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REVIEW ARTICLE

Noninvasive ventilation in acute heart failure: use of continuous positive airway pressure in the emergency department

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Noninvasive ventilation is one of the ventilatory support systems available for treating the patient with acute respiratory failure. Orotracheal intubation is not required. The main modalities are continuous positive airway pressure (CPAP) and bilevel positive airway pressure (BiPAP). Both alleviate respiratory distress quickly and have proven useful for treating acute heart failure due to acute pulmonary edema or pulmonary hypertension. The need for intubation and mortality are reduced. More experience has accumulated with CPAP, which is easier to manage and is associated with few complications. BiPAP, which is more complicated and requires more staff training, has been shown to improve respiratory failure more quickly in patients with heart failure and to be more effective in patients with hypercapnia or respiratory muscle fatigue. In spite of these benefits, noninvasive ventilation is little used in hospital emergency departments, probably because of the lack of staff training and commitment, low availability of material resources, and the absence of clear protocols, which ought to be available in all hospitals. This review aims to describe the role that noninvasive ventilation plays in improving oxygen saturation in the treatment of acute heart failure due to acute pulmonary edema or pulmonary hypertension and to define an appropriate protocol for using these modalities. [Emergencias 2010;22:49-55]

Key words: Acute heart failure. Noninvasive ventilation. Emergency health services.

Introduction

Acute heart failure (AHF) with acute lung edema (ALE) or associated with a hypertensive crisis is a common cause of acute respiratory failure (ARF) in the hospital emergency department (ED). Its incidence and impact are increasing, and sometimes reaches truly epidemic proportions[1].

In recent decades, non-invasive ventilation (NIV) with positive pressure has been widely used to treat both hypoxemic ARF and hypoxemia-hypercapnia frequently seen in patients with AHF[2]. NIV does not require orotracheal intubation (OTI) or sedation and has proved useful in the treatment of various forms of ARF[3].

For the treatment of AHF, two modes of NIV have proved effective: continuous positive airway pressure (CPAP) and bi-level positive airway pressure (BiPAP). Both modes, together with pharmacological treatment for AHF (diuretics, vasodilators, inotropic agents, morphine), have been shown to improve early clinical and blood gas parameters, reducing the number of IOT and its complications, intensive care unit (ICU) admissions and hospital mortality in certain patients, as compared with traditional methods of oxygenation[4].

There is greater experience with CPAP for the treatment of ARF associated with AHF, but the BiPAP mode is recommended when there is evidence of hypercapnia ($PaC0_2$ > 50 mmHg) and respiratory acidosis (pH < 7.25)[5-7].

However, despite these benefits, the use of NIV in the ED is not widespread and only used in less than 6% of patients with AHF[8]. This may be due to lack of training in the technique and the absence of guidelines and protocols. This review aims to establish the role of NIV as a method of oxygenation in the treatment of AHF due to hypertensive ALE and to define an action protocol that facilitates the use of NIV in the ED.

Modes of non-invasive ventilation in ALE

CPAP

This is the most common mode of oxygenation used in the treatment of AHF with ALE and / or hypertensive crisis. It is simple to manage, with low costs and few complications[9].

It involves continuous positive pressure in the airway and consists of a spontaneous ventilation mode that can optionally be applied without the aid of a fan[10]. It is not exactly a mechanical system of ventilation, and is better defined as a mode of continuous positive pressure oxygenation of the airway.

The application of continuous positive pressure air causes deployment or recruitment of partially or completely collapsed alveolar units, improves lung compliance, increases transpulmonary pressure and functional residual capacity. This enhances the effort of breathing and gas exchange[11]. At the hemodynamic level, CPAP results in decreased preload and afterload (by reducing venous return and systolic tension of the left ventricular wall) with a slight decrease in systolic blood pressure and cardiac output in patients with normal cardiac function. In heart failure patients with increased pulmonary capillary pressure and fluid overload, it can increase cardiac output[12].

