NIV (Non-invasive Ventilation)

Hartmut Lang

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5.1 Indications and Contraindications

5.1.1 Indications

Non-invasive ventilation as a therapy for chronic respiratory insufficiency (CRI) can be used for patients with the following diseases:

- Chronic obstructive disease (COPD)
- Restrictive thoracic disease
- Obesity hypoventilation syndrome
- Neuromuscular diseases

Symptoms of chronic ventilatory insufficiency:

- Dyspnoea/tachypnoea (during exertion and/or at rest)
- Morning headaches
- Lassitude
- Limited performance
- Psychological changes (e.g. anxiety, depression, personality changes)
- Sleep disorders (nocturnal awakening with dyspnoea, restless sleep, daytime tiredness, tendency to fall asleep, nightmares)
- Polyglobulia (an increased number of red blood cells in the blood)
- Tachycardia
- Edema
- Cor pulmonale (disease of the heart with reduced performance due to lung disease)

These symptoms can be reduced by the use of NIV. Furthermore, an improvement of the health-related quality of life should be achieved. Ventilation in general, even under NIV, improves the quality of sleep and leads to a prolongation of life.

Possibilities of NIV

Non-invasive ventilation represents an alternative to invasive ventilation. The proven advantages are:

- Decrease in ventilator-associated pneumonia
- Avoiding or delaying a tracheotomy if necessary
- Shortening the intensive stay
- Increase of the probability of survival
- Reduction of dyspnoea
- Avoidance of desaturation
- Improvement or maintenance of the respiratory muscle strength
- Patient can still communicate
- Patient can consume food and beverages during ventilation
- Patient is still mobile or mobilizable
- Intermittent ventilation possibility

The NIV shows high success in the case of respiratory pump failure (► Sect. 2.1.1), breathing work is taken over. The respiratory pump is relieved. It has fewer advantages in hypoxemic lung failure (► Sect. 2.1.2). This is accompanied by a lack of oxygen.

A high tendency of the alveoli to collapse with the development of atelectasis leads to a primary failure of the lung. This leads to a disproportion between pulmonary blood flow and pulmonary ventilation and to a distributional disorder to the disadvantage of ventilation. The tendency to collapse and atelectasis can be avoided by the use of PEEP/CPAP. However, NIV cannot maintain this PEEP reliably enough due to high leakage.

Risks in the Application of NIV

- **Nasal Masks**

Nasal masks are often prescribed because they usually offer a high degree of patient comfort. The ability to continue eating, drinking and talking cannot be overestimated. But people need to be trained for this. During sleep, high leakage through the mouth can occur. This reduces the effectiveness of nasal ventilation. This can be remedied by a chin strap, which reduces the falling of the lower jaw.

- **Full-Face Masks (Nose and Mouth Masks)**

Leaks can be reduced by using a full-face mask. However, the acceptance is usually lower. The mask cushion of the full-face mask has a rather high dead space volume. Therefore, the previously exhaled air must not be rebreathed, because this would cause people to inhale their own exhaled air again, and thus also the exhaled CO_2. However, respirator technology has long been mature. This creates a constant flow of air that "flushes" the exhaled air out of the mask.

NIV ventilation can cause ventilator air to enter the stomach, which can lead to nausea and vomiting. Any vomit that gets into the mask cushion can thus be aspirated again. Coughing and secretion ejection is more difficult. It is coughed out into the mask. The mask must then be removed and cleaned. Even coughing up secretion could be aspirated.

NIV ventilation can lead to increased ear pressure. However, pressure equalization is difficult to achieve. Yawning is one possibility, but it can lead to renewed leakage. This can significantly reduce acceptance by the people. Speaking is restricted and made more difficult. Human speech is unclear to the listeners.

Generally speaking:

- The high air flow can lead to drying of the nasal and oral mucous membranes. Humidification of the respiratory gas is therefore absolutely necessary.
- The skin under the mask can sweat. This is also caused by the moisture in the exhaled air. People therefore need to be able to remove the mask to dry and care for their skin.
- Masks that are not properly fitted can dry out the eyes and cause inflammation due to leakage.
- The contact pressure of the mask cushions can be unevenly distributed, resulting in pressure points. They **can** also cause claustrophobia in those affected. The correct selection and fitting of the mask is the responsibility of the clinics or their ventilation centers.

