Review Article

Noninvasive positive pressure ventilation in hospital setting

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Abstract

Noninvasive positive pressure ventilation (NPPV) refers to the delivery of mechanical ventilation to the lungs using techniques that do not require an endotracheal intubation. In the past decade NPPV has gained wide acceptance and is now used more frequently after development of portable ventilators, new modes of ventilation and other equipments. This article will provide a comprehensive overview of the current stage of NPPV in acute and chronic settings. It will appraise the evidence based efficacy of NPPV in patients who presented with acute exacerbation of chronic hypercapneic respiratory failure. The main focus of discussion in this article is to provide detailed knowledge regarding choosing appropriate ventilators and interfaces, selecting appropriate patients and initiating NPPV and their weaning.

Keywords: NPPV, Mechanical ventilation, Portable ventilators.

Method of literature review:

This review is based on an evaluation of the literature using a multimethod approach. A computerized MEDLINE search from the year 2001 through March 2010 was undertaken using search terms including mechanical ventilation, non invasive positive pressure ventilation, NPPV , acute respiratory failure, chronic respiratory failure, respiratory complications and lung disease/ restrictive. Bibliographies of articles were also searched for relevant articles. Review articles and consensus statements were also examined and recommendations synthesized into general guidelines.

Historical Back Ground:

Historically noninvasive ventilators were the "body" ventilators, because they assist ventilation by applying negative or positive pressure to various regions of the body. Since 1960s these ventilators were used for patients with acute respiratory failure. However body ventilators continued to be used for patients with chronic respiratory failure through the mid-1980s, particularly for those with neuromuscular disease or kyphoscoliosis. Now a day's positive pressure ventilation via translaryngeal endotracheal tubes has become a standard practice for the support of patients with acute respiratory failure.

Intermittent positive pressure breathing (IPPB) was first described in 1949 and was used via a mouthpiece widely until the early 1980s in acute care hospitals. IPPB was used mainly as a means of delivering aerosolized bronchodilators to patients with chronic obstructive pulmonary disease (COPD) and asthma. Fraimow and colleagues observed that intermittent positive pressure breathing (IPPB) reversed the increase in PaCO2 occurring in patients with emphysema receiving oxygen. Noninvasive positive pressure ventilation (NPPV) was used nocturnally and as needed during the daytime successfully at different centers to treat patients with neuromuscular disease at centers dating back to the early 1960s.

These centers were using mainly mouthpiece interfaces that failed to gain wide acceptance elsewhere. Face masks were not widely accepted for the chronic administration of noninvasive ventilation, largely because of poor patient tolerance. The signal change that led to the recent proliferation of noninvasive ventilation came in the early 1980s with the introduction of the nasal continuous positive airway pressure (CPAP) mask for the treatment of obstructive sleep apnea. Recent work has defined the role in the management of patients with acute respiratory failure. Subsequent sections will critically review this recent work

and provide guidelines on current indications for NPPV in both acute and chronic settings.

Introduction

Mechanical ventilation through endotracheal tube is highly effective and reliable in supporting alveolar ventilation and carries well-known risks of complications.[1]

Endo tracheal tube-associated discomfort and the compromised ability to eat and communicate contributes to feelings of powerlessness, isolation, and anxiety among patients.[2] The major reason for gaining the popularity for switching to noninvasive ventilation has been the desire to avoid the complications of invasive ventilation. If patients are carefully selected using established guidelines noninvasive ventilation has the potential of avoiding the problems of translaryngeal intubation. Different studies indicates that NPPV reduces infectious complications of mechanical ventilation, including nosocomial pneumonia and sinusitis.[3] Noninvasive ventilation may enhance comfort, convenience, and portability at no even less cost than endotracheal intubation.[4,5] It has been evidenced that NPPV has been successfully used in emergency department, in acute exacerbation of chronic obstructive pulmonary disease (COPD) and asthmatics. In this article the discussion is mainly focused on the equipment used, modes of ventilation and intiation and management of NPPV in adult patients who present with acute exacerbations of chronic hypercapnec respiratory failure.

Noninvasive Positive Pressure Ventilation:

Positive pressure ventilation provided either through invasive or noninvasive methods, assists ventilation by delivering pressurized gas to the airways, increasing transpulmonary pressure, and better inflation of lungs. Exhalation occurs due to elastic recoil of the lungs and force exerted by the expiratory muscles. In NPPV gas is delivered to the airway via "interface" rather than via a translaryngeal tube. This open breathing circuit of NPPV allows air leaks around the mask or through the mouth, rendering the success of NPPV in patients critically dependent on ventilator systems. Now adays a new interface has been designed to deal effectively with air leaks and to optimize patient comfort and acceptance. NPPV improves alveolar ventilation by decreasing the work of breathing and gives rest to the respiratory musculature. Bilevel intermittent positive airway pressure (BIPAP) improves the gas exchange because of an increase in alveolar ventilation. Administration of positive end-expiratory pressure (PEEP]) decreases the work of breathing by partially overcoming the auto-PEEP which is usually present in these patients. In NPPV the patient has to generate less negative inspiratory force to initiate a breathing cycle.