The comparison of CPAP with traditional oxygenation systems[4] shows a significant declining rate of intubation (between 50-60%) and of hospital mortality (40-47%), and is considered the oxygen therapy system of choice for the early treatment of AHF associated with ALE[4]. It is recommended as Class IIa with level of evidence A in the guidelines for the diagnosis and treatment of AHF by the European Society of Cardiology[13] and the recommendations of the British Thoracic Society (BTS) for the treatment of hypoxemic ARF due to ALE[14].

BiPAP

This also consists of applying continuous air pressure, but helps the patient during inspiration by means of a ventilator. The result is ventilation with two pressure levels, one inspiratory (IPAP) and other expiratory (EPAP)[15].

When BiPAP is compared against conventional oxygen therapy, it shows significantly reduced OTI (50%) and mortality (40%)[4,16,17]. On comparing CPAP and BiPAP, no significant differences appear in the proportion of intubations, short-term mortality or hospital stay, but BiPAP shows faster improvement of clinical and blood gas parameters, especially in the presence of hypercapnia and respiratory acidosis[18-20].

Since the CPAP technique is simpler, requires minimal training, little experience and less expensive equipment, it is recommended as initial treatment of AHF with ALE[14]. The use of BiPAP is indicated when CPAP fails, or when there is an initial association with hypercapnia and respiratory acidosis[21].

Types of ventilators, interfaces and non-mechanical devices in NIV

Types of ventilators

NIV can be achieved using conventional ventilators (less effective) or those specifically designed for this ventilatory function (less sophisticated but high performance)[22].

Traditionally, ventilators are described as being of limited volume (ventilation of the chronically ill) or limited pressure (recommended in acute illness). Ventilators of limited pressure designed for NIV are portable, manageable, and cost effective. In these devices, a turbine originates the flow, taking in ambient air to generate inspiratory and expiratory pressures (IPAP and EPAP). These ventilators can cycle by flow or pressure. They usually have a sensor to detect flow variations, responding rapidly to inspiratory and expiratory cycles. Patient inspiratory flow triggers the release of IPAP and flow reduction leads to exhalation where expiratory pressure is maintained constantly positive, or EPAP[21]. The circuit is simple in bidirectional ventilators (such as BiPAP Vision® or BiPAP Focus®) with an anti-reinhalation valve at the distal end and a pressure valve (sensor) attached to ventilator and to the interface[23].

Not all ventilators can regulate FIO_2 (fraction of oxygen in inspired air) which is an essential parameter in ventilation. When no other source of auxiliary oxygen is available, direct input from an external source to the interface is necessary.

Interfaces

The interface or mask is what makes this type of ventilation non-invasive. Correct choice is fundamental for the success of NIV, and requires a balance between minimizing leakage and maximising patient comfort. The most frequently used NIV masks for acute patients are oro-nasal and total facial masks. Nasal masks are usually used in chronic respiratory disease[24]. The helmet has also been used successfully, but is usually limited to treating respiratory failure with acute CPAP or as an alternative in the case of skin complications in patients with prolonged ventilation[25]. Helmet use has been questioned in the treatment of acute hypercapnia because cycling is more difficult and may favour CO_2 re-inspiration. Helmet price, less availability and less emergency staff experience mean it is a less common interface. It is also important to have various devices for securing the masks.

Non-mechanical CPAP devices

In addition to CPAP incorporated into mechanical ventilators, there are two non-mechanical continuous flow systems capable of generating continuous positive airway pressure throughout the respiratory cycle: a system connected to an airtight mask with an interchangeable exhalation valve (PEEP), and a system with a virtual PEEP valve as part of the mask (Boussignac system). In Boussignac CPAP a virtual PEEP valve is generated inside a small open tube due to turbulent flow resulting from the confluence of four high-flow jets inside. Pressure level is regulated by a flowmeter and controlled with a manometer or using tables. It has a FIO_2 ring regulator and a T-shaped nebulizer. Handling is simple and requires little training, with low cost and high performance[26].

