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Review

Current methods of non-invasive ventilatory support for neonates

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SUMMARY

Non-invasive ventilatory support can reduce the adverse effects associated with intubation and mechanical ventilation, such as bronchopulmonary dysplasia, sepsis, and trauma to the upper airways. In the last 4 decades, nasal continuous positive airway pressure (CPAP) has been used to wean preterm infants off mechanical ventilation and, more recently, as a primary mode of respiratory support for preterm infants with respiratory insufficiency. Moreover, new methods of respiratory support have been developed, and the devices used to provide non-invasive ventilation (NIV) have improved technically. Use of NIV is increasing, and a variety of equipment is available in different clinical settings. There is evidence that NIV improves gas exchange and reduces extubation failure after mechanical ventilation in infants. However, more research is needed to identify the most suitable devices for particular conditions; the NIV settings that should be used; and whether to employ synchronized or non-synchronized NIV. Furthermore, the optimal treatment strategy and the best time for initiation of NIV remain to be identified. This article provides an overview of the use of non-invasive ventilation (NIV) in newborn infants, and the clinical applications of NIV.

INTRODUCTION

The transition from dependence on placental gas in utero to breathing of air after birth is a critical event, and several processes occur in utero to ensure an effective switch. However, full respiratory adaptation to breathing of air takes several weeks. Soon after birth, the newborn may suffer from incomplete transition because of prematurity, respiratory distress syndrome (RDS), asphyxia, persistent pulmonary hypertension, infection, or acute respiratory problems.[1] Despite technological and clinical progress in neonatal care, pulmonary disorders remain the most common cause of neonatal mortality, are associated with morbidities that have severe long-term consequences,[2] and are responsible for 20% of neonatal deaths.[3]

In previous decades, it was common to initiate endotracheal intubation and mechanical ventilation in neonates with moderate or severe respiratory distress. However, it is now known that such actions may have adverse effects on the respiratory system. Moreover, it is accepted that the application of positive pressure ventilation for an extended duration increases the likelihood of bronchopulmonary dysplasia (BPD).[4] Despite the increased use of antenatal steroids; surfactant replacement therapy, and modern ventilation techniques, including patient-triggered ventilation, volume target ventilation, and high-frequency oscillation,[5,6] the incidence of BPD in very low birth weight (VLBW) infants has not changed significantly over the last decade.[7] Furthermore, once a tube is in the trachea, this can serve as a bridge between the sterile lower respiratory system and the outside world.[8] In 80% of intubated infants, bacterial colonization of the trachea occurs within a few days.[9] These bacteria initiate inflammation, which can lead to lung injury and BPD. Furthermore, as recently shown, VLBW infants have the highest incidence of endotracheal tube leaks, which also impair mechanical ventilation.[10]

BPD primarily affects premature infants, and improved survival of very immature infants has increased the number of babies with this disorder. This has placed a heavy burden on healthcare resources, because these infants frequently require re-admission in the first 2 years after birth.[11] The overall concepts of ventilator-induced lung injuries (VILIs) are: Volu/barotrauma, injury related to lung over-distension or stretching of the pulmonary structures; atelectrauma, injury caused by alveolar collapse; biotrauma, injury caused by hyperactive inflammatory responses secondary to

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Abbreviations: BiPAP, Bilevel positive airway pressure; BPD, Bronchopulmonary dysplasia; COIN, CPAP Or Intubation for Neonates; CPAP, Continuous positive airway pressure; ELBW, Extremely low birth weight; HFNC, Humidified high-flow nasal cannula; INSURE, INtubation, SURfactant, Extubation; nBiPAP, Nasal bilevel positive airway pressure; nCPAP, Nasal continuous positive airway pressure; nHFV, Nasal high-frequency ventilation; NICU, Neonatal intensive care unit; nIPPV, Nasal intermittent positive pressure ventilation; NIV, Non-invasive ventilation; nSIPPV, Synchronized nasal intermittent positive pressure ventilation; RDS, Respiratory distress syndrome; VILI, Ventilator-induced lung injury; VLBW, Very low birth weight.