Interfaces for the Delivery of NPPV or CPAP:

Interfaces are devices that connect ventilator tubing to the face which facilitates the entry of pressurized gas into the upper airway during NPPV. Mouthpieces, nasal and oronasal masks interfaces are currently easily available everywhere.

The nasal masks are widely used for chronic administration of CPAP or NPPV. The nasal mask is a triangular or cone-shaped clear plastic device provided with a soft cuff to form an air seal over the skin and fits easily over the nose. The nasal mask cuff can exert pressure over the bridge of the nose and can often cause skin irritation and redness, and occasionally ulceration. However various modifications have been introduced to minimize these complications like forehead spacers, gel seals or the addition of a thin plastic flap that permits air sealing with less mask pressure on the nose. In the market custom-moulded masks are available that fit to unique facial contours.

Oronasal or full-face masks that cover both nose and the mouth are mainly used on patients with acute respiratory failure but can also be used for chronic applications. Theoretically the risk of aspiration and rebreathing are greater with oronasal than with nasal masks. Chronic users of oronasal interface usually object because of interference with speech, eating, and expectoration, and the likelihood of claustrophobic reactions. However oronasal masks are preferable to nasal masks in acute settings, because dyspnoeic patients are mouth breathers, predisposing to greater air leakage and reduced effectiveness during nasal mask ventilation. Also, a report from a controlled trial comparing nasal and oronasal masks found that Paco2 and respiratory rate fell at equal rates when the masks were used for patients with acute respiratory distress.[6]

Mouthpieces held in place by lip seals have been used to provide NPPV for as long as 24 hours a day to patients with chronic respiratory failure.[7] These devices have been successfully used in a large number of patients with neuromuscular disease, having little or no vital capacity. The use of mouthpieces has allowed some quadriplegic patients to be successfully converted from tracheostomies to NPPV.[8] NPPV with different levels of expiratory pressures and masks with exhaust vents, prevent rebreathing. In addition it is seen that the use of spacers do not generate this undesirable phenomenon.[9]

Modes of Noninvasive Ventilatory Assistance:

Continious Positive Airway Pressure (CPAP) opens collapsed or underventilated alveoli, increases functional residual capacity, decreases the right to left intrapulmonary shunt and improves oxygenation. The increase in functional residual capacity may also improve lung compliance, decreasing the work of breathing.[10] In addition, by lowering

left ventricular transmural pressure, CPAP may reduce afterload and increase cardiac output.[11,12] It has been observed that CPAP improves the vital signs and gas exchange in patients with acute exacerbations of chronic obstructive pulmonary disease (COPD). Pressures ranging from 5 to 12.5 cm H2O are commonly used to deliver CPAP in patients with acute respiratory distress. Such pressures can be applied through ventilators used in critical care units and through a wide variety of devices including CPAP valves connected to a compressed gas source and small portable units are used for home therapy of obstructive sleep apnea. NPPV and CPAP have also been found to be effective in emergency departments for some other causes of acute respiratory failure.[13]

Pressure control through bilevel devices cycles between two different positive pressures, are lighter (5 to 10 kg) and more compact (< 1 ft^3) than critical care ventilators, offering greater portability at lower expense.[14] The determining level of pressure support depends on the difference between the peak inspiratory and expiratory positive airway pressures (IPAP and EPAP). Alterations in EPAP without parallel changes in IPAP will alter the pressure support level. The bilevel devices have proven ideal for home or in areas other than critical care settings because of their portability, convenience, and at low cost. NPPV immediately after extubation is effective in avoiding respiratory failure after extubation in patients at risk for this complication, particularly those with chronic respiratory disorders and hypercapnec respiratory failure.[15]

A new ventilator mode is proportional assist ventilation (PAV), which targets patient effort rather than pressure or volume.[16] By instantaneously tracking patient inspiratory flow and its integral (volume) using an in-line pneumotachograph. This mode has the capability of responding rapidly to the patient's ventilatory effort. This ventilator mode is not yet commercially available but preliminary reports on noninvasive applications are promising.[14]

Choice of Ventilators:

NPPV can be given by conventional critical care ventilators or portable pressure or volume limit ventilators. When non invasive positive pressure bilevel ventilation (NPPBV) modes are used via a critical care ventilator, the presence of variable leaks produces frequent alarming. Therefore a close monitoring of leaks is mandatory. NPPV may be delivered more successfully using specially designed portable pressure ventilators such as (Bilevel positive airway pressure generators). These provide a high flow CPAP or cycle between high inspiratory and low expiratory pressures. These devices are sensitive enough for detection of inspiratory efforts even in the presence of leaks in the circuits.