Orotracheal intubation in ALE

The main benefit of NIV is avoidance of OTI. Thus, knowing OTI risk factors in patients with ALE can help as a guide for the indication of NIV. These criteria are shown in Table 1. Patients with these factors should automatically be candidates for NIV even though it may fail in many of them. However, since NIV has been shown to improve ARF more rapidly than conventional oxygen therapy, it can be used with most ALE patients, assuming adequate material and experience.

Factors associated with successful NIV in ALE

There are a number of factors that portend a good response to NIV (Table 2).

The experience and training of health professionals and cooperation or tolerance of the patient are important factors. Despite all these, NIV failure is possible, and most often reported in the elderly, the critical (high APACHE II or SAPS II scores) with non-hypercapnic ARF or with acute respiratory distress (ARDS) or pneumonia. It is also likely to fail when there is no improvement of hypoxemia after 30-60 minutes[27,28].

Table 1. Independent risk factors for intubation in acute cardiogenic lung edema

- Acute myocardial infarction with severely depressed left ventricular ejection fraction.
- APACHE II score > 21.
- Refractory hypercapnia.
- PH < 7.20.
- Systolic blood pressure < 140 mm Hg.
- High comorbidity (Charlson index > 3).
- Radiological pattern of extensive alveolar edema.

APACHE: acute physiologic and chronic health evaluation: pH < 7.20 is an independent parameter of maximum risk.

NIV protocol in cardiogenic ALE

The evidence supports the benefits of NIV over conventional methods of oxygenation in the treatment of ALE and it should be considered as the first line of intervention. The existence of a protocol means increased degree of compliance and commitment by emergency medicine professionals[29,30]. In our opinion, CPAP should be the method of choice for ALE treatment, given its simplicity, easy application and low cost.

General measures

Patient selection criteria

Clinical diagnosis and early implementation are critical for the success of the technique.

NIV should be applied along with the rest of the conventional measures and there are no contraindications for use, in the following forms of AHF:

Table 2. Factors associated with the success of noninvasive ventilation

- Patient-ventilator synchrony.
- Glasgow coma score over 9.
- Acceptance of the technique by the patient.
- Few secretions.
- No pneumonia.
- APACHE II score less than 21.
- Hypercapnia.
- Initial pH above 7.1.
- Good response in the first hour of treatment.
- Arterial hypertension at baseline.
- Good response to treatment, correction of acidosis and hypoxemia.

APACHE: acute physiologic and chronic health evaluation.

– ALE: sudden onset of dyspnea with accessory muscle use, SaO_2 <90%, respiratory rate > 30 rpm and compatible chest radiograph.

– Acute hypertensive heart failure: signs and symptoms of AHF accompanied by high systolic blood pressure, relatively preserved left ventricular systolic function and chest radiography compatible with ALE.

There should be no delay in starting NIV while waiting for the results of a chest radiograph or arterial blood gas test. The patient must be aware and co-operative at the start, hemodynamically stable, and able to maintain his/her airway and manage secretions.

Contraindications

There is no clear consensus on absolute and relative contraindications for the use of NIV[31]. Some are accepted as such on being described as exclusion criteria in many studies (Table 3).

Monitoring

The first 30-60 minutes are crucial for success of the technique. Therefore clinical control at the bedside is essential from the first moment. Heart rate, respiratory rate, SaO_2 and blood pressure must be monitored continuously and arterial or venous blood gas must be monitored intermittently[32].

Initiation of NIV

1. Patient monitored.
2. Bed at 45 degrees.
3. Administer oxygen conventionally while setting up all the NIV instruments, prepare the harness attachment, select the type and size of the interface (the oronasal, total facial or helmet for ALE) and FIO_2 should be kept as high as possible.
4. Explain the technique to the patient, and that a "jet of air" will be felt, etc.).
5. Place some protection on the nasal bridge (colloid dressing, vaseline gauze) when using the oronasal mask.