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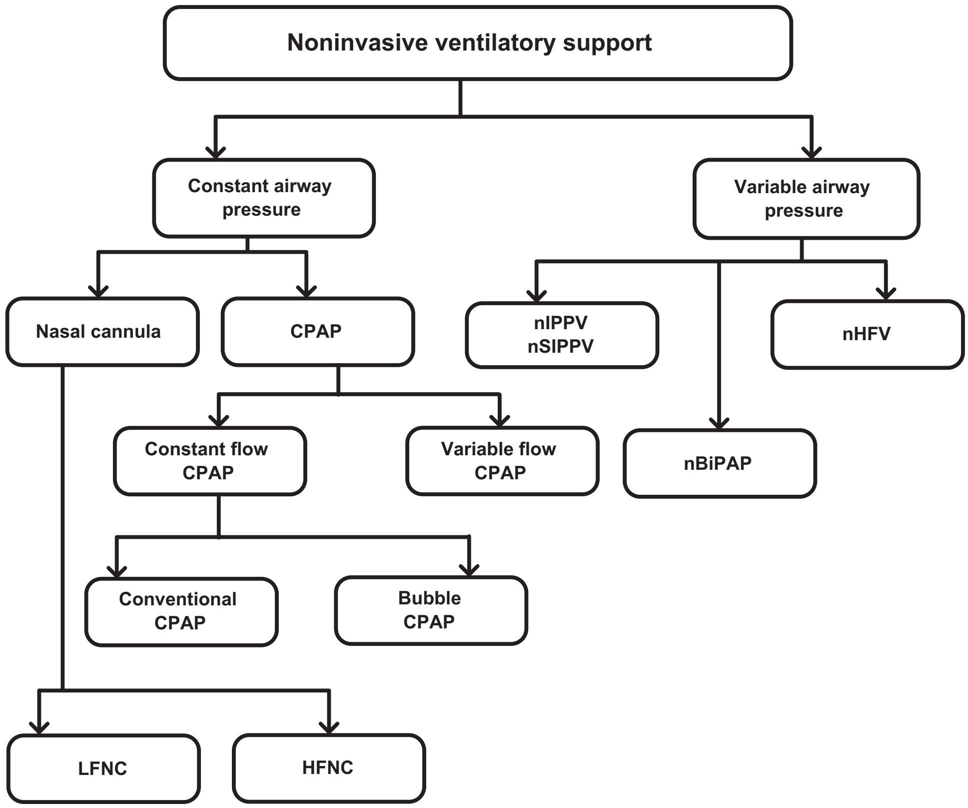

Figure 1. Types of non-invasive ventilatory support given to neonates. Abbreviations: CPAP; continuous positive airway pressure, HFNC; high-flow nasal cannula, nBiPAP; nasal bilevel positive airway pressure, nIPPV; nasal intermittent positive airway pressure, nSIPPV; synchronized nasal intermittent positive airway pressure, nHFV; nasal high-frequency ventilation.

bacterial airway colonization; and endotrauma, injury to the airway.[8,12]

In recent years, there has been an increase in clinical attempts to reduce the incidence of BPD. Such efforts begin with resuscitation of preterm infants in delivery rooms. As shown by te Pas et al.[13] VLBW infants who did not stabilise following early nasal continuous positive airway pressure (nCPAP) in the delivery room and who were mechanically ventilated during the first 3 days of life had less BPD than did VLBW infants who were initially given mechanical ventilation. Furthermore, it has been shown that survival rate and incidence of BPD in some medical centres improved when early nCPAP therapy was administered.[14–16]

Improvements in the measurement of volume and flow in modern neonatal ventilators have led to a variety of alternative non-invasive ventilation (NIV) procedures, in addition to the well-known nCPAP (Figure 1). NIV refers to any technique that uses constant or variable pressure to provide ventilatory support, but without tracheal intubation e.g. nasal intermittent positive pressure ventilation (nIPPV) combines nCPAP with superimposed ventilator breaths which may be synchronized (nSIPPV) with patient breathing movements. Currently, NIV is widely used in neonatal intensive care units (NICUs),[17] however, its place in neonatal respiratory support is not yet fully defined. The aim of this overview is to describe the basic principles of NIV techniques and to review recent reports on the application of NIV techniques in NICUs.

CONTINUOUS POSITIVE AIRWAY PRESSURE (CPAP)

The use of CPAP for the treatment of newborns with respiratory distress was first described by Gregory et al. in 1971.[18] However, the basic principle of CPAP in newborns had by then already been developed by Benveniste and Pedersen in 1968.[19] Gregory's first description has paved the way for the use of CPAP as the primary treatment for preterm infants with respiratory distress. Since that time, many prospective studies have shown an improved survival of premature infants treated with early CPAP.[20,21] However, development of more refined ventilator technologies in the early 1980 s has led to the increased use of mechanical ventilation. Such ventilation, together with prophylactic surfactant replacement therapy, came to substitute for CPAP as a treatment of RDS. Following reports that mechanical ventilation contributed to lung injury and the development of BPD, interest in the use of CPAP for respiratory support of newborn infants has revived.[14,22–24] Since two retrospective studies showed a significant decrease in the incidence of BPD in institutions with a high usage of CPAP,[25,26] many neonatologists have been encouraged to employ early CPAP as an alternative to mechanical ventilation. In 1987, Avery et al.[25] compared data from eight North American NICUs, and concluded that NIV support was associated with a significant reduction in BPD. A more recent study by van Marter et al.[26] compared clinical practices in two neonatal units at Harvard University and Columbia University, and the outcomes of infants born with birth weights of 500-1,500 g. The results indicated that initial CPAP was more commonly used at Columbia (63%) than at Harvard (11%), and the rate of BPD was substantially lower at Columbia (4%) than at Harvard (22%). Several subsequent studies have explored the positive effects of CPAP on lung function and gas exchange.[15,27] However, despite the well-known beneficial effects of CPAP, there are also drawbacks to CPAP (Table 1).

Components of CPAP systems

In general, all CPAP devices contain: **(i)** a gas source, which provides a continuous supply of warm humidified air and/or oxygen; **(ii)** a pressure generator, which creates positive pressure