Nurse Planning and Family and Caregivers Support in Noninvasive Mechanical Ventilation

35

Cristina Muñoz Ramos, Irene Reboredo Gutierrez, and Helena De La Fuente Martín

Abstract

Nursing care in the treatment of patients with NIV and HFT is key to the success of therapy. The evidence recommends that monitoring during the first hours of these patients should be carried out by nurses adequately trained to recognise complications early. This chapter will address minimum recommendations that can serve as a basis for standardised, evidence-based nursing care in both acute and chronic respiratory failure treatment with NIV and HFT and also serve as a basis for their caregivers at home.

Keywords

Nursing care · Noninvasive ventilation · High-flow therapy · Paediatric nursing care · Skin care · Pressure ulcers · Interface

Introduction

NIV has been a known therapy since the 1920s, but it was not until the 1960s that the field was further developed, and its use became widespread. Since then, its application has been relegated to intensive care areas. During the last decades, the use of noninvasive mechanical ventilation has spread outside intensive care units, becoming the Gold Standard in the treatment of respiratory acidosis in COPD patients also in emergency units in and out of hospital, as well as in hospital wards and even at home in chronic patients. To ensure the success of the therapy, it is crucial, on the one hand, to get the patient's cooperation and, on the other hand, the

C. Muñoz Ramos (✉) · I. Reboredo Gutierrez · H. De La Fuente Martín
Emergency Care Department, Hospital Ramón y Cajal, Madrid, Spain

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_35

meticulous dedication and adequate training of the nursing staff involved in the care of the patient. This will allow early recognition of complications and improved tolerance to treatment [1, 2]. Nursing interventions in these patients are numerous. The following are some minimum actions that can serve as a basis for standardised nursing care based on scientific evidence for the care of this type of patient.

Nursing Care of Adult Patients Undergoing Noninvasive Mechanical Ventilation and High-Flow Therapy in Acute Respiratory Failure

Throughout the chapter, reference will be made to the care to be taken prior to the start of treatment and during the various therapies.

Preconnection Care

- The first action to be taken is to inform the patient and those accompanying the patient of the technique to be performed.
- In 2016, at the XXXVII National Congress of the Spanish Association of Cardiology Nurses held in Valencia, a paper entitled "Non-invasive mechanical ventilation: patient perceptions" won second prize. It referred to a study conducted by the authors in which a sample of patients were asked about the information received about the technique, their impressions about the safety related to NIV and about the complications that most bothered them. The study concluded that training nurses in NIV was useful not only to prevent complications, but also to provide adequate and accurate information to the patient, thus improving patient participation, which is crucial for the success of the therapy [3].
- Simultaneously with or immediately after the above, it is essential to prepare the necessary equipment, checking and verifying that it is functioning optimally. This includes choosing the interface and its size, checking the battery level, checking the availability of a working oxygen supply and the water level of the humidifier.
- What size of interface is the most suitable? It is recommended to make use of the gauges provided by the manufacturers, in the case of nasal interfaces measuring from the junction of the cartilage with the nasal bone at the top and at the bottom above the upper lip and in the case of oronasal masks from the junction of the cartilage with the nasal bone, occupying the nasolabial fold to the bottom of the lower lip. Whenever possible, use the smallest size.
- An essential element of safety is antimicrobial filters. Prior to the COVID 19 pandemic, only one filter was required at the connection between the ventilator and the tubing to prevent contamination of the machine by microorganisms, Since March 2020, it is recommended to place a second antimicrobial filter between the interface and the tubing, limiting the dispersion of particles and

protecting healthcare professionals and other patients in close proximity to the patient, which becomes even more important in case of infection by COVID 19 or any other type of infectious disease via the respiratory tract.

- At this point it would be advisable to check the availability and correct functioning of the expiratory valve to be fitted (Plateau®, Whisper®) or disposable exhalation port as well as the chosen elbow.
- Before connecting the patient to the ventilator, we must check the alarms programmed by default and that the programmed parameters are those prescribed by the physician.
- There is disagreement in the literature on whether to remove dentures, due to the increased resistance in the upper airway if they are not removed and the risk of aspiration in patients with a low level of consciousness, although evidence-based practice shows that the adjustment of the interfaces is better, minimising leaks and associated complications. Bearing in mind that these patients should be cared for in highly complex boxes with close monitoring by nursing teams trained in the technique, the authors recommend not to remove them [4].
- The most suitable positions for these patients are Fowler and Semifowler, always considering and seeking the patient's comfort.
- All interfaces should be placed between two people in an attempt to achieve symmetry of fit and avoid or reduce pressure-related complications. It is advisable to teach patients who are conscious and cooperative to remove the device in case of an emergency such as nausea or vomiting.
- Another recommended aspect is the initial adjustment of the fixed clips, if the mask has them, and subsequently adjusting the straps, helping in the case of rapid removal of the device due to breaks or any other aspect (nausea, vomiting) to maintain the position of the interface once the break is over. Although in some cases, such as when fitting the Boussignac® Cpap, it is recommended to adjust the straps in an X-shape, the most widespread way of fitting the straps is from top to bottom and always by two people, thus minimising ocular leakage.
- Depending on the manufacturer, brand and geographical origin of the interfaces, we can find that they may or may not have a built-in anti-suffocation valve, a safety device that allows the entry of outside air in the event of failure, obstruction or depressurisation of the system. If they are fitted, it is essential to check that they are detached and allow air to enter correctly before fitting them.
- An especially important aspect of the care of patients undergoing noninvasive mechanical ventilation and high-flow therapy that is the sole and exclusive competence of nursing is skin and mucosal care. Therefore, because nurses have been excluded from research in their daily practice for decades, there is little literature relegating this aspect to the evidence-based practice of these professionals but without normalisation or standardisation in this care.
- In the prevention of mucosal lesions, the recommendation is to use water-soluble ointments on the nose and lips, excluding the use of vaseline and any other flammable products.

Skin Care in NIV and HFT Patients

One of the most frequent complications in this type of patient is facial pressure ulcers in relation to the tisular hypoxia produced by the pressure maintained over time by the interfaces on the skin, which is necessary for an adequate sealing of the system that leads to the achievement of the pressure and volume objectives.

According to Iglesias [5], the injuries associated with clinical devices are problems with a high prevalence that not only deteriorate the health of patients, but also prolong hospital stay. The incidence of pressure ulcers on the nasal bridge caused by interfaces for NIV administration is estimated to be over 17% [6].

In 2002, a prospective observational study was carried out at the Hospital General Universitario Morales Meseguer in Murcia with the aim of analysing the complications derived from noninvasive mechanical ventilation. The sample consisted of 45 patients who underwent noninvasive mechanical ventilation, 31.8% of whom developed pressure ulcers despite having taken preventive measures such as placing hydrocolloid dressings in 78.6% of cases: 58% of the ulcers were grade I, 21% grade II and 21% grade III.

The location of facial pressure ulcers is directly related to the type of interface used. The most frequent locations are the forehead, nose, cheekbones, nostrils and nasal septum. The area most susceptible to injury is the bridge of the nose due to the small amount of subcutaneous cellular adipose tissue it has adipose tissue. This, together with the fact that the most frequently used interface is the nasobuccal interface, with direct support in this area, means that it is the area where the most pressure ulcers related to noninvasive mechanical ventilation are most prevalent. On the other hand, the interfaces with less support in the nasal area and which therefore produce fewer lesions are the full facial and the helmet-scaffold or helmett®.

Inadequate choice of interphase type or size, excessively tight fastening, tubuludura tractions that are transmitted to the interphase and inadequate protection of pressure points together with poor skin hygiene and hydration are often the causes of such injuries [7].

The negative impact not only affects the health of patients but also the economy of the health system related to a large administration of pharmaceuticals. According to the literature, spending on medical devices related to pressure ulcers accounts for 5% of total health care spending in Spain [8].

Efficient nursing actions regarding pressure ulcer prevention reduce the incidence and recurrence of pressure ulcers.

The available evidence is scarce, outdated and of inferior quality, leading to a false consensus.

A review of the literature (eight studies less than 10 years old) reveals three main lines of research.

Of the eight studies reviewed, all but one of them recommended some form of pre-preparation preparation before applying the mask to the patient's face. Six of them proposed some form of wet dressing and only one of them proposed the application of hyperoxygenated fatty acids to the facial skin.

Regarding dressing recommendations, two of them do not recommend any specific dressing, two recommend the use of polyurethane foams and two recommend the use of hydrocolloid dressings.

One of the studies advised against the use of dressings to prevent pressure ulcers in patients undergoing NIV, since according to the authors, they may increase the pressure exerted by the interface on the pressure ulcers in patients undergoing NIV, because, according to the authors, they may increase the pressure exerted by the interface on the face and cause leakage, making it difficult to achieve pressure or volume targets.

It is therefore clear that there is a need to apply preventive measure on the skin of these patients to prevent pressure ulcers.

Regarding which of these preventive measures should be applied, there is variability in recommendations. Most authors indicate that some form of wet dressing is necessary, but there does not seem to be much evidence on the superiority of one over the other.

Only one of the studies introduced the possibility of using hyperoxygenated fatty acids for pressure ulcer prevention compared to direct application of the mask on the skin, hydrocolloid dressings and polyurethane foams. Surprising results were obtained, where hyperoxygenated fatty acids were shown to be clearly superior to dressings with respect to injury prevention.