5.1.2 Contraindications of NIV

NIV cannot be offered to all persons requiring ventilation. In the following situations NIV is not a suitable therapy choice:

Inability to adapt a suitable ventilatory access for NIV

- Intolerance of NIV
- Ineffectiveness of the NIV
- Severe bulbar symptomatology with recurrent aspirations
- Ineffectiveness of non-invasive secretion management
- Failure to switch to NIV after invasive ventilation
- Inability of the person concerned to put the mask on and take it off independently:
  - patients with increasing muscular weakness
  - patients with tetraplegia (full-blown neuromuscular diseases, high paraplegia)
  - patients with severe respiratory centre disorders (severe stroke or severe hypoxic brain damage involving the respiratory centre)

- **Bulbar Symptoms**

If the medulla oblongata is diseased, the so-called bulbar symptoms or bulbar phenomena occur. The medulla oblongata is not only the control centre for breathing (respiratory centre), but also for the coordinated movement of the tongue, lips, facial muscles, palate, pharynx and larynx.

If these centres are diseased, which is usually irreversible, these patients become ill:

- Disorders in speech formation,
- Facial expression disorders and
- Disorders of the swallowing reflex
- with simultaneous increase in saliva and secretion production.

The risk for the patient in this case is the lack of swallowing reflex with subsequent risk of aspiration of saliva, oropharyngeal secretions, drinks and food into the lungs.

5.2 Characteristics of the NIV

Table 5.1 gives an overview of the complications and problems of invasive and non-invasive ventilation.

Table 5.1 Comparison between invasive and non-invasive ventilation (mod. according to the AWMF guideline "Non-invasive ventilation as a therapy for acute respiratory insufficiency", 2008)

Complications and clinical aspects	Invasive ventilation—tracheal cannula	Non-invasive ventilation
Tracheal early and late damage	Yes	No
Intermittent application	Rarely possible	Often possible
Effective coughing possible	No	Yes
Food and drink possible	Complicated (tracheostoma)	Yes
Communication possible	Difficult (speaking essay)	Yes
Upright body position	Only limited realizable	Often possible
Difficult weaning from the respirator	10–20%	Rare
Access to the airways	Direct	Complicates
Pressure points in the facial area	No	Occasionally
CO_2 rebreathing	No	Rare
Leakage	Hardly	More or less strong, mostly present
Aerophagy (air swallowing)	Hardly	Occasionally

Source: AWMF Guideline "Non-invasive ventilation as a therapy for acute respiratory insufficiency", led by DGP (Deutsche Gesellschaft für Pneumologie) (German Society for Pneumology), status 01.06.2008

5.3 Different Mask Systems

5.3.1 Nasal Mask

This mask is very often used in patients with chronic respiratory insufficiency (CRI) and in the therapy of sleep apnea. It only covers the nose not the mouth (◘ Fig. 5.1), so that speaking and eating is possible. The nasal airways must be free.

Advantages:

- Comfortable to wear
- Easier to use
- Better tolerance of the patient
- Coughing up is possible
- Good tightness
- Communication is possible
- Nasal mask can be adjusted/modelled to the facial contours

Cons:

- Effective breathing only possible with nasal breathing
- Good cooperation required

5.3.2 Full-Face Mask (Oronasal Mask)

The full-face mask is the mask of choice for patients with acute respiratory insufficiency (ARI) (◘ Fig. 5.2). It covers the mouth and nose. This allows a patient to breathe through both without having to concentrate. If a nasal mask is not sufficient for ventilation, the full-face mask offers an alternative.

