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Articles

Navigating the Numerous Options and Decisions for Providing Non-Invasive Respiratory Support in the Management of Infants With Pulmonary Insufficiency

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ABSTRACT

Non-invasive respiratory support has re-emerged as an important treatment strategy for managing infants with pulmonary insufficiency. Current clinical practice is primarily guided by personal preference and experience due in part to the absence of large, randomized controlled trials aimed at evaluating the various treatment strategies. Definitive guidelines regarding best practices remain poorly defined. Clinicians have numerous options to choose from and many decisions to make regarding the clinical use of non-invasive respiratory support. This article reviews many of these options and decisions, specifically, the types of devices currently available, patient interfaces, surfactant administration, patient assessment and positioning, and weaning strategies.

Over the last decade, non-invasive respiratory support has re-emerged as an important treatment strategy for managing infants with pulmonary insufficiency. The variety of support options available is rivaled only by the diverse management strategies currently being employed. To date, there are few established guidelines for using non-invasive support in the management of pulmonary insufficiency, with clinical practice being primarily guided by personal preference and experience. When combined with evolving technology and the various patient interfaces that are available, making decisions regarding what is considered best practice can prove daunting. The purpose of this article is to review the various types of support options that are available and to discuss many of the decisions that must be made in the non-invasive management of infants with pulmonary insufficiency.

Non-Invasive Support Options

Continuous or Variable Flow?

Devices used for non-invasive support generally fall into two categories: continuous or variable flow. With continuous flow devices, the pressure generated is dependent on the resistance created by an exhalation valve (conventional ventilator) or by submerging the expiratory limb of the breathing circuit in a column of water (bubble CPAP). Bubble CPAP has been used with great success since the 1970s. It is relatively simple and inexpensive to assemble, making it a viable treatment strategy for resource-poor countries. One major drawback to bubble CPAP is the lack of audible alarms to alert the caregiver of a patient disconnect or leaks within the circuit. Vigilant evaluation of the patient and monitoring of the 'bubbling' in the column of water are a crucial part of ensuring patient safety with this system.[1] NCPAP generated using a conventional ventilator is an attractive alternative because there is no need for a separate piece of equipment. If an infant fails NCPAP, the change to invasive ventilation can be more easily accomplished. While the expense of using a conventional ventilator to deliver NCPAP may be prohibitive for some, the disposables and patient interfaces that can be used are similar to those used with bubble CPAP.

With variable flow devices, pressure levels are maintained by a change in the flow rate at the patient interface with little variability in pressure. Using dual flow injector jets, pressure is generated at the airway using the Bernoulli principle. Gas flow is directed toward the patient during inspiration and shunted away during exhalation by way of a principle called the Coanda effect. A study by Pandit et al demonstrated that the work of breathing associated with variable flow nasal CPAP was 13%–29% lower in comparison to continuous flow CPAP.[2] Additionally, they found that lung compliance was improved and that variable flow CPAP was associated with better lung recruitment at similar pressures when compared to a continuous flow device.[3] One of the factors that detract from variable flow devices is their expense. The stand alone units and proprietary circuits and disposables make such devices cost prohibitive in smaller facilities and underserved areas.

Non-Invasive Positive Pressure Ventilation and Bi-Level CPAP

Nasal intermittent positive pressure ventilation (NIPPV) and bi-level CPAP (Infant Flow® SiPAP) are additional ways of providing a higher level of non-invasive support before moving to invasive ventilation. Both are thought to improve an infant's respiratory drive, increase mean airway pressure allowing for greater alveolar

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recruitment, increase functional residual capacity, improve tidal and minute ventilation, as well as induce Head's paradoxical reflex (where lung inflation provokes an augmented inspiratory reflex).[4] NIPPV provides positive pressure ventilation via nasal prongs or cannula using a mechanical ventilator (continuous flow device). NIPPV has been shown to reduce the incidence of extubation failure more effectively than NCPAP alone and is better for controlling apnea of prematurity.[5,6] While there is a great deal of variability in the types of settings used in NIPPV, control settings typically reflect those used in invasive ventilation: baseline end-expiratory pressure of 5 cm H_2O with inspiratory pressures typically ranging from 10 to 20 cm H_2O (with variable rate and inspiratory time).

