



eNeonatal Review

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Over the past 30 years, CPAP - Continuous Positive Airway Pressure - has become a very useful method for assisting the work of breathing in infants suffering from respiratory distress.

While clinicians over the years have become more knowledgeable in the diverse applications assigned to CPAP, and although CPAP systems are in use in almost every Neonatal Intensive Care Unit (NICU) for the management of RDS, there has been on-going debate about which CPAP application currently on the market is likely to yield the best clinical outcome for the patient.

In this month's issue, we focus on the literature comparing the effectiveness and situational appropriateness of the various available devices.

Reviews by
Marc Leaderstorf

Commentary and Review by:
Dale Bloomberg

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Guest Editors of the Month

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Dale Bloomberg

Faculty Disclosure: Faculty Disclosure: Mr. Bloomberg has indicated a financial relationship as a consultant with Forest Laboratories

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COMMENTARY

In the 1960's and 70's, Idiopathic Respiratory Distress Syndrome (IRDS) was the leading cause of respiratory failure in low birth weight infants. In 1971 Gregory et al¹ speculated that the hypoxemia seen in IRDS was the result of atelectasis associated with higher surface tension that caused the alveoli to collapse, and that the grunting performed by the IRDS infants was their attempt at overcoming this high surface tension. The study found that while placing an endotracheal tube into the airway of these infants relieved the grunting, oxygenation did not improve. However, if the tube was removed, the infants resumed grunting but oxygenation increased. With the addition of positive pressure to the tubes of the intubated neonates, clinicians were able to reduce the concentration of oxygen an average of 37.5% over twelve hours. This method of support improved oxygenation and survival of the IRDS patients.

We have moved far beyond the simple improvement of oxygenation as reported by Gregory. Today, despite the controversies surrounding the incidence of BPD, we look to CPAP to assist in maintaining lung volumes, preventing apnea, reducing upper-airway resistance, and as a means of either preventing re-intubation or as an alternative to intubation altogether.

While there is no doubt that CPAP is a useful tool in the treatment of RDS^{2,3}, the indication, application, and/or the policy and procedure for the application of CPAP can vary greatly from one clinical site to another. In the quest to provide optimum care for each patient, both researchers and clinicians must address a wide range of issues surrounding CPAP, including:

- Are nasal cannulae an appropriate means of delivering CPAP?
- Should there be humidification with the cannulae delivery?
- Is it more appropriate to place a simple mask securely on the neonate's face as opposed to

prongs?

- Which prongs are the best: short or long?
- What are the advantages of single prong versus double prong applications?
- Is it effective to simply pull the endotracheal tube past the cords to the roof of the mouth to provide CPAP?
- Can a ventilator rate be delivered through the tube as well?
- How much flow is too much?
- How much pressure is too much?
- How can leaks be assessed and prevented?
- In the case of leaks, what parameters should be employed to ensure that the CPAP is still being delivered?
- What effect can other clinical complications, such as pulmonary air leaks, gastric distension, and erosion of nasal septum, have on outcomes?
- Does the repositioning of the prongs over-stimulate the patient?
- Should clinicians give surfactant to these infants before applying the CPAP?
- Will this course of therapy really reduce the incidence of BPD?⁴

As the above questions indicate, the application of CPAP is not simply another method of respiratory support for the distressed patient. Varying stages of support will almost always be needed to improve the clinical status of a patient at various stages of the disease process, requiring the practitioner to understand the clinical application of a variety of CPAP applications.

In the case of CPAP, one system may not fit everyone.

References:

1. Gregory et al Treatment of the Idiopathic Respiratory-Distress Syndrome with Continuous Positive Airway Pressure. *NEJM*, 1971;284:1333-40.
2. Morley et al Continuous distending pressure. *Arch Dis Child Fetal neonatal Ed* 1999, 81:F152-F156.
3. De Paoli AG et al Nasal CPAP for neonates: what do we know in 2003? *Arch Dis Child Fetal Neonatal Ed* 2003, 88:F168-F172.
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NASAL PRONG COMPARISON

Rego M, Martinez F: "Comparison of two nasal prongs for application of continuous positive airway pressure in neonates." *Pediatr Crit Care Med* 2002; 3:239-243

Comparing the tolerance and efficacy of delivering CPAP by two different sets of nasal prongs.

This study compared the Argyle prongs (Sherwood Medical, St. Louis MO) with the Hudson prongs (Hudson RCI, Temecula, CA), using the Sechrist iv-100B (Sechrist Industries, Anaheim, CA) conventional neonatal ventilator to deliver CPAP.

Ninety-nine infants were separated into three weight classes (≤ 1000 grams, $>1000\text{--}\leq 1500$ grams, and $>1500\text{--}\leq 2500$ grams). Seventy-one infants were assigned to either set of nasal prongs as their initial means of ventilatory support. The remaining twenty-eight infants received nasal prongs while weaning from mechanical ventilation. Lots were drawn to determine specific prongs per patient.