Care During Treatment

- The water level in the humidifier as well as the correct functioning and set parameters of the fan must be checked continuously.
- To avoid increased airway resistance, it is essential to maintain correct alignment of the neck, which may be aided by the use of a soft collar.
- There are many aspects that nurses must review when caring for patients undergoing noninvasive mechanical ventilation, one of them being the level of interface leakage. Considering that the latest generation ventilators compensate for elevated levels of leakage, we can tolerate leaks of 15–25 bpm or up to twice the minute volume, always with the aim of achieving optimal pressure, volume and flow patterns beneficial to the patient and preventing complications associated with leaks such as eye damage. It is for this reason that all nurses must know how to place the diverse types of interfaces and the most appropriate way to do so, to avoid ocular leaks and to apply care in a systematic way to prevent such injuries and treat them if they occur.
- As mentioned in the previous section, the main focus of nursing care should be on skin and mucosal care, reapplying and checking the chosen products or dressings in each of the breaks every four hours and whenever necessary.
- Another important aspect is the monitoring of the occurrence of abdominal distension in relation to the high pressure parameters prescribed (with IPAP above 20 cmH_2O, the resistance of the upper oesophageal sphincter is overcome, resulting in abdominal distension with a risk of nausea and vomiting). If this occurs, a

nasogastric tube can be placed to reduce the risk of aspiration, but it will not be systematically placed in all patients.

- In the SEPAR (Spanish Society of Pneumology and Thoracic Surgery) manual on NIV [9], in the chapter entitled "Procedures in NIV of acute or chronic patients with acute illness," the importance of monitoring during NIV is discussed in order to provide control and surveillance of the clinical situation, providing safety and serving as a guide to adjust or correct, depending on the data obtained, the ventilation parameters and the rest of the treatment, thus achieving better results. Remember that no technology can replace good clinical observation, and that this can only be done if the nursing staff knows the technique and acts with dedication and speed in the correction and prevention of side effects.

That Being Said, What Parameters Should Be Monitored? [10]

1. All critical or semi-critical patients should undergo electrocardiographic monitoring, including all vital signs. Blood pressure is even more important because of the possibility of hypotension due to increased intrathoracic pressure, especially in cases of extremely high IPAP.
2. If available, transcutaneous capnography is an excellent method of determining PCO_2 without the need for invasive procedures and minimising patient venipunctures, thus increasing patient comfort and reducing infectious and thrombotic complications of the technique. An initial arterial blood gas measurement prior to treatment is necessary to determine the baseline situation and to base the choice of treatment and the parameters to be established on it. Since the variation of PCO_2 in venous and arterial blood is very small, the following blood gases once the pH has been corrected could be venous (at one hour, at four to six hours and prior to withdrawal of treatment). Whenever the patient's clinical situation changes, there is a worsening or a change of mode or of the prescribed parameters, it will be necessary to take a new sample every thirty minutes to one hour until stabilisation. This should always be assessed on a case-by-case basis. It is important to emphasise that there may be clinical improvement although not gasometric improvement, which is why it is more important in the first hour to reduce the respiratory rate than to improve PCO_2.
3. It is also important to assess and observe the oral tolerance of these patients, noting the presence of nausea and vomiting in relation to the gastric distension resulting from the treatment.
4. Either because of hypercapnic or hypoxaemic patients, we may find variations in the level of consciousness; therefore, it is recommended to pass the Glasgow Coma Scale at least three times a day and to check for variations.
5. As a result of treatment, interface, positioning, posture and many other factors, this type of patient can frequently develop pain, either chronic or acute, and the Visual Analogue Scale is a simple method to assess it, and any other method with which the nurse is familiar can be used.

6. We must not forget that these are respiratory patients, which is why respiratory monitoring must be closer. In this aspect, it is essential to assess the respiratory pattern, the presence of cyanosis, and dyspnoea scales such as the modified Borg Dyspnoea Scale can be used as a support. Despite its subjectivity, it is easily reproducible and accessible [11].
7. Just as important as observing the patient is observing the ventilator, as it provides us with up-to-date information on the patient's clinical situation, helping us therapeutically and prognostically and in many cases in anticipation of the blood gas assessment. It is vital that the machine and the patient work synchronously, not only for the ventilatory benefit but also for the greater patient comfort related to a higher probability of successful therapy. This level of adaptation between ventilator and patient can be observed not only by physical examination of the patient but also by assessing asynchronies in the pressure, volume and flow graphs. It is important to note that a very high percentage of these asynchronies are due to leaks, a factor in which nursing is of particular importance.
8. As mentioned in previous sections, the focus of nursing care in patients treated with noninvasive mechanical ventilation should be skin and mucosal care. It is essential to take scheduled breaks of five to fifteen minutes every four hours, taking the opportunity to remove the interface and reapply or change the products chosen to protect the skin (dressings or hyperoxygenated fatty acids). If drinking is not contraindicated, water should be given to patients during these breaks to reduce xerostomia due to the pressure that occurs in this type of treatment. In relation to pressure and leakage, and as mentioned above, dry eyes and even corneal ulcers are common, and to prevent these, artificial tears or epithelial ointments should be applied. A strategy to take into account in order to rotate the pressure points and reduce the complications associated with pressure is the rotation of interfaces according to the clinical condition of the patient. Whenever pressure lesions appear, they should be treated like any other lesion of this type, in which case the use of hyperoxygenated fatty acids should be discouraged.
9. Another complication of the pressure is otitis, which can be prevented by regular nasal lavage with isotonic saline.
10. To assess the cleanliness of the oral cavity, the Walt Scale can be useful, passing it at least five times a day, providing information not only on the hygiene of the mouth but also on the level of xerostomia mentioned above. Oral hygiene should be carried out every 6–8 h with a 0.12–0.2% chlorhexidine rinse and always with the head of the mouth elevated.
11. There are complications related solely and exclusively to certain interfaces that nurses should be aware of. This is the case of the risk of thrombosis of the axillary veins in relation to the use of the Helmett®, and the nursing staff must check the placement, position and adjustment of the interface fixation harnesses in a systematic way.

A 2016 study in patients with acute respiratory failure concluded a reduction in mortality, shorter ICU stay and reduced intubation rate when comparing the use of Helmett® with orofacial interfaces [12]. Despite this, its use is not widespread in Spain, partly due to the lack of training of nursing staff with this type of interface.

1. Checking the condition and correct functioning of the ventilators is also the responsibility of the nursing staff, which is why the circuits should be changed every seven days unless there are biological remains or malfunctions, and the filters every 24 h or after the administration of nebulised medication (in this aspect, vibrating mesh devices are recommended due to the greater bioavailability of the drug). The most appropriate way to clean the interfaces is with water and detergent, avoiding the use of bleach and other more aggressive products that can damage the silicone of the interfaces.
2. To avoid condensation in the tubing, the tubing should be positioned to prevent backflow to the patient, and the humidifier settings may be changed if condensation is very present.
3. The important role of patient comfort in the success of therapy has already been mentioned several times in this chapter, and it is essential that the patient is kept informed at all times of the process, integrating him/her in his/her care. To this end, it is recommended that alternative communication methods such as providing paper and pen, using pictograms are provided. In addition, relaxation techniques can be taught and conducted, always providing emotional support, and encouraging a good night's rest.
4. Finally, in this section, we should mention the possibility of aspirating secretions if necessary and collaborating in a multidisciplinary way in respiratory physiotherapy.

Specific Care in High-Flow Therapy

All the above-mentioned precautions are also applicable to patients undergoing treatment with high-flow therapy. Specifically, once the equipment has been checked and prepared, with special emphasis on the availability of an electrical outlet as some of the HFT devices do not have a battery, the interface should be chosen to occlude at least fifty percent of the diameter of the nares.

The care of these patients should focus on reducing and early detection of complications. It is important to take into account the main complaints of patients undergoing this treatment.

1. Discomfort in the nose
2. Discomfort from the cannulae
3. Paradoxical dyspnoea
4. Sensation of chest pressure
5. Lack of knowledge of therapy

6. Mobility problems
7. Claustrophobia
8. Intolerance

One of the potential complications of high-flow therapy as well as noninvasive mechanical ventilation is pneumonias. It is the responsibility of the nursing staff to clean the equipment to reduce the risk of transmission of microorganisms. Some specific high-flow devices such as the Airvo or Airvo2 require not only external cleaning but also high-level disinfection, and it is the nurses' responsibility to carry out such disinfection and to check that they are in good condition before connecting patients.

Specific Care of the Paediatric Patient on Noninvasive Mechanical Ventilation and High-Flow Therapy in Acute Respiratory Failure Situations

Introduction

The use of noninvasive mechanical ventilation in paediatrics has increased in recent years due not only to its proven efficacy in the treatment of both acute and chronic episodes of respiratory failure, but also because of its ease of use, its rapid implementation, its greater ability to provide patient comfort and the possibility of continuing treatment at home [13].

The efficacy of this mechanical ventilation system means that this option is becoming increasingly common in paediatric intensive care units, so that nursing staff require expert and specialised knowledge in the handling of the technique and the care necessary for its proper functioning, to resolve or reduce the complications derived from its management [14].

Over the last 15 years, the use of NIV has reduced the number of intubations and complications associated with invasive mechanical ventilation, but above all, it has reduced the length of stay in paediatric intensive care units.

The participation of nursing professionals in the management of patients undergoing NIV is of vital importance, as they are the ones who will be at the bedside during the entire process, observing any anomaly in the patient's condition during treatment, ensuring the proper functioning of the mechanical ventilator, preventing the appearance of pressure ulcers due to the use of the different interfaces and are responsible for providing comfort measures to the patient at all times.

The training of nurses in the application of NIV treatment will ensure the success of the technique. This training is necessary to be able to apply quality nursing care. It will be the Paediatric Emergency/Paediatric Intensive Care units together with the related Scientific Societies who will guarantee the adequate training of these professionals [15].

NIV in Paediatrics

Respiratory emergencies in the paediatric age group are one of the most frequent reasons for hospital admission, so early detection of situations of acute respiratory failure avoids preventable risks and even death. Early recognition, support and appropriate treatment can prevent them [15]. For this reason, it is vitally important that nursing professionals working in units where NIV is administered know the indications and contraindications of this ventilation system, the most up-to-date recommendations in related nursing care and are able to identify the needs and patterns that may be altered in order to be able to act on them and provide the paediatric patient with comprehensive quality care that guarantees their well-being.