Suitability and Clinical Application of NPPV in Hospital Setting:

NPPV is suitable for a cooperative and relaxed patient and is not optimal for an anxious, uncooperative patient or for a patient fighting with the ventilator. Patients must be selected carefully because of the risk of complications, which could be increased if noninvasive ventilation is used inappropriately. The patients must be prepared adequately and the process of ventilation should be explained before the application of the mask. Prior explanation usually increases the patient's tolerance and compliance. The inspiratory and the expiratory pressures should be increased gradually for better tolerance.

Conditions in which patient is unable to protect his/her airway, (facial trauma/burns , recent facial, upper airway, or upper gastrointestinal tract surgery, impaired consciousness level, bowel obstruction, copious respiratory secretions) life threatening hypoxaemia, haemodynamic instability, severe co-morbidity and undrained pneumothorax are considered absolute contraindications for initiation of NPPV.

NPPV-trial in the emergency department for all possible patients with acute respiratory failure (ARF) of pulmonary etiologies, excluding those with recurrent pneumonia, may reduce overall in-hospital mortality and ICU stays.[17] Hypoxaemic acute respiratory failure may benefit from noninvasive ventilation or continuous positive airway pressure, but undue prolongation should be avoided. However the evidence is less convincing to show efficacy of NPPV in hypoxaemic respiratory failure. Possible indications may include cardiogenic pulmonary oedema, community acquired pneumonia, post traumatic respiratory failure and early ARDS. At least two of the following criteria should be present for initiation of NPPV. Obvious respiratory distress with dyspnoea, use of accessory muscles of respiration, abdominal paradox, respiratory rate >25/min and ABG showing pH <7.35 or PaCO2 >45mmHg or PaO2/FiO2 <200.

Early administration of NPPV in COPD patients with chronic hypercapneic respiratory failure admitted for acute exacerbations with a pH of 7.35 or higher, results in a reduced hospital stay and faster improvement of arterial blood gases.[18] It has been shown that NPPV, in a pulmonary ward, reduces the need for endotracheal intubation, particularly in the more severe patients and leads to a faster recovery in patients with acute exacerbation of chronic obstructive pulmonary disease.[19] Signs of fatigue, hypersomnolence and dyspnoea, rising trends of PaCO2 and worsening of pH values (ABG showing pH <7.35, PaCO2 >55 mmHg) and persistent oxygen saturation of <88% for more than10% of monitoring time despite oxygen supplementation are indications for considering the patient as a candidate for NPPV.

NPPV is found to be more effective in improving respiratory distress in acute pulmonary oedema than conventional oxygen therapy and reduces the necessity of intubation, in the subset of patients who can best benefit from these techniques in terms of mortality still requiring further investigation.[20]

NPPV therapy is increasingly popular for the treatment of acute respiratory failure as well as for new indications such as postoperative acute respiratory failure .This widening of indications has been accompanied by improvement in and development of ventilation techniques by physicians and manufacturers. The place of NPPV in postoperative acute respiratory failure is not yet well established. Nevertheless, use of NPPV to avoid reintubation or to treat postoperative acute respiratory failure has often been described in observational and/or randomized studies.[21,22]

In acute asthma, the attack may be fatal enough and may require invasive mechanical ventilation. Mechanical ventilation of the asthmatic patient is associated with a higher risk of complications and therefore, is a measure of last resort. NPPV is another treatment modality available for severe asthmatics who are at an increased risk of developing respiratory failure. However, over the last decade only a few reports of NPPV in asthma have been published.[23-25] These studies mostly involve small numbers of patients and those who have problematic methodology of NPPV in its usage in asthmatic attacks. However these reports are encouraging but still questions are raised regarding initiation and suitability of NPPV for all asthmatic patients and in severe asthmatic attacks on a routine basis are still unanswered. Therefore the use of NPPV in asthmatics is still controversial.[26] Multicenter, and perhaps an international, effort has to be conducted in order to answer some of these questions. Recently in a randomized control trial it has been shown that NPPV improved the respiratory functions in asthmatics. It has been suggested that NPPV can be cautiously tried in selected patients in appropriate environment, such as an ICU with respiratory team experienced in operating and managing patients on NPPV.[27]

NPPV in Paediatric Patients:

