvement in the first hour after the start of NIMV
- Arterial blood gas pH:7.25 and mean $PaCO_2$>75-90 mmHg
- PaO_2/FiO_2<150 mmHg
- High tidal volume
- ARDS and pneumonia in etiology

APACHE II: Acute Physiology and Chronic Health Evaluation, SAPS: Simplified Acute Physiology Score, SOFA :Sequential Organ Failure Assessment Score, PaO_2/FiO_2: Ratio of partial arterial oxygen pressure to inspired oxygen concentration, NIMV: Noninvasive mechanical ventilation, ARDS: Acute Respiratory Distress Syndrome, $PaCO_2$:Arterial partial carbon dioxide pressure

Absolute contraindications to NIMV include respiratory or cardiac arrest, complete upper airway obstruction , a high risk of aspiration due to severe vomiting, facial trauma, and burns. Shock, coma, hemodynamic instability or unstable cardiac arrhythmia, GCS (Glasgow Coma Scale) <10, upper gastrointestinal tract bleeding, multiorgan failure, dense secretions, bulbar dysfunction, upper airway, and gastrointestinal tract surgery are partial contraindications (**Table 2**).[2,5,7]

Table 2. Noninvasive mechanical ventilation contraindications[2,5,7]

- Cardiac or respiratory arrest
- Complete upper airway obstruction
- High risk of aspiration
- Severe vomiting and upper gastrointestinal tract bleeding
- Facial travma and burns
- Shock, coma , hemodynamic instability and unstable cardiac arrhythmia
- Glasgow Coma Scale <10, multiorgan failure
- Bulbar dysfunction
- Upper airway and gastrointestinal tract surgery

DEVICE-MASK SELECTION-MODES-CIRCUITS-HUMIDIFIERS

During the application, where it should be done, the appropriate interface or mask, humidifiers, ventilators, and circuit selection are the points to be considered. It can be applied in intermediate intensive care units, emergency departments, intensive care units, and during patient transfers. Patients with the possibility of endotracheal intubation, severe acute respiratory failure, and hypoventilation risk should be treated with NIMV in intensive care. Leakage compensation, rebreathing, modes, triggering, monitoring parameters, and alarms are among the criteria that should be included in device selection. Inspiratory flow rate, rise time, number of backup breaths, FiO_2, IPAP (positive airway pressure), and EPAP (expiratory positive airway pressure) levels should be technical. There are three types of ventilators: bilevel portable, transport, and intensive care. Bilevel portable ventilators are available in many different types and with different technical features. It is easy to use and inexpensive. The exhalation valve works passively. A single hose circuit is used; a leak port close to the patient or on the mask is recommended. It is recommended to be on the mask because it provides high EPAP. In the intensive care type, the exhalation valve is active, and a double circuit with inspiration and expiration valves is used. It provides high FiO_2, IPAP, and EPAP pressures and detailed monitoring.[2,4,5] There is no carbon dioxide retention associated with rebreathing compared to single-circuit systems used in bilevel ventilators.[8,9]

The interface or mask is a spacer that connects to the patient's face and allows compressed air to be delivered from the upper airways to the lungs.[10] Mouthpieces, nasal pillows, nasal, oronasal, total face, and helmet-type masks are available. The ideal mask should be robust, lightweight, leak-free, non-traumatic, non-allergenic, non-deformable, low-cost, and suitable for long-term use. It should also be of different sizes, have low dead space, and have low resistance to airflow. It is recommended that the fixation used to attach the mask to the patient's face should be easy to attach and remove, nontraumatic, soft, and of different sizes compatible with masks. The masks that are frequently used in daily practice for acute respiratory failure are oronasal, total face, and helmet types. Oronasal masks are masks that cover the mouth and nose, less air leakage and less need for cooperation are important advantages. Vomiting, claustrophobia, nasal skin ulcerations, difficulty in speaking and coughing are disadvantages. While vomiting, claustrophobia, and speech difficulty are disadvantages, minimum air leakage, less cooperation, easy wearing, and application are advantages. It is a helmet type of mask that covers the whole head and neck. Its advantage is that it can be used in cases of minimal air leakage, wounds on the face and nose root. The disadvantages are re-breathing, excessive loudness and noise, asynchronization in pressure-assisted modes, and skin lesions in the axilla due to ligaments.[5,10-12] During the application, the appropriate size mask (S, M, L, XL) should be selected for the patient. The masks used are mostly composed of two parts: the soft face-fitting part and the transparent part that forms the periphery. There are four types of cushions that protect the face: transparent, non-inflated, inflated, full hydrogel, and full foam.[5,10] The most common complication of the interface is skin complications on the nasal root, upper lip, nasal mucosa, and axilla. To minimize them, checks every four to six hours, foam pads, hydrocolloids, and transparent dressings are recommended.[5,10,13] In acute respiratory failure, oronasal and total face masks are primarily recommended.[14]