At present, very few paediatric emergency departments have the appropriate conditions for initiating treatment with NIV in paediatric patients with acute respiratory failure, so it is used in these departments as a tool to stabilise the patient until subsequent transfer to the paediatric intensive care unit (PICU) or hospital ward, where the appropriate conditions are met for the safe management and subsequent follow-up of this type of patient. In the not too distant future, given the boom in the management of the technique, NIV could be used in paediatric emergency departments for the treatment of asthmatic patients of moderate severity [16].

The initiation of NIV in the acute paediatric patient can rarely be performed on the hospital ward except in specific cases due to overloading of the PICU due to seasonal endemic periods (bronchiolitis) or oncological or neuromuscular patients with acute or chronic respiratory failure that becomes acute during admission, as it is necessary to have properly trained staff capable of dealing with any problems that may arise. Ideally, intermediate care units should be available to ensure adequate treatment of such patients who require admission but do not meet the criteria for admission to the PICU [16].

The NIV in Acute Respiratory Failure (ARF)

NIV is a respiratory support modality that allows increased alveolar ventilation without the need for artificial access to the patient's airway, and therefore does not require an endotracheal tube. It is performed by means of positive pressure through distinct types of interfaces (devices that connect the patient to the ventilator) [15, 16].

NIV is used in the treatment of both acute and chronic respiratory failures.

Acute respiratory failure occurs when the lungs are unable to perform the gas exchange (oxygen/carbon dioxide) necessary to meet metabolic needs. Acute failure may occur in one or more phases of respiration (in the transport of oxygen to the alveolus, in the diffusion of oxygen across the alveolar-capillary membrane, during the transfer of oxygen from the lungs to the tissues or in the removal of carbon dioxide from the bloodstream to the alveolus for exhalation).

Acute respiratory failure can also be defined as the alteration of blood gas parameters measured in arterial blood, but these will not be determinant for the

establishment of an early and adequate treatment, which will depend more on the underlying cause and the clinical evolution of the child than on the blood gas values [15, 16].

ARF is more common in children than in adults because of their different physiology [15]:

1. They have a higher basal metabolic rate, which implies a lower metabolic reserve.
2. Neonatal breathing is irregular, so there is less response to hypoxaemia and hypercapnia. Their airways are smaller in diameter, so airflow resistance is greater.
3. The infant's thorax is more elastic and deformable, its respiratory muscles are underdeveloped and its ribs are horizontalised.
4. The diaphragm is shorter, and its type I muscle fibres are smaller, making them more prone to fatigue.
5. Alveolar septa exert traction on the airway and help to keep it open. In addition, the smaller number of alveoli per body surface area facilitates collapse, which, together with reduced collateral ventilation, predisposes them to atelectasis.

Clinical management should be based on two pillars: the treatment of the underlying disease and the administration of supportive measures for acute respiratory failure aimed at achieving acceptable arterial oxygen levels and pulmonary ventilation.

The benefits of noninvasive mechanical ventilation (NIV) in the child with ARF are increasingly recognised, although the evidence is still limited. It has been shown to improve the patient's symptoms [15, 16]:

1. It reduces the load on the respiratory muscles, stabilises the chest wall and improves minute ventilation.
2. Produces recruitment of collapsed alveolar units and increases end-expiratory lung volume.
3. Improves functional residual capacity and decreases the alveolar-arterial oxygen gradient.
4. Prevents (but does not replace) endotracheal intubation.
5. Improves gas exchange while the process that led the child to the ARF is resolved. Child to the ARF.

There are also a number of drawbacks or complications that will limit its use, generally all of them mild, related to the interface: the appearance of irritative conjunctivitis secondary to leaks, skin ulcers due to support and facial deformities; related to humidification of the system: nasal and pharyngeal dryness, mouth breathing and related to ventilation: high pressure, gastric distension (which can favour vomiting and aspiration), hypercapnia and rarely, pneumothorax [15, 16]. Some children are anxious about mask placement, which may hinder correct positioning and subsequent efficacy. The efficacy of NIV should be assessed according to the

appearance of agitation, worsening respiratory distress or gas exchange, all of which are signs of failure of the technique. If, on the other hand, there is a decrease in respiratory rate, this is an early sign of success [15]. Determining whether NIV will fail is difficult but particularly important. The best predictor of failure is high oxygen requirements on admission ($FiO_2 > 0.6$) and initial PCO_2 and within hours of initiation of ventilation. The pathology with the highest failure rate is acute respiratory distress syndrome [15]. On the other hand, high-flow oxygen therapy systems have recently been introduced in paediatric units. They are a simple technique and evidence of their efficacy in neonatal and paediatric practice is beginning to emerge [15].

Indications and Contraindications for NIV in Paediatrics

Indications for NIV [16–18]

1. Decompensated obstructive pulmonary diseases: asthma, cystic fibrosis, bronchiolitis, upper airway obstruction.
2. Decompensated restrictive diseases: chest wall and spinal deformity (congenital, achondroplasia, kyphoscoliosis), neuromuscular diseases (infantile spinal atrophy, Guillain-Barré) and obesity-hypoventilation syndrome.
3. Parenchymal diseases: acute respiratory distress syndrome (ARDS) of the newborn, pneumonia, tracheomalacia, pulmonary fibrosing diseases.
4. Cardiogenic alterations: heart failure, acute oedema of the lungs.
5. Other causes: pulmonary complications of sickle cell anaemia, apnoea after adeno-tonsillectomy, postoperative scoliosis surgery, ventilator weaning, situations requiring high oxygen intake (sepsis, shock, anaphylaxis) and severe respiratory failure in terminal illness (palliative).

In paediatric patients with asthma, the administration of NIV acts as a bridge between the effect of pharmacological treatment and the use of invasive mechanical ventilation. It reduces bronchospasm, acute lung damage, barotrauma, pneumonia and cardiovascular instability that can result from invasive ventilation.

Patients with neuromuscular disorders (spinal muscle atrophies, myasthenia gravis, congenital myopathies and muscular dystrophies) do well undergoing NIV by decreasing the work of the respiratory muscles, increasing carbon dioxide sensitivity and decreasing sleep disturbances. Obstructive sleep apnoea is one of the main indications for NIV when tonsillectomy does not achieve the expected results. ARDS is one of the most frequent problems that occur in the neonate due to lack of lung maturation, with the incidence increasing the younger the gestational age. Thanks to the use of ventilatory support, it is possible to treat and increase the survival of neonates suffering from this pathology.

Contraindications to NIV [16, 17]

When considering treatment with noninvasive ventilation in paediatric patients, different parameters that may contraindicate it must be assessed, such as: age, the type

of respiratory system dysfunction, the presence of cardiorespiratory instability or the clinical condition of the child.

It is contraindicated in patients with established haemodynamic instability and the child must be stabilised first, which may result in sedation and intubation of the patient for better haemodynamic control. Other fundamental contraindications for the use of NIV are related to the inability to adequately protect the patient's airway, as in the case of patients with neurological disorders, incoercible vomiting, severe swallowing disorders or the inability to mobilise secretions.

It is also contraindicated when there is physical limitation for interface placement (due to facial deformity or trauma), if there is severe fixed airway obstruction, if the need for ventilation exceeds 16 h/day, in cases of previous pneumothorax, or when IV offers increased patient survival.

Extreme anxiety or lack of cooperation from the patient during treatment as well as lack of family support are reasons to contraindicate the technique.

The lack of education and training of the personnel who manage NIV in paediatric patients is an absolute contraindication for this type of treatment, as its success cannot be guaranteed if they do not know how to administer the quality and highly specific care that it requires.

Treatment with a High Level of Safety and Efficacy

The first thing to assess in a child with signs and symptoms of ARF is the urgency of taking measures such as the need for intubation or noninvasive respiratory support [15]. This decision should be made by the responsible physicians within the first few minutes after close monitoring of the child, assessing whether spontaneous breathing is present and whether the airway is patent.

Once the decision has been taken to treat the patient with NIV, the environment will be adapted and the different actions necessary to receive and treat the patient will be coordinated.

The patient (if the patient's age permits) and family will be informed about the technique to be performed, providing the calmest possible environment, providing confidence and security in order to obtain a constant assessment of tolerance and response to ventilatory therapy. Patient tolerance will be directly related to good patient participation, so it will be essential to provide clear and understandable explanations for each age range, supported, if necessary, by drawings or other multimedia formats that allow the paediatric patient to understand the treatment to be applied [13].