Table 3. Contraindications for noninvasive ventilation

– Inability to maintain airway: patient in coma not hypercapnic, or agitated.
– Recent gastrointestinal or upper airway surgery (<15 days), uncontrolled vomiting, active HDA.
– Inability to control secretions.
– Hemodynamic instability (established shock uncontrolled by fluids and / or vasoactive drugs), uncontrolled malignant arrhythmia.
– Epilepsy.
– Impossibility of securing the mask.
– Lack of training in the technique.

6. Hold the mask to the patient's face (or offer it to the patient), without pressure, allowing the patient to adapt, and start ventilation, but not secured with the harness, without concern about leakage at this stage.
7. If systolic blood pressure on ED admission (independent risk factor for morbidity and mortality in AHF) is between 90-110 mmHg, inotropics are necessary to achieve higher values and initiate NIV.

CPAP

8. Select minimum pressure levels (5 cmH_2O manometer) and after 2-5 minutes of adaptation, increase by steps of 2 cmH_2O pressure until the value that yields best respiratory frequency, reducing respiratory effort and maintaining SpO_2 > 90%. Values will range between 7-12 cm H_2O (the pressure most frequently used is 10 cm H_2O)[33], with higher values if necessary (values above 20 cm H_2O pose a risk of intolerance to the technique), with an FIO_2 as high as possible (ideally 100%).
9. Monitor the pressure and the degree of leakage (with a manometer if using devices that are not of the mechanical Boussignac CPAP type; needle oscillation should not exceed 1 cm H_2O).
10. Fasten the harness without undue tension, verify leakage, and apply more tension if required (In NIV, any harness allowing a 2 finger gap without difficulty is recommended, otherwise there may be excessive stress and risk of intolerance).
11. If bronchodilators are required, use a device designed to spray (T tube), without changing or interrupting CPAP oxygenation, connecting it to medicinal air rotamers at a pressure of 4-5 cm H_2O[34].

BIPAP

12. In patients with severe debut or signs of poor response to initial treatment, with hypercapnia and respiratory acidosis (pH < 7.25), BIPAP ventilation or noninvasive pressure support is an alternative to CPAP.
13. The approach is identical, starting with low IPAP (8-10 cm H_2O) and EPAP values (4 cm H_2O), to progress after adaptation to IPAP values between 12-20 cm H_2O and EPAP of 5-6 cm H_2O, with maximum FIO_2 (if possible 100%) to achieve SaO_2 > 90% and obtain an average tidal volume approximately 7.10 ml x weight of the patient (volume higher than 400 ml for an adult weighing 70-80 Kg)[35]. In patients with some degree of drowsiness, program the safety respiratory rate around 10-15 breaths per minute.

Table 4. Most common complications of noninvasive ventilation

– Discomfort.
– Injuries to the nasal bridge: erythema, ulceration.
– Claustrophobia.
– Dry mucous membranes or eye irritation.
– Gastric distension (common but tolerated).
– Low blood pressure.
– Intolerance of the technique: asynchrony.

Complications

NIV failure varies among different series, between one 7-42% of patients, but only 10-15% are due to technical complications, usually poor application of the technique (Table 4).

When to withdraw CPAP?

Withdrawal is usually progressive. In our experience the average time on CPAP in the ED is 3 hours. In general, CPAP can be withdrawn under the following conditions:

– Improvement of dyspnea, without use of ancillary muscles

– Heart rate < 100 bpm.

– Respiratory rate < 30 rpm.

– When, with FIO_2 of 50% (Venturi mask type) and spontaneous breathing (without CPAP), one achieves SaO_2 > 90% in a comfortable patient, with improved blood gas (PaO_2 > 70 mmHg or PaO_2/FIO_2 ratio > 200 mmHg).

