Noninvasive Ventilation in Pediatric Acute Respiratory Illness

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Abstract:
Noninvasive ventilation (NIV) for pediatric acute respiratory illness reduces work of breathing, improves ventilation, and potentially avoids complications associated with endotracheal intubation and mechanical ventilation. Modalities of NIV include continuous positive airway pressure and bilevel positive airway pressure, which have been used in a range of pediatric diseases. In addition, high-flow nasal cannula is a newer modality that is increasingly used in pediatric patients. This article describes the properties of different modalities of NIV and reviews the medical literature regarding use of NIV in pediatric patients with acute respiratory illness.

Keywords:
noninvasive ventilation; acute respiratory illness; pediatric; continuous positive airway pressure (CPAP); bilevel positive airway pressure (BPAP); high-flow nasal cannula (HFNC)

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Noninvasive ventilation (NIV) refers to delivery of assisted ventilation without the use of a transtracheal breathing tube (ie, endotracheal tube or tracheostomy tube). Noninvasive ventilation can improve alveolar ventilation, oxygenation, and work of breathing while avoiding potential complications related to endotracheal intubation, such as laryngeal injury, ventilator-induced lung injury, ventilator-associated pneumonia, and complications from sedation and neuromuscular blockade. Noninvasive ventilation has been studied in adults since the 1980s; published reports in pediatric patients have increased in the past decade.[1–3]

Noninvasive ventilation is commonly used in pediatric patients in both acute and chronic settings.[4] Although both positive and negative pressure systems are available, noninvasive positive pressure ventilation is the most common modality, including continuous positive airway pressure (CPAP) and bilevel positive airway pressure (BPAP). Heated, humidified, high-flow nasal cannula (HFNC) is a relatively new form of NIV used increasingly in pediatric patients for a variety of respiratory illnesses.

This review describes the use of different modalities of NIV in pediatric patients with acute respiratory illnesses. Continuous positive airway pressure and BPAP will be discussed separately from HFNC because of their distinct reporting in the literature. The use of NIV in the management of neonatal respiratory distress is beyond the scope of this review.

OVERVIEW OF NIV MODALITIES

Continuous Positive Airway Pressure

Continuous positive airway pressure provides constant flow to maintain a target distending pressure to the lower airways throughout the entire respiratory cycle. There is no inspiratory pressure support. The major physiologic effects of CPAP are; (1) increasing functional residual capacity, which improves oxygenation, and (2) reducing airway resistance, thereby decreasing work of breathing.[5] Continuous positive airway pressure can be delivered by various interfaces, including nasal prongs, face mask, or head boxes (also called *helmet CPAP*).

Continuous positive airway pressure has been used in pediatric patients since the 1970s.[6] Early experience was mostly in neonates, but it is now used across all pediatric ages for numerous indications. Although optimal pressures for various ages and disease processes have been reported, CPAP is often started at pressures of 4 to 5 cm H_2O and titrated to effect based upon physiologic response and patient tolerance.[7,8] Pressures of 8 to 10 cm H_2O have been reported with no adverse hemodynamic effects.[9]

Bilevel Positive Airway Pressure

Bilevel positive airway pressure provides 2 levels of positive airway pressure: a higher level during inspiration (inspiratory positive airway pressure, IPAP) and a lower level during expiration (end-expiratory positive airway pressure, EPAP). *BiPAP* refers to the delivery of BPAP using a proprietary ventilator, although the terms are commonly used interchangeably. In assisted spontaneous mode (pressure support), breaths are given synchronously with patient effort. Timed modes give a combination of spontaneous breaths and breaths at regular intervals. The ventilator is triggered to deliver a breath by detecting changes in inspiratory flow or pressure generated by patient effort. Care must be taken to ensure adequate IPAP delivery in young infants who may not be able to adequately trigger the ventilator. Selection of an appropriately sized interface for the child is key in ensuring adequate triggering and delivery of IPAP.

Bilevel positive airway pressure is usually initiated with an EPAP of 4 to 5 cm H_2O and IPAP of 8 to 10 cm H_2O. Like CPAP, pressures are titrated to effect and tolerance. End-expiratory positive airway pressure ranges from 2 to 20 cm H_2O and IPAP ranges from 2 to 25 cm H_2O have been reported.[4,10–12]

High-Flow Nasal Cannula

High-flow nasal cannula is a relatively new type of NIV in which heated, humidified oxygen is delivered via nasal cannula at flow rates that match or exceed the patient's inspiratory flow rate to minimize entrainment of room air.[13] One reason for its growing popularity is that HFNC is fairly comfortable and generally better tolerated than forms of NIV that require a nasal or facial mask.

Observational studies have shown that the HFNC therapy improves ventilation and oxygenation, reduces work of breathing, and decreases the need for intubation.[14–16] The mechanisms of action include washout of nasopharyngeal dead space, leading to improved alveolar ventilation, attenuation of nasopharyngeal inspiratory resistance, improved airway conductance and pulmonary compliance, and provision of positive pressure for lung recruitment.[17] High-flow nasal cannula therapy has also been shown to off-load the diaphragm (measured by electrical activity of the diaphragm), thereby decreasing the work of breathing.[18]

The amount of positive pressure produced by HFNC is variable and depends upon the flow rate and the degree of leakage from the mouth and nares. Care must be taken to ensure that the proper-size nasal cannula is used to allow escape of air at the nares-prong interface. In newborns, HFNC generates positive end-expiratory pressure in the range of 2 to 5 cm H_2O.[19–21] A study in infants with bronchiolitis found that nasopharyngeal pressure increased by 0.45 cm H_2O for every 1 L/min increase in flow.[22] At 6 L/min, pressures in the open mouth state were 2.47 cm H_2O and were 2.74 cm H_2O in the closed mouth state. Another study in older children demonstrated that HFNC provided an average positive expiratory pressure of 4.0 ± 2.0 cm H_2O.[23]

ADVANTAGES AND DISADVANTAGES OF NIV

The chief advantage of NIV over endotracheal intubation is avoidance of potential complications associated with intubation and mechanical ventilation, including laryngeal injury, ventilator-induced lung injury, and ventilator-associated pneumonia. In addition, NIV can generally be tolerated without the need for sedation, which is usually required in intubated pediatric patients. Patients receiving NIV support are better able to communicate and often are able to eat and drink if the degree of respiratory distress is not severe.

Successful use of NIV requires choosing equipment and settings appropriate for the child.[24] Proper nasal prong or mask size depends on the