In the upper airways, air is heated to 32-35°C, humidified to 100%, and particles >2-5 mm are filtered. With NIMV and invasive mechanical ventilation, the upper airways are disabled. As a result, drying of secretions, mucus plugs, atelectasis, a decrease in ventilation perfusion ratio, damage to the tracheobronchial epithelium, and impaired mucociliary activity occur. Two types of humidifiers are used. Heat-moisture exchangers (HME) are systems in which the heat and moisture of the air supplied during expiration are condensed on the membrane in the HME and return heat and moisture on inspiration. A heated humidifier is a system in which gases are actively heated by passing over the surface of a heated water reservoir attached to the aerator.[5,15] While HME is cheaper and provides better maintenance of humidity at low ambient temperatures and high flow, the disadvantages are increased dead space, carbon dioxide retention, increased nasal airway resistance, and increased work of breathing. Heated humidifiers have the disadvantage of increased heat and electricity requirements, but the advantages of reduced dead space, carbon dioxide retention, and breathing work of breathing. There is insufficient evidence on the use of humidifiers in acute respiratory failure.[4,5,15]

In NIMV, the modes are mainly volume- or pressure-assisted. In volume-targeted ventilation, a constant volume is delivered, while the pressure varies with each breath. Airway pressure changes depending on lung compliance and airway resistance. The advantage is that it guarantees a tidal volume independent of changes in compliance and resistance. In pressure-targeted ventilation , a constant pressure is delivered, while the volume varies with each breath. The most important advantage is the compensation for mild to moderate leaks. The most commonly used mode is PSV (Pressure Support Ventilation). This mode is a patient-triggered and flow-cycled mode. While IPAP and EPAP are adjusted in bilevel ventilators, inspiratory pressure is obtained by applying PEEP on pressure support in intensive care type ventilators. In bilevel ventilators, the difference between IPAP and EPAP is pressure support. With EPAP, collapse in the airways is prevented, and functional residual capacity is increased. IPAP increases airway pressure and tidal volume by supporting inspiration. Pressure-assisted hybrid modes are available for a constant tidal volume in clinical practice. In Average Volume Assured Pressure Support (AVAPS), minute ventilation is measured with each breath. Pressure adjustment is made in each inspiration to reach the target tidal volume. Min and max IPAP adjustments are made for pressure adjustment. It is a patient-ventilator-compatible mode. It is recommended in OHS, chest wall pathology, and neuromuscular diseases with hypoventilation risk. CPAP (Continuous Positive Airway Pressure) is not considered a clear mode because it does not support inspiration. It improves ventilation and reduces respiratory workload by increasing functional residual capacity by providing constant airway pressure.[16-18]

CONCLUSION

NIMV should be the first choice in the weaning process for patients with acute exacerbations COPD, acute cardiogenic pulmonary edema, and COPD exacerbations.. The choice of device, mode, and mask is important to the application and success of NIMV. In appropriate diagnosis and indication, NIMV should be the first choice in patients who are cooperative, able to protect their airways, clinically stable, and to whom the mask can be applied.