Controversies in NIV

Risk of myocardial infarction and VNI

There has been controversy over the risk of acute myocardial infarction (AMI) when BIPAP is used in patients with ALE, especially after the publication of two papers that showed higher rates of AMI associated with this technique. The first study compared with CPAP and BIPAP, the second BIPAP versus high doses of nitrates. In the first, the average pressure support used was 5 cm H_2O (IPAP of 9 and EPAP of 4 cm H_2O) which is insufficient and probably caused hypoventilation with increased risk of myocardial ischemia. In the second, there was a patient selection bias with a greater proportion of patients with chest pain on admission treated with BIPAP and thus a higher probability that the AMI was the cause of ALE and not the result of treatment[38,39].

This theoretically higher incidence of AMI theory associated with BIPAP has not been confirmed in subsequent studies. Even a recent study performed specifically to quantify the risk of AMI in the ALE treated with NIV (CPAP compared with BIPAP) concluded that both modes are equally effective and have similar rates of AMI, but should be used with caution in patients with severely depressed ejection fraction[40,41].

Hypotension and NIV

This is rare with proper patient selection. The increase in intrathoracic pressure causes decreased venous return, which favors the onset of hypotension, and is clinically relevant in patients with low intravascular volume and / or severely depressed systolic function. The development of auto-PEEP, typical of chronic obstructive pulmonary disease (COPD), also favors the development of hypotension. Therefore NIV is not recommend in patients with low cardiac output or shock[42].

Conclusions

Patients with ARF due to ALE generally benefit from the use of NIV (CPAP and BIPAP). Early use reduces the number of intubations and complications, enhances clinical and blood gas parameters, and hospital survival rates.

The benefits of CPAP over BIPAP are easy application, minimal staff training, adaptability to different treatment and low cost. CPAP by non-mechanical systems (Boussignac) offers maximum applicability. Thus NIV, especially CPAP, should be made available in all hospital and out-of-hospital emergency departments; training and the commitment of healthcare professionals is essential for implementation of this technique.

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Ventilación no invasiva en la insuficiencia cardiaca aguda: uso de CPAP en los servicios de urgencias

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La ventilación no invasiva (VNI) es uno de los soportes ventilatorios que se ofrece al paciente con insuficiencia respiratoria aguda (IRA) y que no precisa intubación orotraqueal. Los modos usados con más frecuencia en la IRA son la presión positiva continúa en la vía área (CPAP) y la ventilación con doble nivel de presión (BIPAP). Ambas modalidades han demostrado su utilidad en el tratamiento de la insuficiencia cardiaca aguda (ICA) por edema agudo de pulmón (EAP) o hipertensiva, al mejorar con mayor rapidez la IRA y reducir las necesidades de intubación y la mortalidad en algunos pacientes. Existe una mayor experiencia en el modo CPAP, más sencillo en su manejo y con pocas complicaciones, que con el modo BIPAP, más complejo y que requiere un mayor entrenamiento. Cuando se comparan ambos métodos en pacientes con ICA el modo BIPAP sólo ha demostrado mejorar la IRA con mayor rapidez y es más efectivo en pacientes con hipercapnia o fatiga respiratoria. A pesar de estos beneficios, el uso de la VNI en los servicios de urgencias hospitalarios está poco extendido probablemente debido a la falta de entrenamiento e implicación de los profesionales, la baja disponibilidad de recursos materiales y a la ausencia de protocolos claros, que deberían estar disponibles en todos los hospitales. La presente revisión pretende establecer el papel de la VNI como método de oxigenación en el tratamiento de la ICA por EAP e hipertensiva y definir un protocolo de actuación que facilite su cumplimiento. [Emergencias 2010;22:49-55]

Palabras clave: Insuficiencia cardiaca aguda. Ventilación no invasiva. Servicios de urgencias.