◘ **Fig. 5.1** Nasal mask (courtesy of Prof. Dr. med. Stefan Kluge)

◘ **Fig. 5.2** Full-face mask (courtesy of Prof. Dr. med. Stefan Kluge)

Advantages:

- Effective for limited cooperation
- Sufficient function even with mouth breathing
- Patient does not have to decide whether to breathe through the mouth or the nose

Cons:

- Mask must be taken off for cough ing
- Often only limited fitting accuracy
- Pressure points on the bridge of the nose possible
- Air leakage that can enter the eyes and cause conjunctival irritation or inflammation
- Subjectively felt anxiety

5.3.3 Total Face Mask

This mask covers the entire face (◘ Fig. 5.3). It is the mask of choice for patients with acute respiratory insufficiency if a full-face mask cannot be fitted correctly. In this way, NIV can be performed and intubation may be avoided. This type of mask has not become established in out-of-hospital ventilation, despite the advantages listed below.

Fig. 5.3 Total face mask (courtesy of Prof. Dr. med. Stefan Kluge)

Advantages:
- Applicable if full-face mask does not fit
- Usually has a good seal
- No side air flowing into the eyes
- Patient does not have to decide whether to breathe through the mouth or the nose

Cons:
- Coughing up is possible, but only into the mask
- It is therefore often necessary to remove the mask to clean it
- Mask fogging from inside
- This limits the patient's view
- Good cooperation required
- Communication difficult
- Poor tolerance by the patient

5.3.4 Special Models

Special models are mostly used for patients with chronic respiratory insufficiency or in the therapy of sleep apnea. They are often individually adapted, but there are also industrially manufactured mask systems. Ventilation via mouthpieces is an alternative if the other mask systems cannot be adapted or are not tolerated by the patient.

5.4 Modern NIV Masks

Requirements for modern NIV masks are
- Comfortable to wear for the patient:
  - No pressure points due to masks or retaining straps
  - No sweating
  - No marks on the face
- Leakage-free seat:
  - For the administration of the necessary therapy pressure
  - For the avoidance of side effects
- **Easy** handling and cleaning:
  - Long service life
  - Easy size selection and adjustment
  - Clinically validated disinfection procedures for multiple use

  NIV masks are distinguishable between vented and non-vented masks:
- **Vented masks** have an integrated exhalation port in the mask. This allows the exhaled air to escape directly.
- **Non-vented masks** have no integrated exhalation ports. The exhalation valve is integrated in the ventilation hose system or there is a dual hose system. Non-vented masks are typically colored **blue.** Either at the connector to the mask or the entire mask.

Modern NIV masks have a double-walled mask cushion (Fig. 5.4). They consist of an inner and an outer cushion. The inner cushion consists of a solid membrane which is anatomically pre-shaped. It provides support and stability. The outer cushion consists of a thin membrane that fills with air.

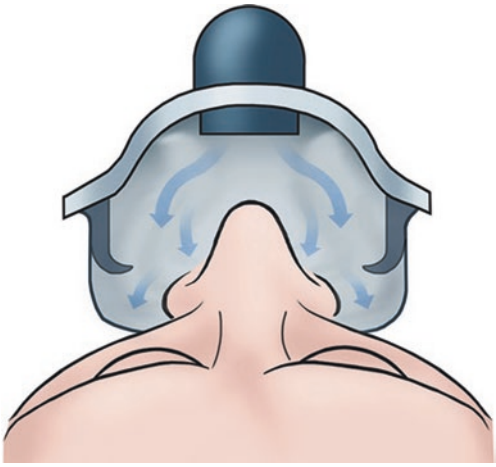

Fig. 5.4 Double-walled mask cushion, adaptation to facial contours (courtesy of Isabel Schlütter)

This allows it to adapt to the contours of the face and the mask is securely sealed, even when the patient moves (Fig. 5.4).

Modern NIV masks have an adjustable and large-area forehead support. Advantages of the forehead support:

- It gives support
- Provides a very good seal around the eyes
- At the same time, avoidance of excessive contact pressure on the root of the nose or the teeth

Table 5.2 gives an overview of the advantages and disadvantages of the mask systems (interfaces) used.

