Review Article

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Non-Invasive Mechanical Ventilation in Children

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Abstract

Non-invasive ventilation refers to delivery of assisted ventilation without the use of advanced airways such as endotracheal tube (ET) or a tracheostomy tube. It can be through positive or negative pressure devices and continuous or intermittent. Non-invasive ventilation can be used in acute respiratory failure as well in chronic conditions such as chronic lung disease, respiratory control disorders and thoracic insufficiency syndromes. The advantage in using non-invasive over invasive ventilation in acute setting is that, intubation can be avoided and thus prevents nosocomial infection and also lesser use of sedation. Patients who are on NIMV in an acute setting, continuous monitoring of oxygen saturation and ECG are indicated. Patients with chronic lung conditions can be managed at home on non-invasive ventilation, thus reducing hospital stay.

Keywords: Non-Invasive Ventilation; NIMV; Home Ventilation.

Introduction

Non invasive ventilation refers to delivery of assisted ventilation without the use of advanced airways such as endotracheal tube (ET tube) or a tracheostomy tube [1]. It can be through positive or negative pressure devices and continuous or intermittent. Non invasive ventilation has reduced the number of tracheostomy and thus has a better impact on quality of life, reduced duration of hospital and ICU stay and also avoiding intubation and thus damage to trachea and vocal cords [2]. Thus, use of non invasive ventilation is becoming increasing popular in ICU and also in chronic settings.

Physiological basis of NIMV

Lung mechanics are largely dependent upon resistance (resistance to flow) and compliance (resistance to change in lung volume) of respiratory system. In disease state, e.g. pneumonia (alveoli are collapsed/consolidated) lungs become stiffer (i.e. less compliant) and the closing volume exceeds the functional residual capacity (FRC). Thus, during end expiration the alveoli are collapsed leading to interruption of ventilation and also more pressure is needed to re-expand these collapsed alveoli during inspiration. Increase in inspiratory pressures is done by increased force of respiratory muscle contraction along with use of accessory muscles of respiration. Children are particularly disadvantaged in doing so, as their pliable chest wall 'gives-in' to increased force, thus leading to ineffective transmission of pressure for lung expansion and ventilation. Other mechanisms used are directed to keep alveoli from collapsing, which are increase in inspiratory muscle tone during expiration, initiation of inspiration before termination of expiration and expiration against closed glottis. If these mechanisms fail, child goes in respiratory failure which can be either due to respiratory muscle fatigue or lungs becoming more non-compliant, unless timely respiratory support is provided. Non invasive ventilation can be defined as delivery of ventilatory support via nose and/or mouth without using endotracheal tube or tracheostomy. Non invasive ventilation can prevent this respiratory failure by providing an external airway pressure, thus preventing alveolar collapse and stabilizing respiratory system. Also non invasive ventilation can help the over worked respiratory muscles by providing enough oxygen.

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Ventilators and interfaces used in NIMV

Ventilators that are used for NIMV are of three types *viz*: (1) conventional ICU ventilators with double limb and no leak compensation; (2) ventilators with single limb and leak compensations; and (3) ventilators with double limb and leak compensation. Type 1 ventilators are used in ICU and require high pressure gas system. Type 2 and 3 are used in both home and hospital and don't require high pressure gas system. Maximal FiO_2 with category 2 and 3 ventilators used are 45–50% and if higher FiO_2 is needed and intubation is not indicated then category 1 ventilators are used. Non-invasive home ventilators are usually with a single tube. The circuit can be provided with a "non-rebreathing" exhalation valve which allows CO_2 elimination of the exhaled air. Alternatively the circuit can be free of the expiratory valve, but provided with a CO_2 dispersion system [1].

Available interfaces for non invasive ventilation are: nasal masks, full face masks, oro-nasal masks, nasal pillows and head hood. Most commonly used are nasal masks [2] and different sizes are available for children. Nasal masks rest between the nasal bridge and upper lip and smaller the mask better the fit. Oro-nasal masks covers the bridge of the nose up to the lower lip, it should be moldable to the contours of the face (to prevent leak). Oro-nasal masks are fitted via a strapping system that goes through head. Most important in use of all interface is prevention of air-leaks which reduces the effectiveness of ventilation [3]. In children interface acceptance is also very crucial to successful non invasive ventilation. Interface should be light, should have a good adhesion and also exert less pressure on skin.