ETHICAL DECLARATIONS

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

REFERENCES

1. MacIntyre NR. Physiologic effects of noninvasive ventilation. *Respir Care.* 2019;64(6):617-628.
2. Rochwerg B, Brochard L, Elliott MW, Hess D, Hill NS, Nava S, et al. Official ERS/ATS clinical practice guidelines: noninvasive ventilation for acute respiratory failure. *Eur Respir J.* 2017;50(2):1602426.
3. Roussos C, Koutsoukou A. Respiratory failure. *Eur Respir J Suppl.* 2003;21(47):3s-14s.
4. Gay PC, Owens RL, Wolfe LF, et al. Executive summary: optimal NIV Medicare access promotion: a technical expert panel report from the American College of Chest Physicians, the American Association for Respiratory Care, the American Academy of Sleep Medicine, and the American Thoracic Society. *Chest.* 2021;160(5):1808-1821.
5. Chawla R, Dixit SB, Zirpe KG, et al. ISCCM guidelines for the use of non-invasive ventilation in acute respiratory failure in adult ICUs. *Indian J Crit Care Med.* 2020;24(Suppl 1):S61-S81.
6. Gregoretti C, Pisani L, Cortegiani A, Ranieri VM. Noninvasive ventilation in critically ill patients. *Crit Care Clin.* 2015;31(3):435-457.
7. Baudouin S, Blumenthal S, Cooper B, et al. Non-invasive ventilation in acute respiratory failure. *Thorax.* 2002;57(3):192-211.
8. Çiledağ A, Kaya A. Yoğun bakım ventilatörü ve BiPAP ile noninvaziv mekanik ventilasyon uygulamalarındaki farklılıklar. İçinde: Öcal S., eds. Noninvaziv Mekanik Ventilasyon Uygulamaları. TÜSAD: 2017;21-27.
9. Kasapoğlu US, Seven S, Cinel İ. CPAP/BIPAP cihazları. İçinde: Baykara ZN, eds. Yoğun Bakımda Noninvaziv Yöntemlerle Solunum Desteği. *Turkiye Klinikleri:* 2019:14-20
10. Aydoğdu M. Noninvaziv mekanik ventilasyon başarısını etkileyen arayüz (maske), devre, ekshalasyon portu ve oksijen destek girişi nasıl olmalıdır? İçinde: Öcal S, eds. Noninvaziv Mekanik Ventilasyon Uygulamaları. TÜSAD: 2017:43-53.
11. Esquinas Rodriguez AM, Papadakos PJ, Carron M, Cosentini R, Chiumello D. Clinical review: Helmet and non-invasive mechanical ventilation in critically ill patients. *Crit Care.* 2013;17(2):223.
12. Ozsancak A, Sidhom SS, Liesching TN, Howard W, Hill NS. Evaluation of the total face mask for noninvasive ventilation to treat acute respiratory failure. *Chest.* 2011;139(5):1034-1041.
13. Davidson AC, Banham S, Elliott M, et al; BTS Standards of Care Committee Member, British Thoracic Society/Intensive Care Society Acute Hypercapnic Respiratory Failure Guideline Development Group, On behalf of the British Thoracic Society Standards of Care Committee. BTS/ICS guideline for the ventilatory management of acute hypercapnic respiratory failure in adults. *Thorax.* 2016;71(Suppl 2):ii1-ii35.
14. BaHammam AS, Singh TD, Gupta R, Pandi-Perumal SR. Choosing the proper interface for positive airway pressure therapy in subjects with acute respiratory failure. *Respir Care.* 2018;63(2):227-237.
15. Şimşek M, Öcal S. Noninvaziv mekanik ventilasyonda nemlendirme. İçinde: Öcal S, eds. Noninvaziv mekanik ventilasyon uygulamaları. TÜSAD: 2017:53-63.
16. Ortaç Ersoy E. Cihaz, modlar, maske seçimi nasıl yapılmalı? İçinde: Kunter E, Öcal S, eds. Noninvaziv mekanik ventilasyon uygulamaları. *Turkiye Klinikleri:* 2019:5-11.
17. Soytürk AN, Kahveci FŞ. Noninvaziv mekanik ventilasyonda yeni modlar. İçinde: Baykara ZN, eds. Yoğun bakımda noninvaziv yöntemlerle solunum desteği. *Turkiye Klinikleri:* 2019:66-69.
18. Yarrarapu SNS, Saunders H, Sanghavi DK. Average volume-assured pressure support. [Updated 2023 Aug 8]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK560600/