Table 5.2 Advantages and disadvantages of common interfaces (according to: AWMF guideline "Non-invasive ventilation as a therapy for acute respiratory insufficiency, 2008)

Aspect	Nose mask	Full-face mask
Mouth leakage	–	+
Volume monitoring	–	+
Initial response of the blood gases	o	+
Speak	+	–
Coughing up (expectoration)	+	–
Aspiration risk	+	o
Air swallowing (aerophagy)	+	o
Claustrophobia	+	o
Dead space (compressible volume)	+	o
Noise and irritation of the hearing	+	+

Source: AWMF Guideline "Non-invasive ventilation as a therapy for acute respiratory insufficiency", led by DGP (Deutsche Gesellschaft für Pneumologie) (German Society for Pneumology), status 1.06.2008
+ Advantage
o neutral
– Disadvantage

5.5 Typical Applications

As described in ► Sect. 5.1.1, NIV can be used in patients with different diseases:
- COPD
- Thoracic restrictive diseases
- Obesity hyopventilation syndrome
- Neuromuscular diseases

5

5.5.1 COPD

Indication for initiation of out-of-hospital NIV is when a patient is suffering from the symptoms of chronic hypercapnia (► Sect. 5.1.1). Restriction of the quality of life is also included. However, according to the S2 guideline, at least two additional criteria must be included:
- Permanently elevated CO_2 levels in blood during the day ($PaCO_2 \geq 50$ mmHg/6.65 kPa)
- During nighttime rest and sleep the CO_2 content increases again ($pCO_2 > 55$ mmHg/7.3 kPa)
- Permanent but stable daytime hypercapnia (46–50 mmHg/6.1–6.65 kPa), but increase in CO_2 level during sleep
- Permanent but stable daily hypercapnia (46–50 mmHg/6.1–6.65 kPa), but at least two acute hospitalization-bound exacerbations with respiratory acidosis in the last 12 months (exacerbations = exacerbations of COPD requiring hospitalization; acidosis = acidification of the blood)
- Previous exacerbation of COPD, which was so severe that artificial respiration became necessary
  (For the values, ► Chap. 27 BGA blood gas analysis)

5.5.2 Thoracic Restrictive Disorders

The restrictive ventilation disorder, which causes a reduction in lung volume, is caused by reduced compliance (ability to stretch) of the lung and thoracic wall. If the lung volume is less than 50% of normal vital capacity (VC), it is called a severe restrictive ventilation disorder. An unfavourable breathing mechanism can lead to severe desaturation.

Indications for NIV:
- Symptoms of hypoventilation (► Sect. 5.1.1) and at least one of the following findings:
- Permanently elevated CO_2 levels in blood during the day ($pCO_2 \geq 45$ mmHg/6.0 kPa)
- At night ($pCO_2 \geq 50$ mmHg/6.65 kPa)
- Normal CO_2 values during the day, but the CO_2 value increases during sleep
- Rapid relevant decrease in vital capacity (VC) (► Sect. 1.4.5)

Targets of Ventilation in Thoracic Restrictive Diseases:
- Elimination of hypoventilation
- Prevention of hypercapnia
- Taking over the breathing work
- Supply with oxygen if necessary

5.5.3 Obesity Hypoventilation Syndrome

The obesity hypoventilation syndrome (OHS) describes the presence of obesity with a body mass index (BMI) > 30 kg/m_2. In addition, chronic alveolar hypoventilation occurs and a resulting hypercapnia ($PaCO_2 > 45$ mmHg/6.0 kPa) in the waking state under resting respiration.

Clinic and Symptoms:
- Pronounced daytime sleepiness
- Rapid exhaustion
- Shortness of breath
- Headaches
- Sign of right-cardiac decompensation
- Pulmonary hypertension
- Polyglobulia (proliferation of red blood cells/red blood cells greater than standard values)

Indications for NIV:
- Persistent hypercapnia greater than 55 mmHg/7.3 kPa that persists for more than 5 min
- Permanently elevated CO_2 levels in the blood during sleep pCO_2 > 10 mmHg/1.3 kPa compared to the waking state
- Desaturation SpO_2 < 80% for more than 10 min

5.5.4 Neuromuscular Diseases (NME)

Indications for NIV:
- Symptoms of hypoventilation (► Sect. 5.1.1) and at least one of the following findings:
  - Permanently elevated CO_2 levels in blood during the day (pCO_2 ≥ 45 mmHg/6.0 kPa)
  - At night (pCO_2 ≥ 50 mmHg/6.65 kPa)
  - Normal CO_2 values during the day, but the CO_2 value increases during sleep
  - Rapid relevant decrease of VC