Pre-nursing Care Prior to the Start of the First Year of Life

An assessment of the patient's condition prior to the introduction of NIV shall be performed in order to be able to evaluate the impact of this ventilation modality on the patient. It shall consist of:

1. Monitoring and recording of vital signs: blood pressure, heart rate, respiratory rate, oxygen saturation.
2. Venous or arterial blood gas sampling in order to subsequently assess the effectiveness of ventilation.
3. Record the presence or absence of pain, the general condition of the child, the abdominal diameter; if there is a cough and its effectiveness; if there are skin lesions, with emphasis on those on the face and, if present, assess the degree to which they are present; assessment of the patient's state of hydration, both systemic and tissue; recording whether there are signs of conjunctivitis, muscular fatigue (such as tachycardia, tachypnoea, sweating, dyspnoea, cyanosis or the use of accessory muscles).
4. The patient will be placed in their bed or cot, the need for restraint and safety measures (bed or cot bars) will be assessed and the patient will be placed in the position that optimises their respiratory effort and provides the best degree of comfort and safety. This position is the semi-sitting or semi-Fowler position with the neck in a neutral position, the trachea aligned with the trunk, the legs semi-flexed and the feet at 90° on a plane. The upper limbs should be in a neutral position, slightly separated from the body. This posture facilitates relaxation of the abdominal muscles and allows wider diaphragmatic movements with less effort [19, 20].
5. Depending on the age of the patient, different supports or cushions can be used to maintain the most appropriate posture to provide the best comfort for the child while providing effective ventilatory therapy. In infants, bracing can be used on both sides of the face to centre the head in a neutral position, a cervical support will prevent flexion of the neck over the thorax, but it must be taken into account, especially in young children, that excessive cervical extension may compromise the opening and therefore the patency of the airway [18].
6. Check that the treatment orders correspond to the patient who has to undergo NIV and that there are no contraindications to undergo NIV.
7. Maintain the patient on the previous oxygen therapy for the duration of the preparation of the device.
8. Ensure the presence of patent vascular access for sampling or drug administration as prescribed.
9. Check the patency of the airway, aspirating secretions if required.
10. The skin of the areas that will be in contact with the interfaces and the harness shall be prepared. These areas shall be subjected not only to pressure and friction, but also to the action of moisture and heat.
11. Adequate hygiene of the mouth, nostrils and eyes shall be carried out prior to the start of treatment and routinely thereafter. The areas under pressure should be hydrated with hyperoxygenated fatty acids. It is advisable to apply hydrocolloid dressings in these areas to prevent pressure ulcers if necessary.
12. The need for a nasogastric tube should be assessed to allow gastric emptying on an ad hoc basis or, if it is decided to leave a permanent tube in place, to fix it appropriately.
13. The assembly and operation of the ventilator shall be checked. Where available, a dedicated ventilator is the ventilator of choice, which will give better results

due to its higher trigger sensitivity and leak compensation [16], although conventional ventilators with NIV mode can also be used.

14. The ideal interface is one that is comfortable, light, transparent, adaptable to the facial morphology of each patient, easy to fit and remove, with reduced dead space, which is easy to secure and allows an adequate seal without exerting excessive pressure. It is recommended that it be fitted with an anti-asphyxia valve and prevent rebreathing or re-inhalation of carbon dioxide. It should be hypoallergenic, inexpensive, disposable or easy to clean [14, 17, 20].

An excellent choice of interface is directly related to the success of NIV as it promotes patient comfort and tolerance. There are several types, so it will have to be individualised in each case, considering the resources available and the types of ventilators. In addition, the characteristics of the patient (age, facial anatomy), as well as their condition (if they are conscious, cooperative), or if it is an acute or chronic process, will also be taken into account.

The available interfaces are nasal (covering the nose), nasobuccal (covering the mouth and nose), facial, full facial (covering the whole face) and *helmet* type (covering the whole head). In the case of neonates or infants under 5 kg, nasal pillows, or pillows (incomplete nasal) are used [21].

In paediatrics, the bucconasal interface is the interface of choice in the acute phase or when NIV treatment is first initiated [16]. although full nasal prongs are extremely popular because they are easy to fit, are well tolerated and, unlike in adults, can be used in situations of acute respiratory failure with optimal results [21]. There are varied sizes and varied materials (silicone, gel, rubber). Most of the existing ones are made of silicone, but the gel ones, being modellable, allow a better coupling. Incomplete nasal pillows or nasal pillows are especially useful in patients who have not tolerated oronasal pillows or complete facial pillows, in patients with skin lesions around the nose and, as already mentioned, in neonates.

The Helmet system is rarely used in paediatric patients, because although it requires less cooperation from the patient and is more comfortable for them, it has more dead space and generates greater claustrophobia.

It is important to choose a cap size that is the correct size for the patient's head to avoid injury. In the case of neonates and smaller patients, this should be based on weight, length and head circumference [18].

Nursing Care During NIV Therapy

Once the patient is prepared, the selected interface is fitted. This process is preferably conducted by two people (whenever possible). The ventilator will be switched on and already programmed by the physician. First, the headgear is placed in the correct position starting at the back of the head and bringing the interface over the patient's face. A first hold is made with the practitioner's hands, giving the patient room to adjust. In a second phase, the straps of the headgear or cap should be adjusted to allow the interface to fit properly. The pressure of the headgear on the

mask should be evenly distributed, so it is advisable to tighten the headgear straps crosswise rather than on one side of the face. Lateral displacements of the interface should also be monitored to avoid, as far as possible, an increase in pressure at any point between the anchorages and the support areas of the interface.

- The patient's adaptation shall be checked to ensure that he/she is comfortable, and any leaks shall be checked. An initial monitoring of the patient's vital signs shall be performed after the start of the procedure [20].
- Once NIV therapy has been instituted, close monitoring of the patient should be maintained; records should be made of time of initiation, duration of treatment (if previously established) and the care that has been provided throughout the process.
- The monitoring of vital signs will be continuous, being of vital importance during the course of the first hours in which it will be possible to assess how the patient is adapting to the therapy and how it is achieving its objectives. In this way, the ventilator parameters can be readjusted, correcting the positioning of the interface and harness, if necessary, in order to avoid possible leaks or modifying the patient's posture according to its efficacy and degree of comfort. Reduction in respiratory rate and improvement in pH as well as PaO_2/FiO_2 ratio 2 h after treatment are key markers of response to the technique [16].
- The correct functioning of the ventilator shall be monitored, and the tubing, connections, humidifier, interface and harness shall be properly maintained by periodic cleaning with sterile water; the anti-suffocation valve shall be checked, and the filters shall be replaced at least once per shift.
- The interphase should be changed every 4–6 h and, according to some recommendations, the type of interphase should be rotated at least twice a day, in order to exchange areas of support and therefore also of pressure, minimising the appearance of lesions, which are more frequent in exceptionally low birth weight newborns. The interphase should be changed by cleaning the support area and placing the new one in the same position to avoid pressure points in other areas that could cause damage. Even if the interface is not changed so frequently, it is advisable to moisturise the area by administering creams and hyperoxygenated fatty acids at each constant monitoring or the necessary intervention on the patient in order to maintain a close monitoring of the skin. This is especially important in neonates to avoid deformities and lesions.

Dressings can also cause damage to the skin of patients, especially neonates, which is even more delicate. Dressings should be changed every 12 h.

- Abdominal distension is also a parameter to watch for during the monitoring of the patient undergoing NIV, because the accumulated air at the digestive level causes discomfort and discomfort due to the elevation of the diaphragm, which hinders breathing and thus the goal of positive pressure ventilation therapy. It can also cause nausea and vomiting for which it is sometimes necessary to place a

nasogastric tube to relieve abdominal distension. The patency of this tube should be checked periodically.

- If not contraindicated, patients on NIV therapy can maintain adequate enteral feeding. The most appropriate nutrition should be chosen in each case if the patient is a neonate (tube, bottle or breastfeeding). It is preferable to disconnect the NIV at the time of feeding. If the patient's situation does not allow disconnection, placement of a nasogastric tube for enteral nutrition would be indicated.
- Routine monitoring of airway patency is recommended for effective ventilation. In the case of the smallest patients, it is recommended that checks be made every 3h, trying to coincide with feedings to avoid excessive manipulation of the neonate [18]. In many cases, the loss of patency is due to the accumulation of secretions in the upper airways, for which the introduction of a probe connected to a vacuum system is recommended, which, introduced through the nose or mouth, aspirates the contents that are obstructing the airway. It is advisable to moisten the nostrils beforehand with physiological saline solution in order to fluidify the secretions and make them easier to remove. This technique is an invasive process that is uncomfortable for the patient, entails a risk of bronchoaspiration, mucosal lesions, episodes of desaturation, etc., and should therefore be performed only when strictly necessary.
  - One way to minimise airway obstruction by secretions and to keep the patient's mucosa hydrated in order to avoid injury is to maintain the ventilation system at a good humidification and temperature (around 37 °C). The presence of water in the tubes or any other obstruction in the system may be due to over-humidification, which can cause difficulty in airflow and increased resistance. Conversely, a lack of humidity will dry out the patient's mucosa, facilitating the formation and accumulation of secretions that will become increasingly dense, becoming more difficult to eliminate and increasing the risk of infection, making the objective of the therapy more difficult.
  - Maintain proper ocular hygiene and hydration, especially in patients wearing a full face mask. Physiological saline solution should be used for routine cleaning, and artificial tears should be administered to maintain hydration. It is important to check that the interface is properly secured, as air leakage over the conjunctiva can lead to irritative conjunctivitis [20].
  - The use of a dummy should be avoided during the application of NIV with a face mask, as in the event of vomiting, this would be an obstacle that would add to the difficulty of eliminating the contents that accumulate in the mask. On the other hand, in acute respiratory failure, breathing is mainly mouth breathing (gasping) and therefore, the use of a dummy will significantly limit the child's ventilatory capacity. However, this device can be especially useful when nasal interfaces are used, as it contributes to improve pressure control by reducing air leakage through the neonate's mouth. On the other hand, it is a great analgesic measure as an alternative to breastfeeding and kangaroo care when the mother is not at the patient's bedside and is a crucial factor in reducing the risk of sudden infant death [21].

- Postural changes should be made periodically, as a recommendation every 3–6 h to avoid the appearance of pressure ulcers, which would generate an extra complication to the patient's original process and could cause an accessory infection pathway [18].
- Situations that may cause stress in paediatric patients should be reduced as far as possible by providing them with a calm and comfortable environment, avoiding noise, alarms, lights, the tone of conversations, etc., and paying attention to any postural or thermal discomfort, etc., resorting, if necessary, to the administration of analgesia and/or sedation [18, 19].

It is important to provide paediatric patients with elements or situations that make them feel protected (their favourite doll, their sleeping blanket) and keep them distracted (talking about their favourite football team, their favourite children's series). During therapy, the effect of the permanent or occasional presence of the family will be assessed, depending on their degree of anxiety and collaboration and the impact it has on the patient's condition [18].

It is also interesting, depending on availability, to have at their disposal entertainment media appropriate to the age and situation of each child, such as TV, films, games, reading... and when available, to request the presence of specific personnel such as teachers, members of children's associations that collaborate with paediatric hospitals.

