Chapter 4
Discomfort and Adaptation in Non Invasive Mechanical Ventilation: Mask Interface Problems

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Abbreviations

ARF	Acute respiratory failure
BIPAP	Bilevel positive airway pressure
COPD	Chronic obstructive pulmonary disease
CPAP	Continuous positive airway pressure
EPAP	Expiratory positive airway pressure
FiO_2	Fraction of inspired oxygen
GCS	Glasgow coma scale
IPAP	Inspiratory positive airway pressure
NIV	Non invasive ventilation
$PaCO_2$	Partial pressure of carbon dioxide
PaO_2	Partial pressure of oxygen
PC-BIPAP	Control pressure—bilevel positive airway pressure
PEEP	Positive end- expiratory pressure
PS	Support pressure
PVD	Patient-ventilator dyssynchrony
$SatO_2$	Arterial oxygen saturation
VDd	Dead space of the mask
VDdyn	Dynamic dead space
VDph	Physiologic dead space

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Case Clinic
A 67-year-old man with COPD went to the emergency room due to exacerbation of his lung disease. On arrival at the emergency department, the patient was in a situation of hypercapnic encephalopathy, GCS 10 points, oxygen saturation (SpO_2) 60% with a Venturi oxygen mask at fraction of inspired oxygen (FiO_2) = 30%. The clinical exploration showed superficial breathing, tachypnea (25 breaths per minute), sweating and cyanosis. Arterial blood gases showed pH 7.01; PaO_2 45 mmHg; $PaCO_2$ 155 mmHg. The patient was transferred to the ICU for treatment of respiratory failure. The patient was connected to a NIV ventilator, with an oro-nasal mask, in BIPAP mode. The parameters initially programmed were: IPAP 12 cmH_2O, EPAP 5 cmH_2O, FiO_2 0.5, inspiratory ramp 100 ms. Initial adaptation to the ventilator was poor; leaks and discomfort prevented adequate ventilation so the interface was changed to a total face mask and optimized ventilator support. Few minutes later, a good adaptation was achieved, with almost all of the inspiratory efforts of the patient being assisted. The IPAP managed to ensure an appropriate tidal volume was 17 cmH_2O. One hour later, blood gas analysis showed pH 7.23; $PaCO_2$ 90 mmHg; PaO_2 70 mmHg. The level of consciousness improved. After 8 h of therapy, pH had normalized and the $PaCO_2$ was 56 mmHg. The patient remained with NIV for 3 days intermittently and finally discharged to hospitalization ward.

4.1 Choosing the Interface

Using a correct interface is crucial to success of the NIV. There are many different types of interfaces that can be used during NIV therapy in the acute setting (nasal, oronasal, total face mask and helmets) (Table 4.1). Choosing the appropriate interface involves consideration of patient preference and tolerance and selecting the correct size and fit is overrinding to successful ventilation (Fig. 4.1).

When choosing the most appropriate interface, great consideration should be given to minimize non-intentional leaks, which may impair the efficiency of NIV, in particular during the first few hours of ventilation when the patient needs to adapt to NIV[1]. Fortunately, ventilators for NIV are designed to compensate for a variable amount of air leaks.

Another challenge regarding interfaces is the amount of dead space. Dynamic dead space (VDdyn) derives from the physiologic dead space (VDph) plus the dead space of the device (VDd). The VDph is influenced by inspiratory flow rate, expiratory flow rate and tidal volume, while the VDd depends on the inner volume of the interface.

Although NIV is well tolerated by most patients, it is not entirely free from serious adverse side-effects and complications.

Table 4.1 Advantages and limits of different interfaces [1]

Interfaces	Advantages	Disadvantages
Nasal mask	Use of the mouth to drink, communicate, cough and expectorate	Decubitus Need for nasal patency Mouth leaks
Oro-nasal mask	No need for cooperation Breathing through mouth and nose	Vomiting, claustrophobia Decubitus Difficult communication and cough Edentulous
Nasal pillows	No decubitus	Reduces seal at high pressure (>15 cmH_2O) Nasal irritation Holes inside (no circuit with valve)
Total face mask	Few leaks Rapid to put on No need for cooperation Good for edentulous	Vomiting Claustrophobia Difficult cough and communication
Helmet	Few leaks Rapid to put on No facial decubitus No need for cooperation	Claustrophobia Vomiting Rebreathing Noise Asynchronies Axillary decubitus

4.2 Problems Related to the Interface [2, 3]

Air leaks. *There* are two kinds of air leaks: intentional and unintentional leaks.

- Intentional leaks are deliberately generated during NIV when a single-limb circuit without an expiratory valve is used. The aim is to avoid rebreathing by having holes in the mask or in the circuit to allow a leak proportional to their size and the set inspiratory pressure or mean inspiratory flow.
- An unintentional leak can occur between the mask and the skin, through the open mouth with nasal mask, or through the nose with mouthpiece ventilation.

Large air leaks have detrimental effects on the success of NIV, as leaks decrease the FiO_2 and arterial oxygen saturation ($SatO_2$) and increase ventilator autotriggering, increasing patient discomfort, which increase the risk of NIV failure. Moreover, air leaks may cause mouth and throat dryness, conjunctivitis or sleep disturbances.

Nasal/oral dryness and nasal congestion. Usually indicates air leakage through the mouth, which results in the loss of the nasal mucosal capacity to heat and to humidify inspired air. Increased nasal congestion and nasal resistance reduces tidal volume and patient discomfort [4].

Fig. 4.1 Different types of interfaces. (**a**) Total face mask. (**b**) Oro-nasal mask. (**c**) Nasal pillows. (**d**) Nasal mask. (**e**) Helmet

Patient-ventilator dyssynchrony (PVD). Of all interfaces, studies reported the helmet has more problems with patient-ventilator synchrony and ventilator cycling due to its soft compliant wall, upward displacement, and elevated internal compressible volume. This increases work of breathing [5].