Targets of Ventilation in Thoracic Restrictive Diseases:
- Elimination of hypoventilation
- Prevention of hypercapnia
- Taking over the breathing work
- Supply with oxygen if necessary

5.6 Assessment of an Adjusted Ventilation Setting

A patient should find confidence in the NIV. First of all, he/she needs enough air per breath. This can be achieved by setting the ventilation pressure accordingly. The air should arrive quickly. The faster the air arrives, the less effort an exhausted patient has to make, because he/she does not have to breathe in the air so hard. This results in a saving of energy for the patient. The patient should have an easy time triggering ventilation or pressure support. The air that has been inhaled must also be able to be exhaled in a relaxed manner.

In most cases, patients on NIV ventilation are able to communicate. The success or failure of NIV also depends on the ventilation setting. In order for this to be adjusted and for the patient to tolerate it, specific YES/NO questions must be asked. Under a mask, differentiated talking is hardly possible for the patient.

Questions to the patient:
- **"Are you getting enough air?"**
  - If NO, increase IPAP/Pinsp/P-ASB by 2–3 cm H_2O
- **"Are you getting too much air?"**
  - If YES, decrease IPAP/Pinsp/P-ASB
- **"Is the air coming fast enough?"**
  - If NO, shorten the rise time/ramp, set to a shorter time:
  - 0.0–0.1 s
  - 0–100 ms (milliseconds)
- **"Is the air coming too fast? Is there too much pressure?"**
  - If YES, extend rise time/ramp to 0.1–0.3 s:
  - 100–300 ms (milliseconds)
- **"Do you find it easy to breathe?"**
  - If NO, lower the trigger threshold, make the trigger more sensitive:
  - to 1–2 L/min
- **Observe whether "auto-triggering" occurs accidentally, i.e. pressure support not triggered by the patient is administered.**
  - If YES, increase trigger threshold, increase trigger value:
  - if necessary 3–5 L/min
- **"Can you exhale in a good, relaxed manner?"**
  - If NO, increase ETS/Insp.Term. value, set larger% number:
  - 40–50%
- **"Do you feel that your inhalation is too short?"**
  - If YES, decrease ETS/Insp.Term. value, set smaller% number:
  - 25–40%

5.7 Ventilation Setting of the NIV

Nearly all modern ventilators have a NIV function. This should also be active when mask ventilation is performed on a patient. Turbine-driven ventilators usually seem to be more beneficial to the patient than intensive care ventilators driven by compressed air (► Sect. 6.6).

Turbine-driven respirators are usually equipped with a single hose system. The breathing tube leads from the ventilator to the mask. An exhalation valve is integrated in the tube system. A two-hose system is used for compressed air driven intensive care ventilators. This allows the measurement of inspiratory and expiratory breath and minute volumes.

The use of NIV with positive pressure ventilation is common in acute medicine. An assisted ventilation mode such as CPAP-ASB/pressure support with spontaneous breathing (PS/SPONT) is selected (► Chap. 12). A back-up frequency is also set to avoid bradypnoea and apnoea. If such a frequency is present, controlled ventilation is performed. Additional oxygen is also administered to prevent desaturation. The goal is to achieve oxygen saturation of more than 90%. A PEEP setting is usually chosen. However, its level depends on pathophysiology. A fast rise time/ramp is chosen to facilitate breathing for the patient.

A volume-controlled ventilation setting only appears to make sense for patients who are used to it. This is not to be expected in patients with acute respiratory insufficiency. Therefore, it is almost never used. NIV in pressure-controlled ventilation mode has the effect of relieving the respiratory muscles. However, the problem is a difficult adjustment of the ventilation parameters in patients with acute respiratory failure. A "fight" or "struggle" with the ventilator can result. CPAP is mainly used for recruitment, the recovery of lung areas that have not been involved in ventilation until now. CPAP prevents an end expiratory alveolar collapse.

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