The discussion regarding effectiveness of NPPV in paediatric patients is out of the scope of this article. The experience of NPPV in the paediatric ICU (PICU) is limited. However early case reports showed promising results when NPPV was used as an alternative to standard treatment in children with acute respiratory distress[28] and for acute hypoxaemic respiratory failure mainly due to pneumonia.[29] In addition several physiologic studies have shown beneficial effect of NPPV in some critical conditions responsible for alveolar hypoventilation such as upper airway obstruction[30] and cystic fibrosis.[31] Sandrine has suggested that NPPV can be considered as the first-line intervention in children with severe acute respiratory failure due to community-acquired pneumonia, respiratory failure in the immunocompromised patient, and sickle-cell disease.[32] Recently it has been shown that in selected patients, age range 2-12 years, with upper airway obstruction or lung disease, noninvasive positive-pressure ventilation may represent a valuable tool to treat the recurrence of obstructive symptoms after decannulation and may facilitate early weaning from tracheotomy in children who failed repeated decannulation trials.[33]

Initiation and Monitoring of Patients on NPPV:

Different types of protocols for initiation and monitoring of patients on NPPV are available in literature. These protocols depend upon the institutional setup and the area where NPPV is applied. However the indications and targets for achieving the desirable results are almost the same in all available protocols.

Before instituting the NPPV the procedure should be explained and the patient's permission taken. Nurse patient in prop up position at an angle of 45°. Choose the correct size of the mask and initiate ventilator at CPAP (expiratory positive airway pressure or EPAP) of zero centimeters(cm) water with a pressure support of 10 cm water. Secure the mask with head straps. Slowly increase CPAP to more than 5 cm water. Increase pressure support (ie inspired positive airway pressure or IPAP, 10-20 cm water) to achieve maximal exhaled tidal volume (10-15 ml/kg). Evaluate the ventilator settings, which are indicated by an improvement in dyspnoea, a decreased respiratory rate, achievement of desired tidal volume, and good comfort for the patient. Oxygen supplementation is achieved through NPPV machine to mach patient oxygen saturation of greater than 90%. A backup rate may be provided if the patient becomes apneic. In patients with hypoxaemia, increase CPAP in increments of 2-3 cm water until FiO2 is less than 0.6. Set the ventilator alarms and backup apnea parameters. Monitor with oximetry and adjust ventilator settings after obtaining arterial blood gas results. Keep on asking the patient to call for needs and provide reassurance and encouragement.

Clinical monitoring of the patient should include assessment of patient comfort, conscious level, chest wall motion, accessory muscle recruitment, and coordination of respiratory effort with the ventilator, respiratory rate and haemodynamics. Patients receiving NPPV should be assessed at regular intervals to evaluate their response to the treatment and to optimize the ventilator settings. The need for arterial blood gas (ABGS) analysis will be governed by the patient's clinical progress. Initially ABGS should be measured in most patients after every 1-2 hours of NPPV and then after 4-6 hours accordingly. If there has been no improvement in

PaCO2 and pH after this period, despite optimal ventilator settings, NPPV should be discontinued and invasive ventilation should be considered. Oxygen saturation monitoring should be continued continuously for at least 24 hours after commencing and weaning off the NPPV. Administration of supplementary oxygen should be continued to maintain saturations between 85% and 90%.

NPPV can be discontinued briefly for oral drug administration , physiotherapy and meals etc. Patients who show improvement from NPPV in the first few hours should be ventilated for as much as possible during the first 24 hours, or until improvement has set in.

All patients who have been treated with NPPV for acute hypercapneic respiratory failure should undergo spirometric testing and arterial blood gas analysis before being discharged from the facility.

Weaning From NPPV:

Once the patient becomes clinically stable and primary pathology is settled enough then weaning from NPPV may be accomplished either by progressively decreasing the levels of positive airway pressure or by intermittent discontinuation of therapy for increasing lengths of time. A combination of both strategies can also be used depending on the patient's response.

Infection Control and Equipment:

Now a day's, disposable masks and valves have solved the problem of infection control and avoiding the reprocessing and disinfection of the different equipments used for NPPV. However a bacterial filter should be attached to the ventilator outlet during NPPV. The external surface of the ventilator should be cleaned between patients. Maintenance and electrical safety checks on ventilators should be undertaken at least annually by the biomedical department according to the manufacturer's recommendations.

Conclusion

The evidence grade provided for recommendations in this document is low , indicating the need for more research in this field. For some of the recommendations the studies needed to improve the evidence base would be extremely difficult or impossible to carry out. Bi-level pressure support is becoming established as the main mode used for acute NPPV, however the optimal settings remain to be determined. NPPV is considered to be beneficial when used at an early stage in COPD, but the exact indications need refinement. Further research is still required for establishing exact indications in conditions other than COPD and cardiogenic pulmonary oedema. The duration of NPPV, target SpO2, adjustment of ventilator settings and weaning from ventilatory support also require further investigation.

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