Infant Flow® SiPAP is a comparatively new device (released September 2003) that allows the infant to breathe spontaneously at two pressure levels. SiPAP is a variable flow device that uses a flow generator to create pressure at the patient's airway. During the 'sigh' interval, additional flow is diverted to the patient, thereby increasing the inspiratory pressure at which the infant is breathing spontaneously. While only a small increase in pressure is typically used (3–4 cm H_2O above baseline), the higher pressure serves to increase the mean airway pressure, resulting in better alveolar recruitment and improved gas exchange.[7] There are very few studies concerning SiPAP for users to reference regarding control settings. Migliori et al. looked at infants between 24–31 weeks gestation and evaluated them for a 4 hour period with four alternating NCPAP and SiPAP ventilation phases lasting 1 hour each. SiPAP settings for each subject were: rate of 30 'sighs' per minute, inspiratory time 0.5 seconds, and an inspiratory pressure of 4 cm H_2O above end-expiratory pressure.[7] Long et al. conducted an observational study of infants between 24–27 weeks gestation following extubation from mechanical ventilation to SiPAP. Control setting for this study were: initial 'sigh' rate of 6 (maximum rate of 30), inspiratory time of 1.0 second, end-expiratory pressure of 5–6 cm H_2O and an inspiratory pressure 2–3 cm H_2O above baseline.[8] As with other variable flow devices, the cost of the machine and proprietary disposables may serve as a barrier for some users.

High Flow Nasal Cannula

Heated high-flow nasal cannula (HFNC) systems, also considered a continuous flow device, have been utilized as an alternative to traditional CPAP. The attractiveness of HFNC systems stems from their relatively simple set-up, reduced risk of trauma to the nares and nasal septum, and increased patient comfort. A study by Locke et al. conducted in the early 1990s showed that the FiO2 and end-expiratory pressure delivered via a nasal cannula was dependent on breathing patterns, cannula size, and the size of the infant.[9] Another study by Sreenan et al. further demonstrated that the flow rate needed to generate an end-expiratory pressure similar to 6 cm H_2O NCPAP was proportional to the size of the infant (liter flows ranging from 1 to 2.5 L/min).[10] A more recent randomized controlled trial by Yoder et al. found that among infants >28 weeks gestation, HFNC therapy had similar efficacy and safety when compared to traditional CPAP devices. One finding of significance was that infants randomly assigned to NCPAP had a significantly shorter duration of support when compared with infants randomly assigned to HFNC therapy.[11] This finding is consistent with a study conducted by Abdel-Hady et al. that looked specifically at the practice of weaning preterm infants from NCPAP with or without transitioning to HFNC. After randomization, the no nasal cannula group had fewer days on oxygen (5 vs. 12 days; $p < .001$) and a shorter duration of respiratory support (10.5 vs. 18 days; $p = 0.03$).[12] One of the greatest drawbacks of HFNC therapy is the inability to accurately determine the level of end-expiratory pressure that is being generated. Additionally, there is still a limited amount of data regarding the safety and efficacy of this management strategy (see Table 1).

Patient Interfaces

There have been many improvements in the patient interfaces available for use with non-invasive support in the neonatal population over the last decade. Skin friendly materials, anatomically designed masks and prongs, and size specific disposables make it possible to create the best fit for the majority of patients. Extremely low birth weight (ELBW) infants present unique challenges as even the smallest nasal prongs are too large in some instances. The advent of nasal masks has helped to fill the need in these patients, however, maintaining a proper seal while avoiding excessive pressure can be difficult. Improvements in design have prompted some users to incorporate nasal cannulas as an interface for NIPPV using a conventional mechanical ventilator in ELBW infants with some success. More research is needed to establish this as a safe and effective practice.

One interesting finding in the Pandit et al study was the potential for lung over-distention at CPAP pressures of 6–8 cm H_2O with the variable flow device.[2] It should be noted that the type of patient interface being used significantly influences the pressure required to adequately maintain lung volume. Devices using an interface associated with higher resistance (i.e. long prong binasal airway) will require a higher set CPAP pressure at the device in order to achieve the desired physiologic pressure in the lung. Clinicians must be aware that no two CPAP devices or patient interfaces are the same

Table 1
Summary of Non-Invasive Support Options.

Non-Invasive Support Options		
Therapy	Advantages	Disadvantages
Bubble CPAP Manual Assembly, Fisher & Paykel, Babi.Plus	• Relatively simple and inexpensive to set-up and maintain	• Lack audible alarms for pressure and FiO2 • Associated with a higher work of breathing
Variable Flow CPAP Infant Flow CPAP/SiPAP (Carefusion)	• Maintains consistent pressures • Associated with a lower work of breathing and better alveolar recruitment	• Expensive • Proprietary disposables which further drives costs
Conventional Ventilator Drager, Avea, Maquet, etc.	One device for invasive and non-invasive support (CPAP, NIPPV)	• Expensive • Associated with a higher work of breathing
High Flow Nasal Cannula Manual Assembly, Vapotherm, Fisher & Paykel, RAM Cannula, etc.	• Relatively simple set-up • Increased Patient Comfort • Decreased risk for breakdown • Potential for use with conventional and high frequency ventilation	• Unknown delivery pressures • Limited data supporting use