Facial skin lesions. Nasal skin lesions such as erythema and ulcers may appear at the site of mask contact. It may occur in almost 100% of patients after 48 h of NIV with a mask. There are different types of skin lesions, ranging from slight redness over the nasal bridge to open ulcers or necrosis, which is an important factor that limits the tolerance and duration of NIV [3].

Arm oedema and deep venous thrombosis. The helmet is secured by two armpit braces; prolonged compression may produce venous and lymphatic stasis with consequent oedema, that may promote deep venous thrombosis in the axillary vein.

Carbon dioxide (CO_2) rebreathing. The interface represent an additional dead space which increases the chances of CO_2 rebreathing in proportion to dead space volume. The dead space of facial and nasal masks sin small compared with the tidal volume, and the amount of CO_2 rebreathed is also small. On the other hand,

helmets predispose to CO_2 rebreathing because its internal gas volume is larger than the tidal volume.

Claustrophobia. It may present as minor discomfort or as a frightening sense of restriction and suffocation. Nasal masks are less likely to cause claustrophobia than face mask. On the other hand, helmet use minimizes this event.

Discomfort. It is related to the device and the ventilation modality adopted for NIV. Among different of masks, tolerance is poorest for the mouthpiece followed by the nasal and oronasal masks. Helmets are better tolerated than masks, although a short NIV duration may explain lack of differences in comfort between the mask and helmet in the acute setting.

Noise. Device noise may increase patient discomfort, cause sleep disruption and affect ear function (tinnitus, hearing loss). Noise level is significantly greater during helmet NIV than during mask NIV [6].

Airways dryness. Cool and dry gases alter the tracheobronchial mucosa and may cause mucous plugging and atelectasis. This is less important during helmet NIV, because the high internal gas volume could serve as a mixing chamber between the heated humidified expired gas and the dry medical gas entering the helmet [7].

Gastric insufflation. Large tidal volumes, high airway resistance, low respiratory system compliance and short inspiratory time increase airway pressure and air entering the stomach. Gastric insufflation also facilitates vomiting and inspiration of gastric contents can cause severe complications.

Key Teaching Points

- The choice of the interface during NIV represents the main determinant of its success in an acute setting and one important factor contributing to the long-term tolerance and efficacy of NIV in a chronic setting.
- The availability of different types of masks could allow different approaches for each individual situation, optimizing patient tolerance and avoiding side effects.
- The main reasons for choosing a particular interface are patient comfort, the prevention of leaks or complications and the amount of dead space.

Questions and Answers

1. Which one is NOT a disadvantage of non invasive mechanical ventilation using a helmet?

   (a) Claustrophobia.
   (b) Noise.
   (c) Rebreathing.
   (d) Vomiting.
   (e) Nasal decubitus.

   Answer: (e) Nasal decubitus.

2. Arm oedema and deep venous thrombosis may appear more frequently in NIV with:

   (a) Nasal mask.
   (b) Oro-nasal mask.
   (c) Nasal pillows.
   (d) Helmet.
   (e) Total face mask.

   Answer: (d) Helmet.
3. Air leaks have different effects; choose the INCORRECT answer:

   (a) Decrease the FiO_2 received.
   (b) Decrease arterial oxygen saturation.
   (c) Increase patient discomfort.
   (d) Decrease ventilator autotriggering.
   (e) Increase the risk of NIV failure.

   Answer: (d) Decrease ventilator autotriggering.
4. Which of the following interfaces produces more carbon dioxide rebreathing?

   (a) Helmet.
   (b) Total face mask.
   (c) Oro-nasal mask.
   (d) Nasal mask.
   (e) Nasal pillows.

   Answer: (a) Helmet.
5. Airway dryness is an important problem related to the interface during NIV, but it less important when using…

   (a) Nasal mask.
   (b) Oro-nasal mask.
   (c) Nasal pillows.
   (d) Total face mask.
   (e) Helmet.

   Answer: (e) Helmet.
6. What is not a problem related to the interface during NIV?
   (a) Air leaks.
   (b) Facial skin lesions.
   (c) Gastric insufflation.
   (d) Discomfort.
   (e) All can be problems related to the interface during NIV.

   Answer: (e) All can be problems related to the interface during NIV.

References

1. Pisani L, Carlucci A, Nava S. Interfaces for noninvasive mechanical ventilation: technical aspects and efficiency. Minerva Anestesiol. 2012;78:1154–61.
2. BaHammam A, Singh T, Gupta R, et al. Choosing the proper interface for positive airway pressure therapy in subjects with acute respiratory failure. Respir Care. 2018;63:227–37.
3. Carron M, Freo U, BaHammam A, et al. Complications of non-invasive ventilation techniques: a comprehensive qualitative review of randomized trials. Br J Anaesth. 2013;110:896–914.
4. Esquinas Rodriguez A, Scala R, Soroksky A, et al. Clinical review: humidifiers during non-invasive ventilation—key topics and practical implications. Crit Care. 2012;16:203.
5. Costa R, Navalesi P, Spinazzola G, et al. Influence of ventilator settings on patient-ventilator synchrony during pressure support ventilation with different interfaces. Intensive Care Med. 2010;36:1363–70.
6. Cavaliere F, Conti G, Costa R, et al. Exposure to noise during continuous positive airway pressure: influence of interfaces and delivery systems. Acta Anaesthesiol Scand. 2008;52:52–6.
7. Chiumello D, Chierichetti M, Tallarini F, et al. Effect of a heated humidifier during continuous positive airway pressure delivered by a helmet. Crit Care. 2008;12:R55.