Noninvasive Home Mechanical Ventilation for Patients with Chronic Respiratory Failure

Over the last 15 years or so, the use of noninvasive home mechanical ventilation has become widespread, largely due to medical and technological advances that have contributed to increased survival of critically ill patients, better diagnosis and knowledge of diseases with increased upper airway resistance or central and/or peripheral hypoventilation, the new development of easy-to-use devices adapted to home treatment, the ageing population and the increased incidence of chronic diseases such as COPD and obesity [22, 23].

The increase in NIV prescribing may also be since medicine is increasingly considering aspects other than patient survival, such as quality of life [24]. The term "health-related quality of life" (HRQoL) is an individual's multidimensional assessment of the impact of illness on his or her own life. It includes personal aspects such as health status, autonomy, independence, life satisfaction or beliefs, and environmental aspects such as support networks or social services. The assessment of HRQOL is important because it allows us to know and treat our patients better. There is sufficient evidence in the literature linking home NIV with an increase in HRQOL.

Another interesting aspect of home NIV is the economic aspect. Although it is difficult to establish its exact cost due to the variability of the causative pathologies that make different resources necessary for each patient and the various sources of funding, it is generally accepted that the implementation of home NIV saves costs for

administrations. Home ventilation can be performed with positive pressure either invasively through a tracheostomy or noninvasively. It can also be performed with negative pressure thanks to the implantation of a diaphragmatic pacemaker in patients with hypoventilation of central origin, usually caused by spinal cord injury. Ventilation through tracheostomy has advantages such as reducing dead space and airway resistance, facilitating drainage of secretions, and allowing long-term ventilation. But it also has associated complications such as increased patient complexity, risk of potentially serious complications, reduced quality of life or impaired phonation. This, together with the development of new systems, has led to a growing preference for NIV.

The objectives of home-based NIV are [22, 24]:

1. Improve gas exchange by correcting alveolar hypoventilation, decreasing work of breathing and improving respiratory muscle function.
2. Prolonging survival.
3. Improve the quality and duration of sleep.
4. Improve quality of life and functional status.

Indications

Consensus criteria for the indication of home NIV were established in 1999 [22, 23, 25]. These are:

- In neuromuscular diseases, presence of clinical symptoms such as dyspnoea, morning headache or daytime hypersomnia associated with the presence of physiological criteria such as hypercapnia in baseline arterial blood gases, nocturnal desaturations with SpO_2 below 88% for 5 or more consecutive minutes, peak inspiratory pressure below 60 cmH_2 or forced residual capacity below 50% of baseline.
- In patients with COPD, hypercapnia above 55 mmHg or in the range 50–54 mmHg with nocturnal desaturations below 88% for at least 5 min and frequent exacerbations with respiratory acidosis (more than two in the last year). The pathologies for which home NIV is most frequently prescribed are: neuromuscular diseases such as ALS, Duchenne disease or myotonic dystrophy.
- Diseases of the rib cage such as kyphoscoliosis.
- Hypoventilation syndromes such as hypoventilation-obesity syndrome or congenital central alveolar hypoventilation.
- COPD in the stable phase (controversial use and only in selected cases). In any case, the decision whether or not to indicate NIV should not be based solely on clinical criteria but should also consider the patient's environment and willingness or, if necessary, also that of the caregivers. So much so that lack of motivation and lack of social and family support are considered relative contraindications for home NIV.

Another factor to take into account is age. Some authors consider that its indication beyond 75 years of age is not appropriate, but there are many studies that show that

in these patients, it produces a gasometric improvement, reduces nocturnal desaturations, the number of hospital admissions and their duration and therefore improves quality of life [22]. For its indication in palliative care, the wishes of the patient and family must be taken into account, ensuring that they have received all the information necessary to make the decision.

Contraindications to Home NIV

- Absolute: complete airway obstruction, very abundant secretions that cannot be cleared, lack of patient cooperation or inability to maintain interface.
- Relative: significant impairment of swallowing, lack of cooperation from family or caregiver or need for continuous ventilatory support.

Complications of Home Nursing

They are the same as those for noninvasive mechanical ventilation in acutely ill patients.

1. Irritant dermatitis secondary to pressure of the interface on the support points. This can progress to pressure ulceration. A strategy of interface rotation combined with the use of hyper-oxygenated fatty acids or moist wound dressings is useful to prevent pressure ulceration.
2. Irritative conjunctivitis related to air leakage into the eye. Leakage at this level should be prevented as far as possible by correct adjustment of the interface and hygiene and hydration of the eye, if necessary, with artificial tears. Patients with poor ocular occlusion are especially at risk and may require eye shields to allow vision.
3. Gastric distension due to opening of the upper oesophageal sphincter at pressures greater than 25 cm H_2O or 20 cm H_2O in neuromuscular patients. Nasogastric tube placement may be necessary.
4. Food aspiration, especially in patients with dysphagia and in nasogastric tube carriers. It is advisable to allow a period after ingestion or intake of enteral nutrition before restarting ventilation.
5. Related to humidification, nasal mucosal alteration and mucus plug formation may occur, which can lead to airway obstruction [26].

Necessary Equipment

The equipment that patients should have at home will be [22–24]:

- Respirator. Ideally, it should be simple, quiet, lightweight and have alarms. In patients who require therapy for more than twelve hours a day, they should also

have a spare. It should have at least anti-bacterial, pollen and dust filters to ensure the quality of the air supplied to the patient. The tubing should be anti-collapsible, of low distensibility and of a standard length of two metres and a diameter of 15–22 mm. It is also recommended that they be equipped with downloadable software systems to facilitate therapy monitoring.
- Interfaces and restraint systems, plus a submental band if required.
- Pulse oximeter. It should be simple, reliable, easily transportable and with acoustic alarms.
- Secretion aspirator with adjustable suction pressure.
- Assisted cough devices. They favour the expulsion of secretions and are especially useful in cases of neuromuscular pathologies.
- Humidification. The need for this will be assessed on a case-by-case basis.
- Oxygen therapy devices if required by the patient.

Interface

The ideal interface should be easy to put on and take off, light, soft, made of breathable, transparent, washable material and available in several sizes. To increase patient safety, it is recommended that all of them are fitted with an anti-suffocation valve.

In addition to the choice of the interface, it is equally important to choose a suitable anchorage system. It should be stable, easy to put on and take off, non-traumatic, light, soft, washable, breathable, and available in several sizes. To fix it with adequate but not excessive tension, it should be possible to pass two fingers between the sling and the skin [23, 26, 27].

Team Responsible for Assistance

The control and follow-up of these patients is complex, requiring multidisciplinary management by specialised units that can provide their services if necessary, moving to the patient's home. This will have a positive psychosocial impact on the patient and family and a positive economic impact on the health care system. For home NIV to be carried out successfully, it is not only necessary to have the technical means. It is crucial to train and educate the patient, family and caregivers about the pathology, management, and control of NIV equipment and associated techniques, possible complications, recognition of worsening of the underlying pathology and emergency situations. In addition to all this, there must be an adequate psychosocial assessment and support, assessing the family environment, home, economic needs (financing and aid) and social support. Ideally, the patient and family should be cared for by a multidisciplinary team consisting of at least a pulmonologist, an intensivist, a nurse, and a physiotherapist specially trained in noninvasive ventilatory therapies. This team should be properly coordinated with the primary care team responsible for the patient [23].

Start of Treatment

Therapy can be administered in hospital or in the patient's own home. Some authors argue that home-based therapy has some advantages, such as being cheaper and having shorter waiting lists than hospital-based therapy and has not been shown to result in poorer compliance with the prescription. On the other hand, hospital-based treatment allows for better observation and monitoring of the patient. It is also more practical, because its prescription is usually decided after the resolution of an acute process that has required hospitalisation, which means that the patient is already admitted to hospital.

Ideally, treatment should begin in a service with the appropriate material, personal and technical resources. A 3–5 days admission is usually required, during which the necessary parameters will be optimised and during which the family and the patient will have the opportunity to familiarise themselves with the therapy, the interfaces and their management, the most common problems or side effects and to learn how to solve them. The first step is to choose a suitable ventilator, tubing and interface for the patient, taking into account the patient's physiognomy, degree of mobility and available equipment. Initially, if the patient's condition permits, therapy should be started for short periods of time and at low pressures, even if these are lower than those required by the patient. This, although it may produce ventilation that is not entirely effective, makes it more comfortable at the start and avoids subsequent rejection of the technique. Sometimes it will be necessary to start with a CPAP mode and when the patient becomes accustomed to the continuous airflow, progress to BiPAP mode. The ramp should also always be used during adaptation. Subsequently, its use or non-use will be maintained on an individual basis. When the appropiate settings have been reached, the patient is comfortable and the SpO_2 relative to baseline (with or without supplemental oxygen) is maintained above 94% for at least 30 minutes, an efficacy arterial blood gas measurement should be taken. It is recommended that therapy is started with the same equipment that the patient will later take home [22–24, 27].

Other Aspects to Assess Before Discharge Home

To ensure continuity of care and patient follow-up, coordination of the hospital noninvasive mechanical ventilation team with the primary care team responsible for the patient is necessary. The primary care physician responsible for the patient should be informed of the patient's situation and agree with the primary care physician how the patient will be monitored and the responsibilities of each physician. The nurse in charge should also be contacted, informed of the nursing care required and provided with a list of the equipment and drugs that the patient will need.

Depending on the autonomous community, the responsibility for providing consumables for home NIV will fall on the primary care centre, on the hospital ventilation unit or on the company supplying the equipment. Most commonly, it is the

responsibility of the supplying company, which will also carry out maintenance of the equipment and training of patients and caregivers.

Patients should contact the electrical companies to inform them of the need for the use of respiratory support equipment dependent on electrical power. The patient should have a list of emergency telephone numbers at home to resolve any problems that may arise and a complete and always up-to-date report of the type of ventilator, the prescribed parameters, the name and telephone number of the company supplying the equipment and the telephone number of the monitoring team at the hospital.