Types of NIMV and ventilator settings

Two types of non-invasive ventilation are used: nCPAP (nasal CPAP) and nPPV (nasal positive pressure ventilation). In nCPAP a constant positive pressure is applied in a spontaneously breathing child to the airway through nose in the entire respiratory cycle. nCPAP can be delivered through a bubble CPAP, fluid logic system or a ventilator CPAP system. In nPPV a patient triggered positive breath is delivered to a preset limit during inspiration along with a PEEP throughout the respiratory cycle. nCPAP works by opening the collapsed alveoli and thus reduces work of breathing and also splints the airway preventing apnea. In contrast nPPV delivers pressure supported breaths to the patient similar to that in an intubated child and thus might help better than nCPAP in recruiting lung volumes and hence ventilation (4). nPPV can be given through portable and ICU ventilators. Pressure mode is preferred for nPPV as the flow will continue to increase until the target pressure is reached and thus will automatically compensate for leaks around the interface [2]. To avoid asynchrony during nPPV lowest possible inspiratory trigger threshold should be kept at the lowest (but avoid auto-trigger) and ventilator with leak compensation software should be preferred. In mechanical ventilators with expiratory flow cycling having air leaks, defects in expiratory flow cycling can lead undue prolongation of inspiration, known 'hung-up', which can be very uncomfortable for the patient. This can be avoided by setting up an inspiratory time limit beyond which flow cycling doesn't continues. Humidification of gases may not be necessary in non invasive ventilation, but if there is upper airway dryness humidification can be used. When NIMV is used in acute settings, then two approaches can be used for pressure settings. In high-low pressure approach high inspiratory pressures (20 to 25 cm of H_2O) are used to start with and with improvement of symptoms lower pressures are used as per patient tolerance. In low-high pressure approach lower inspiratory pressures (8 to 10 cm of H_2O) are delivered initially and then gradually hiked with target of symptoms relief and tolerance of patient.

Indications of NIMV

The advantage in using non invasive over invasive ventilation is that intubation can be avoided and thus prevents nosocomial infection and also lesser use of sedation [5, 6]. Patients on non invasive ventilation can also be managed at home, thus reducing hospital stay.

(a) NIMV in acute settings

Non invasive ventilation can be used in acute respiratory failure as well in chronic conditions such as chronic lung disease, respiratory control disorders and thoracic insufficiency syndromes [2]. Non invasive ventilation in short term use helps in relief from symptoms, reduces the work of breathing, improves and stabilizes gas exchanges and avoidance of intubation [7]. The evidence on use of non invasive ventilation in acute respiratory failure supports its use and thus will prevent intubation and invasive ventilation in a proportion of these children [8]. In a developing country such as of ours where there are limited resources use of nCPAP in cases of pneumonia or respiratory distress syndrome in newborns can be helpful. nCPAP and nPPV are commonly used as non-pharmacological measures for apnea of prematurity. Non invasive ventilation is useful in acute upper airway obstruction, although much data for pediatric population is not available. Studies [9, 10] have shown improvement in children with both nCPAP and nPPV in situation of upper airway obstruction. Use of non invasive ventilation in ARDS in adults has shown to be beneficial, but again data in children are limited. Non invasive ventilation has been used for prevention of post extubation respiratory failure [11].

(b) NIMV in chronic settings

Long term use of non invasive ventilation is amongst children with chronic lung disease, disordered respiratory control and thoracic insufficiency syndromes. Noninvasive ventilation has been most extensively studied in children with neuromuscular disorder and obstructive sleep apnea. Long term non invasive ventilation is delivered mostly during sleep and if required not more than 16 hrs in a day without increasing the risk of skin damage [2]. The aims of long term noninvasive ventilation are reduction of work of breathing and promotion of growth (and also lung growth), correction of hypoxia/hypercarbia and hence pulmonary hypertension, prevention of development of chest wall deformity in children with neuromuscular disease and thoracic insufficiency syndrome by delivering adequate tidal volumes and prolonging life, particularly in children with neuromuscular disorders and diseases of respiratory control [2, 7]. Amongst children with obstructive sleep apnea nCPAP and nPPV are used as main treatment option and as an interim measure to final corrective surgery. In obstructive sleep apnea there is airway collapsibility during sleep which can be prevented by use of nCPAP. Marcus et al [12] has shown that nCPAP and nPPV to be highly effective in obstructive sleep apnea.

Complications and contraindications of NIMV

Complications associated with short term use of noninvasive ventilation are related to skin damage due to air leak [2]. Skin damage can be prevented by use of a proper fitting mask, avoidance of over tightened straps and use of gel pads on at-risk contact points, particularly the bridge of the nose and the forehead. Full face mask covering the nose and mouth is associated aerophagia and abdominal discomfort [3]. Non invasive ventilation can't be used in facial or airway anomalies and is contraindicated in patients with hemodynamic compromise and inability to protect airway. Long-term use of nasal or face mask for noninvasive ventilation is mid-face flattening and malocclusion of teeth (due to under development of maxilla in growing children) [13].

Monitoring of patients on NIMV

Patients who are on NIMV in an acute setting, in-hospital continuous monitoring is indicated. Patients should have a continuous pulse oximetry and ECG. Frequent blood pressure should be recorded along with strict watch on respiratory rate, level of dyspnea and consciousness. These patients should also be watched for patient comfort, patient-ventilator asynchrony, intolerance to interface, gastric distension, dryness of eyes and damage to skin. Amongst patients on long term NIMV, studies should be performed to adjust ventilator settings, such as polysomnography, cardio-respiratory sleep study or nocturnal non-invasive monitoring of oxygen saturation and carbon dioxide [14, 15].

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