Before discharge, we must have ensured that

1. The patient is completely stable.
2. Both patient and caregivers are motivated and adequately trained and prepared.
3. The necessary means and equipment are available at home.
4. Appropriate medical follow-up and 24-h technical assistance are assured.
5. Psychological support for patients, relatives and carers [22, 23].

Effectiveness and Compliance Monitoring

To monitor efficacy, we must assess the patient's symptoms, blood gas status and nocturnal pulse oximetry. If there is intolerance, we should inquire about its causes in order to try to solve them. For clinical monitoring, we should ask the patient about the improvement or not of the symptoms he/she presented prior to the introduction of home NIV (morning headache, daytime sleepiness, fatigue, dyspnoea, etc.), satisfaction with the therapy, quality of sleep and comfort of the interface and support harnesses.

Measurement of arterial blood gases is considered the Gold Standard for assessing the efficacy of NIV. It should be performed whenever there is a deterioration in the patient's condition or when changes in ventilator parameters are made. Its purpose is to determine changes in $PaCO_2$. Despite this, nocturnal transcutaneous $PaCO_2$ measurement is increasingly being introduced as it is more comfortable for the patient and better reflects the situation during sleep.

Pulse oximetry will also be useful to assess SpO_2 during sleep, with the limitation of its low specificity, which means that it does not differentiate the cause of the same. Other tools that can be used to monitor efficacy are nocturnal capnography or polysomnography.

Compliance monitoring will be done by analysing the information provided by the ventilator software [22, 23, 27, 28].

Follow-Up of Patients

The first follow-up consultation will take place in the home NIV monographic consultation. It will assess the symptoms of alveolar hypoventilation, any technique-related problems the patient may have encountered, review compliance and treat

any complications (interface-related discomfort, pressure ulcers, leaks, dry mucous membranes, eye discomfort).

In the case of patients with neuromuscular diseases, aspects such as the degree of nutrition, functional deterioration, secretion management (it may be necessary to introduce the use of mechanical cough aids, humidifiers if not already in use, or to reinforce the technique of secretion aspiration) and to assess the need to switch to invasive ventilation through tracheostomy when the time comes. In these patients, it is also necessary to take care of the caregiver and establish therapeutic limits with them through successive visits.

The second consultation will take place three months after the first and subsequent consultations will be carried out according to the needs and characteristics of the patient and the pathology, but usually every 6 months. Consultations should also be performed whenever ventilator parameters are modified [22–24, 27].

According to the SEPAR manual on noninvasive mechanical ventilation, the role of nursing in the follow-up of patients undergoing home NIV is aimed at [27]:

- Check that everything is in accordance with the discharge report or later.
- Increase compliance.
- Detect all those problems or doubts that have arisen in the home. Prevent and assess the possible existence of undesirable effects.
- Check respirator compliance and ventilation efficiency.
- Family and carer support.
- Assessment of the caregiver and the social environment.

Complementary Techniques

Management of Secretions

This will be done by manual or instrumental management techniques and secretion suctioning. Manual techniques aim to generate flows at different lung volumes to bring secretions closer to the upper airways so that the patient can cough them out. Before discharge from hospital, a physiotherapist should assess the patient and instruct the patient or caregivers in these techniques. Instrumental techniques will require oscillating and non-oscillating positive expiratory pressure devices, intrapulmonary percussive ventilation or external high-frequency chest wall oscillation-compression devices, depending on the pathology and characteristics of each individual, as some of them require the patient's cooperation and a minimum degree of muscular strength.

Manual Assisted Cough Techniques

Indicated to improve coughing efficiency in patients with neuromuscular diseases in whom the peak flow of spontaneous coughing is diminished. Requires patient cooperation. It requires a mechanical device applied to the patient via an oronasal interface that generates a positive pressure followed by a negative pressure alternately, causing secretions to move from distal to proximal airways. The programming of the equipment should be done on an individual basis by the physiotherapist responsible for the

child's care, who in turn will be responsible for instructing the family and caregivers in its management. Mechanical cough support will be provided three times a day and whenever there is an increase in secretions or desaturation due to secretions.

Caregivers should be carefully instructed in the technique. Negative pressures of 120–150 mmHg in adults, 80–120 mmHg in adolescents, 80–100 mmHg in children and 60–80 in neonates are recommended. Insertion of the tube should be shallow, and each aspiration should not exceed 15 s to avoid injury from vigorous aspiration.

The technique should be applied as aseptically as possible, and it is recommended that the probe be discarded after each use or at least cleaned internally by aspirating double-distilled water and externally with alcohol and discarded after 24 h of use.

Inhaled Medication Delivery

Drugs can be administered by pressurised cartridge inhalation devices known as pressured metered dose inhaler (MDI) or by nebulisation using different methods. All of them require an adapter to be placed on the tubing (on the inspiratory branch in the case of a dual-branch ventilator), which should always be placed as close as possible to the interface to prevent drug leakage. For the administration of nebulised medication, there are several systems available on the market:

- Jet type: Requires an oxygen source capable of delivering high oxygen flows (6–10 L/min).
- Ultrasonic: These work by generating sound waves that vibrate a piezoelectric crystal at a high frequency. This converts the liquid into a cloud of micro-droplets that is pushed into the patient's airway by the flow generated by the ventilator. They are used for the administration of saline or bronchodilators. Suspensions and antibiotics should not be administered by this system, as it generates heat, and the drugs can be denatured.
- Vibrating mesh: These consist of a membrane with microscopic holes and a vibrating element that pushes the medication through the holes, generating an aerosol. They are smaller, less noisy and less heavy than all the above. They achieve greater drug deposition and better adherence to treatment, as they take less time to nebulise. Whenever aerosols are administered, there is always a risk of bacterial contamination due to poor cleaning, which increases the risk of respiratory infection. Therefore, it is necessary to insist on proper cleaning of the equipment after each use according to the manufacturer's instructions. The choice of one medication delivery system or the other will depend on the patient and the drug, as not all are available in both presentations.

Oxygen Therapy

In some pathologies, in addition to NIV, oxygen supplementation via tubing or ventilator connections is necessary. There are several sources of oxygen suitable for home use:

- Static concentrator: Concentrates oxygen from ambient air. They need to be permanently connected to the mains. The normal ones achieve flows of up to 5 L/min, but there are high-flow concentrators on the market that can reach 10 L/min.

- Oxygen in cylinders or bullets.
- Liquid oxygen stored in a container called a dewar.
- Portable concentrator: Unlike the static concentrator, it has a battery, which allows the patient to leave home. But it only reaches flow rates of 2–3 L/min.

Noninvasive Home Mechanical Ventilation for Paediatric Patients with Chronic Respiratory Failure

Situation of Home Care in Paediatric Patients

In 2012, a multicentre study was conducted in Spain [28] that analysed the characteristics of children requiring home ventilatory support (both invasive and noninvasive) and their social supports and resources. According to this study, the mean age of initiation of home NIV is 5.9 ± 4.5 years. Regarding the daily time of NIV, the mean was 9 ± 2.8 h distributed at night and allowing the child to do without it during the waking period. This is because up to a quarter of paediatric patients requiring home NIV do so for OSAHS.

Home NIV has a major impact on the functioning of the family unit, since in 98% of cases, home care is entirely the responsibility of the family. Only 3.4% of families have health personnel at home to provide this care.

In 2012, 72.1% of children with home invasive mechanical ventilation in Spain were in school, 93.9% in adapted schools and 6.7% at home. The remaining 26.9% were unable to attend school due to their pathologies. In our environment, the figure of the school nurse is becoming increasingly common in schools, but the presence of health personnel who collaborate with educators to enable the schooling of patients with special needs is still insufficient. The presence of school nurses in schools is beneficial both for children with chronic illnesses and for parents and teachers. For parents, they provide reassurance and security and for teachers, they are a great support, especially in emergency situations.

Objectives of Home-Based Care

In addition to the objectives mentioned above in the chronically ill adult patient, NIV in the paediatric patient aims to enable the child's schooling [29].

Indication of Home NIV

Five factors must be considered for the indication of home NIV [23, 30]:

- Pathology causing chronic respiratory failure (neuromuscular diseases, metabolic diseases, anomalies of the airways, rib cage or lungs, ventilation control disorders).

- Patient and family motivation. It is necessary that the patient and their caregivers are aware of the disease, prognosis, therapeutic possibilities and risks and complications of NIV. They must also have the minimum intellectual capacities necessary to learn how to use the equipment. A high degree of involvement of the team is also important, which will transmit security and confidence to the family.
- Assessment of the family's economic and social resources and housing conditions.
- Clinical situation of the patient. Unlike in adults, in children, there are no validated criteria on when to indicate home NIV. It will be indicated if there are symptoms of hypoventilation or sleep disturbances (morning headaches, daytime hypersomnolence, enuresis, nightmares, etc.), gasometric alterations (pCO_2 greater than 45 mmHg in wakefulness or SpO_2 less than 88% for more than 5 min at night), severe alteration of pulmonary function, frequent hospitalisations due to respiratory causes, if hypoxia and hypercapnia are refractory to other treatments such as physiotherapy or bronchodilators and if there are no contraindications for NIV.
- Clinical stability. It will be necessary that continuous monitoring is not required, an stable airway, the absence of severe dyspnoea, and yhe stability of the other organs. The contraindications for therapy are the same as those for adult patients.

Complications

In addition to the complications found in adults, we must pay special attention to the possible appearance of malar hypoplasia due to the pressure of the interfaces on the developing cartilaginous mass in children under 8 years of age. To avoid this, it is useful to rotate the interfaces, including the use of the total face [30].

Interface

There are important limitations on the choice of interface in children, especially in the youngest, but the industry is constantly developing new tools. Therefore, professionals must be in contact with the companies in the sector, in order to be aware of the possibilities available on the market that can best suit our patients. The most commonly used interfaces in home NIV in paediatric patients are the nasal interfaces, because they are relatively more comfortable, have less dead space and are safer than oters. The main drawbacks of this type of interface are pressure ulcers and mouth leaks. To minimise the latter, the use of dummies or chinstraps may be helpful. If leakage is still excessive, the interface should be replaced by an oronasal interface. In addition to being less comfortable, the latter is less safe because of the increased risk of aerophagia and aspiration. In older children and adolescents, Adams-type interfaces and nasal prongs may be useful, as they have less risk of pressure ulcers than other interfaces and produce less claustrophobic sensations. Total-face interfaces are rarely used, but may be considered especially in patients

who have developed pressure ulcers or malar hypoplasia. The use of helmet-type interface in paediatric home NIV is anecdotal [23, 25, 30].

Start of Treatment

As in the case of adult patients, the ideal is to start therapy in hospital, in a department with the appropriate material, personal and technical resources, with an admission of 3–5 days. There, the necessary parameters will be optimised and the family and the child will have the opportunity to become familiar with the therapy, the interfaces and their management, the most common problems or side effects and to learn how to solve them. In infants, it can be useful to take advantage of moments when they are asleep or in their parents' arms to place the interface and begin the technique. In school-age children, it can help to present it as a game. In adolescents, it is usually easier to adapt, as they are able to understand their pathology and the need for ventilation [23, 30].

Parent and Caregiver Training

Initially, during admission, basic knowledge, use and maintenance of the different devices and the foreseeable problems that may arise will be explained to the parents or carers. It is important not to saturate them with information, to check that they have understood it and to provide them with the information in writing. It may also be useful for them to take their own notes, adapted to the child's situation. They will first observe how the health staff performs the tasks, then they will do them themselves under supervision and finally, they will do them independently. Before discharge, they should have learned:

- Placement of the interfaz
- Leakage monitoring
- Skin and mucous membrane care
- Operation and cleaning of equipment
- Interpretation and setting of alarms
- Adjustment of some parameters if deemed appropriate by the physician—assessment of signs and symptoms of respiratory worsening
- Recognising urgent situations and how to act
- Special feeding techniques if required by the child
- Care for activities of daily living, including play
- Physical and respiratory rehabilitation techniques, speech therapy and occupational therapy if the child needs them [23, 30].

What to Assess in the Follow-Up of the Paediatric Home Care Patient

Symptoms of hypoventilation should be assessed and will vary according to the age of the child. Younger children show irritability, psychomotor retardation, poor school performance, drowsiness, intense night sweats, enuresis, malnutrition and restless sleep with frequent awakenings and nightmares. In adolescents, morning headache, drowsiness, tiredness, difficulty concentrating and sometimes dyspnoea appear. In the physical examination, HF, BF, temperature and SpO_2 should be measured. Ponto-statural development, signs of pulmonary hypertension, neurological assessment, psychomotor development and nutritional assessment will be assessed. SpO_2 during the day and during sleep should be assessed for desaturation. If present, this may be due to persistent hypoventilation, intermittent airway obstruction, excessive leakage or asynchrony. This will help in deciding whether to change parameters, add oxygen therapy, whether humidification or nutritional support is needed. At all times we must be alert to detect complications and adverse effects, swallowing problems, respiratory infections and facial or facial bone deformities derived from the interfaces. Specific questionnaires will help us to assess the psychosocial and quality of life of the child and the family [23, 30].

Process of Nursing Care for Patients Undergoing Treatment with NIV

For the first step of the nursing care process, Marjory Gordon's assessment according to functional patterns has been chosen. This consists of an artificial division of human functioning into 11 patterns that facilitate the systematised collection of data during the anamnesis for subsequent assessment, the formulation of diagnoses, the establishment of objectives and the choice of the relevant interventions to achieve them.

Pattern 1: Perception—Health Management

This pattern assesses how the individual perceives their health and well-being, how they manage everything related to their health, adherence to prescribed treatment and whether they carry out preventive practices (vaccinations, and dietary habits).

To do so, we will assess their hygiene habits, vaccinations, the presence or absence of pathological antecedents, perception of their own health and interest in and knowledge of healthy behaviours and toxic habits.

In these patients, we may find a lack of knowledge about their disease and about the technique to be applied (NIV), which may condition the success of the therapy.

They will also be susceptible to infections due to therapeutic devices, the risk of aspiration inherent to NIV, decreased ciliary action and the possibility of pressure injuries (NIV, prolonged bed rest).

Once this pattern has been assessed, the following nursing diagnoses can be found:

- 00126 Poor knowledge
- 00004 Risk of infection

Pattern 2: Nutritional—Metabolic

This standard is responsible for assessing whether the amount of liquids and food ingested by the individual is sufficient to cover his/her metabolic needs, swallowing problems, anthropometric measurements, body temperature and the condition of the skin, mucous membranes and mucous membranes.

In the case of patients undergoing NIV for acute respiratory failure, we will focus on assessing whether the intake of food and liquids is recommended or whether, due to the patient's condition, an absolute diet, enteral nutrition via nasogastric tube or parenteral nutrition has been prescribed. In the case of being able to ingest food, the patient's ability to chew and swallow must be assessed. We must also be on the lookout for food allergies and intolerances.

Constant assessment of mucous membranes, membranes and tissues will be necessary, focusing on areas of support of interfaces and other therapeutic devices, areas of pressure against the bed, the state of the oral cavity and corneas. Validated scales such as the Norton scale for stratifying the risk of pressure injuries or the Walt scale for assessing the state of the mouth and lips can be used to assess these.

Many of these patients will be in this situation due to a respiratory infectious process, so fever may be found when analysing this pattern.

Once the data have been collected, the following nursing diagnoses can be made:

- 00304 Risk of pressure injury in adults
- 00002 Risk of nutritional imbalance: less than body requirements
- 00028 Risk of fluid volume deficit
- 00047 Risk of deterioration of skin integrity
- 00044 Risk of deterioration of tissue integrity
- 00247 Risk of oral mucosal damage
- 00039 Aspiration risk
- 00219 Dry eye risk
- 00245 Risk of corneal injury
- 00261 Risk of dry mouth

Pattern 3: Elimination

This pattern assesses intestinal, urinary and cutaneous excretory functions.

Constipation related to prolonged immobilisation is to be expected in these patients. It is also possible that, due to their critical or semi-critical condition, they may need a bladder catheter to control diuresis.

The nursing diagnoses we can find related to this pattern are

- 00015 Constipation

Pattern 4: Activity—Exercise

This pattern is responsible for assessing the patient's functional capacity, exercise, activity level and leisure time activities.

In these patients, we will focus on the assessment of blood pressure, heart rate, oxygen saturation, respiratory pattern, sensation of dyspnoea and its variations in response to activity (small efforts such as mobilisation in bed). This will give us an idea of the patient's activity tolerance.

In cases of prolonged bed rest, the degree of joint mobility, strength and muscle tone should also be assessed.

The nursing diagnoses that we can foreseeably find after the assessment of this pattern will be

- 00299 Risk of impaired activity tolerance
- 00091 Impaired mobility in bed
- 00291 Risk of thrombosis
- 00030 Deterioration of gas exchange
- 00093 Fatigue
- 00032 Ineffective breathing pattern
- 00031 Ineffective airway clearance
- 00033 Spontaneous ventilatory impairment
- 00108 Self-care deficits: bathing and hygiene
- 00110 Self-care deficit: toileting

Pattern 5: Sleep—Rest

This pattern describes the person's ability to achieve sleep, rest or relaxation, the patient's assessment of the quality of their sleep, whether or not they require pharmacological sleep aids and their perception of their energy level.

We have to take into account that these patients will generally be admitted to extraordinarily complex hospital units, where there is never silence or total darkness and where procedures are constantly being performed, so their sleep will be very difficult.

In addition, being away from their families and the perceived seriousness of their own state of health can induce states of anxiety or depression.

Nor will pain or discomfort related to therapeutic devices help the patient's rest.

The following nursing diagnosis is expected to be found:

- 00095 Sleep pattern impairment

Pattern 6: Cognitive—Perceptual

This pattern is responsible for the assessment of the patient's level of consciousness, cognitive status, adequacy of the sense organs, pain perception and management, language and the need for communication aids.

The assessment will collect data such as the level of consciousness and orientation in time and space, knowledge of language, hearing, communication or vision problems, existence, location, type and intensity of pain and behavioural alterations such as agitation.

Hypercapnia is frequently present in these patients, which may affect their level of consciousness, cognitive status or agitation.

They will also have communication problems related to the different interfaces. For example with the helmet, it will be difficult for the patient to hear us and with the interfaces covering the mouth, it will be difficult for us to understand what the patient wants to express.

Following the assessment of this pattern, it will be possible for us to make the following nursing diagnoses:

- 00051 Verbal communication impairment
- 00132 Acute pain
- 00173 Risk of acute confusion

Pattern 7: Self-Perception—Self-Concept

Assesses self-concept and perceptions of self, body image, identity, general sense of life, emotional pattern, eye contact, voice and conversation patterns.

In this case, the patient may experience moments of low situational self-esteem due to feeling unable to cope with the situation or events, feeling hopelessness, mistrust and worthlessness. This may be motivated by the functional impairment suffered or by changes in the social or family role.

The nursing diagnoses that can be found after the assessment of this pattern are as follows:

- 00153 Situational low self-esteem risk
- 00124 Despair

Pattern 8: Role—Relationships

This pattern analyses the patient's relationships with his or her environment, family, society in general, self-satisfaction with these relationships and the usual responsibilities he or she carries out.

For the assessment of this pattern, we will have to inquire about who the patient lives with, his or her family structure, whether he or she has dependents and the presence or absence of social support.

It is clear that the situation of illness and hospital admission may condition a change in social and work relationships as well as in the role that the patient had been occupying in his or her family until that moment and may also mean an increase in the need for social support for the patient.

In the context of this pattern, we can state the following nursing diagnoses:

- 00053 Social isolation
- 00054 Risk of loneliness
- 00152 Risk of impotence

Pattern 9: Sexuality and Reproduction

It assesses satisfaction or not with one's own sexuality, alterations in sexuality or sexual relations, security in sexual relations, reproductive pattern, pre- and post-menopause and problems perceived by the person.

In these cases, the hospital admission itself represents a limitation of their sexual activity. If the patient perceives this situation as a concern, we will make the following diagnosis:

- 00059 Sexual dysfunction

Pattern 10: Adaptation—Stress Tolerance

This pattern takes into account the forms and strategies of coping that the person possesses, his or her habitual responses to stressful situations, the capacity to adapt to change and the individual and family support that the individual has.

The patient will be asked about whether they are tense or relaxed, what usually helps them when they are tense and whether this approach has been successful.

Patients requiring noninvasive mechanical ventilation are experiencing a serious health problem and are located in extraordinarily complex hospital units where the presence of loved ones is not always possible, and which constitute a hostile environment for the patient. All this means that we can find the following nursing diagnoses after assessing this pattern:

- 00146 Anxiety
- 00147 Death anxiety
- 00148 Fear

Pattern 11: Values and Beliefs

This pattern identifies the values and beliefs that guide choices or decisions, what is considered right or appropriate, what is perceived as important in life, health-related expectations, decisions about treatment, health priorities, life or death, and religious practices.

In order to assess this, future plans, concerns related to life, death, pain or illness, and membership of any religion that prohibits or limits prescribed treatments, should be asked.

The assessment of this pattern takes on special relevance when NIV is used in the context of palliative care. This will allow us to respect the wishes of patients and relatives when deciding on therapeutic ceilings or limiting the therapeutic effort when necessary.

Within the framework of this pattern, we can find the following nursing diagnosis:

- 00067 Risk of spiritual suffering [31]

References

1. International Consensus Conferences in Intensive Care Medicine. Noninvasive positive pressure ventilation in acute respiratory failure. Am J Respir Crit Care Med. 2000;163(1):283–91.
2. Gómez Grande ML, Esquinas Rodriguez AM. Non-invasive ventilation in the intensive care units. Enferm Intensiva. 2007;18(4):187–95.
3. Goñi Rm Labiano C, Andueza I, Ezenarro A, Falguera M, Juandaburre B, Rubio E, Villanueva N. Noninvasive mechanical ventilation: patient perceptions. Enferm Cardiol. 2017;24(72):50–5.
4. Eife-Oidetam E. Dental prostheses via the airway. EIFE-FUNDETAM. 2016. Available https://eifeoidetam.wordpress.com/2016/06/08/protesis-dentales-via-aerea/.
5. Iglesias RS. Pressure ulcers caused by clinical devices in intensive care unit. Santander: University of Cantabria; 2018.
6. Black J, Alves P, Brindle CT, Dealey C, Santamaria N, Call E, Clark M. Use of wound dressings to enhance prevention of pressure ulcers caused by medical devices. Int Wound J. 2015;12:322–7.
7. Esquinas AM. Nursing care in noninvasive mechanical ventilation: fundamentals. Int Assoc Sch Noninv Mech Vent. 2010;2010:317–8.
8. Posnett J, Soldevilla JJ, Torra Bou JE, Verdú J, San ML. An approach to the economic cost impact of pressure ulcer treatment in Spain. Gerokomos. 2007;18(4):201–10.
9. Semesasturias.es. Editorial Respira. 2022. Available http://www.semesasturias.es/index.php/contenidos/docs/vmni/8-manual-separ-vmni-1/file.
10. Esquinas Rodriguez AM. Nursing care in non-invasive mechanical ventilation. Fundamentals. Spain: International Association and School of Noninvasive Mechanical Ventilation; 2010. p. 111–20.
11. John A. What are the ratings for the Borg scale? Thegatheringbaltimore.com. 2022. Available https://www.thegatheringbaltimore.com/2021/06/23/what-are-the-ratings-for-the-borg-scale/.
12. Patel BK, Wolfe KS, Pohlman AS, Hall JB, Kress JP. Effect of noninvasive ventilation delivered by helmet vs face mask on the rate of endotracheal intubation in patients with acute respiratory distress syndrome. JAMA. 2016;315:2435–41.

13. López Esteban E, Ávarez López C, Cachón PJ. Non-invasive mechanical ventilation in paediatrics: generalities and nuances of nursing care. In: Esquinas Rodriguez A, editor. Nursing care in non-invasive mechanical ventilation. Madrid: Seden; 2022. p. 61–5. Available at https://www.revistaseden.org/boletin/files/2983_cuidados_de_enfermeria_en_la_ventilacion_mecanica_no_invasiva.pdf/. Accessed 3 May 2022.
14. González Pérez M, Medina Villanueva J, García-Maribona R-MJ. Chapter noninvasive ventilation. Nursing in paediatric and neonatal critical care. Almería. 2016. Available https://ajibarra.org/D/post/capituloventilacionnoinvasiva/. Accessed 3 May 2022.
15. Pastor Vivero MD, Pérez Tarazona S, Rodríguez Cimadevilla JL. Acute and chronic respiratory failure. Oxygen therapy. Protoc Diagn Pediatr. 2017;1:369–99.
16. Pons M. Paediatric intensive care. Non-invasive ventilation in children. An Pediatr Contin. 2008;6(6):330–8.
17. López Esteban E, Ávarez López C, Cachón PJ. Current indications, and contraindications of NIV in paediatrics. In: Esquinas Rodriguez A, editor. Nursing care in noninvasive mechanical ventilation. Madrid: Seden; 2022. p. 67. Available https://www.revistaseden.org/boletin/files/2983_cuidados_de_enfermeria_en_la_ventilacion_mecanica_no_invasiva.pdf/. Accessed 3 May 2022.
18. Del Grosso RA. Nursing care in neonatal patients with non-invasive mechanical ventilation. Tenerife: Universidad de la Laguna; 2017. https://riull.ull.es/xmlui/bitstream/handle/915/5326/Cuidados%20de%20enfermeria%20en%20pacientes%20neonatales%20con%20ventilacion%20mecanica%20no%20invasiva.pdf?sequence=1/. Accessed 3 May 2022.
19. García-Maribona R-MJ. Admission of the paediatric patient with NIV in PICU. In: 33rd National Congress of the Spanish Society of Paediatric Intensive Care. Medicine/Nursing round table. La VNI: Un trabajo en equipo; 2018. Retrieved https://secip.com/images/uploads/2018/06/4.-La-VNI.-Un- trabajo....pdf/. Accessed 3 May 2022.
20. Martínez LV. Attention and nursing care for patients with non-invasive mechanical ventilation. Revista electrónica de portales médicos.com. Vol. XVI; No 11; 602 [Internet]. Cádiz; 2021. Available https://www.revista-portalesmedicos.com/revista-medica/atencion-y-cuidados-de-enfermeria-al-paciente-con-ventilacion-mecanica-no-invasiva/. Accessed 5 May 2022.
21. Muñoz Bono J, Curiel Balsera E, Hernández SB. Interfase en pediatría. Selección y tipos de máscaras. In: Esquinas Rodriguez A, editor. Nursing care in non-invasive mechanical ventilation. Madrid: Seden; 2022. p. 73–80. Available https://www.revistaseden.org/boletin/files/2983_cuidados_de_enfermeria_en_la_ventilacion_mecanica_no_invasiva.pdf/. Accessed 3 May 2022.
22. Egea-Santaolalla CJ, Chiner Vives E, Díaz Lobato S, González Mangado N, Lujan Tomé M, Mediano San Andrés O. Mechanical ventilation at home. Open Resp Arch. 2020;2(2):67–88.
23. Rodríguez MJ, Berroya A, Mora A, Bustinza A, Rodríguez Cimadevilla JL, Salcedo A. Home noninvasive ventilation control and follow-up programme in paediatric patients. Multidisciplinary unit. Rev Esp Pediatr Clín Invest. 2010;66(2):127–35.
24. Pallero CM. Non-invasive home mechanical ventilation: adaptation and follow-up (Doctoral thesis on the Internet). Barcelona: Universitat Autònoma de Barcelona; 2015. Available https://ddd.uab.cat/record/148874. Accessed 23 February 2022.
25. Pons M. Non-invasive ventilation in children. An Pediatr Contin. 2008;6(6):330–8.
26. Sevilla RB. Nursing role in non-invasive mechanical ventilation (final degree thesis online). Murcia: Universidad Católica de Murcia; 2014. Available http://repositorio.ucam.edu/bitstream/handle/10952/1272TFG%20Sevilla%20Roca%2C%20Beatriz.pdf?sequence=1&isAllowed=y. Accessed 23 February 2022.
27. Spanish Society of Pneumology and Thoracic Surgery. SEPAR manual of procedures. Non-invasive mechanical ventilation. Respira-Spanish Lung Foundation-SEPAR; 2008. Available https://www.separ.es/node/191. Accessed 23 February 2022.
28. Toledo A, Montiel G, Franceschini C. Guidelines for home mechanical ventilation. Am J Respir Med. 2021;1:107–34.

29. González Cortés R, Bustinza Arriortua A, Pons Ódena M, García Teresa MA, Cols Roig M, Gaboli M, et al. Home mechanical ventilation in children: a Spanish multicentre study. Clin Otolaryngol. 2013;78(4):227–33.
30. Costa Colomer J, Gáboli M, Pradillo Martín MC. Indications, and initiation of mechanical ventilation support at home. Protoc Diagn Pediatr. 2017;1:401–22.
31. Herdman TH, Kamitsuru S, Takáo LC. Nursing diagnoses. Definitions and classification 2021-2023. 12th ed. Amsterdam: Elsevier; 2021.