Except in the smallest weight group, both prongs reduced retraction after two hours of CPAP. Although the therapeutic success in patients $>1,500\text{g}$ was higher in the Hudson group, the difference in gestational age in that group (Hudson group being older) lead the authors to conclude that both prongs are equally effective. The study noted the early onset of nasal hyperemia in the ≤ 1000 gram weight class wearing the Argyle prongs, which the authors felt may have been associated with the difficulty stabilizing the prongs in this weight class, causing more

pressure on the nares. They also reported that the inability to freely visualize the nares through the non-transparent material of the Argyle prongs hampered their nare inspection.

The >1000 and ≤1500 gram neonates wearing the Argyle prongs had more incidence of accidental removal from CPAP than the infants with Hudson prongs. The authors felt this increased frequency was related to the more stable condition of this weight class, in that the increased energy level of the more vigorous neonates contributed to the increased incidence of accidental prong removal.

Although the stratification of neonates across the three weight classes reduced the study numbers, the authors report both sets of prongs to be an equally effective means of delivering nasal CPAP in neonates.

Rego M, Martinez F: "Comparison of two nasal prongs for application of continuous positive airway pressure in neonates." *Pediatr Crit Care Med* 2002; 3:239-243

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COMPARING CPAP SYSTEMS

Stefanescu B, Murphy P, Hansell B, Fuloria M, Morgan T, Aschner J. "A randomized controlled trial comparing two different continuous positive airway pressure systems for the successful extubation of extremely low birth weight infants." *Pediatrics* 2003;112:1031-1038.

Comparing improvements on extubation failure rates in ELBW infants.

Two NICUs in the Winston-Salem NC area compared the Infant Flow Continuous Positive Airway Pressure - IF CPAP - (Electro Medical Equipment Ltd Sussex England) with conventional CPAP via the INCA prongs (Ackrad Laboratories, Inc, Cranford, NJ) to determine if either system would improve on the current extubation failure rate seen in the extremely low birth weight (ELBW) neonates (<1000 grams).

A total of 162 infants were stratified into one of three groups based on weight (≤600 grams, and 601- 800 grams, and >800 - 1000 grams). Extubation failure was defined as those infants needing to be re-intubated in ≤168 hours (7 days) for any reason.

The authors reported no significant differences in the success rate of either CPAP system, with conventional CPAP at 61.9% versus the IFCPAP at 61.5%. However, the authors point out that in this study, the IF CPAP group had fewer total days on supplemental oxygen and shorter lengths of hospitalization. (NOTE: This was the first study comparing these parameters to applications of CPAP).

Failure to remain extubated on either CPAP system was attributed to the increased number of episodes of apnea and bradycardia experienced (similar to results reported in other studies). The authors felt that overcoming the frequency of these episodes in <1000 gram neonates would enhance the ability of keeping these patients extubated in the future.

Stefanescu B, Murphy P, Hansell B, Fuloria M, Morgan T, Aschner J. "A randomized controlled trial comparing two different continuous positive airway pressure systems for the successful extubation of extremely low birth weight infants." *Pediatrics* 2003;112:1031-1038.

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APPLICATION OF NASAL CPAP IN THE DR

Aly H, Milner JD, Patel K, El- Mohandes AAE. Does the experience with the use of nasal continuous positive airway pressure improve over time in extremely low birth weight infants? Pediatrics 2004;114:697-702.

Reporting on early use of nasal CPAP in extremely low birth weight(ELBW) infants

Applying nasal CPAP as early as the delivery room is associated with a host of challenges for physicians, nurses, and respiratory therapists, particularly in extremely low birth weight (ELBW) infants. Not only does it require an understanding of technical aspects, physiology and goals, but more importantly it often requires an attitude change. In the past, providers may have routinely intubated these patients in the delivery room without considering the nasal CPAP option after careful assessment of respiratory effort and/or response to face mask CPAP. This study reports on experiences over 4 years, and discusses the learning curve involved.

In the delivery room, ELBW infants were dried, stimulated, and assessed. Those with spontaneous respiratory effort were placed on face mask CPAP and immediately transferred to the NICU to be continued on nasal CPAP. In infants with signs of respiratory failure such as severe retractions, frequent apnea, or requiring >60% FiO₂, intubation and placement on mechanical ventilation were initiated. In the DR, those infants who did not breathe spontaneously were supported with bag-and-mask ventilation for 30 seconds. If they continued not to breathe spontaneously, they were intubated and placed on mechanical ventilation. Surfactant was given on the basis of rescue therapy if the infant's clinical condition and radiographic examination warranted. Application rates of early nasal CPAP increased over time. The authors report that over this time span, BPD incidence decreased from 46% to 11%; surfactant use and ventilator days decreased; rate of sepsis decreased; and daily weight gain improved. Non-pulmonary outcomes such as IVH and ROP showed no significant change. Although an increased incidence of NEC occurred, it did not reach statistical significance; the authors note that this outcome requires further study.

Aly H, Milner JD, Patel K, El- Mohandes AAE. Does the experience with the use of nasal continuous positive airway pressure improve over time in extremely low birth weight infants? Pediatrics 2004;114:697-702.

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POSITIVE END-DISTENDING PRESSURE WITH NASAL CANNULA

Locke RG, Wolfson MR, Shaffer TH, Rubenstein SD, Greenspan JS. Inadvertent administration of positive end-distending pressure during nasal cannula flow. Pediatrics 1993;91:135-138.

Investigating the potential benefits of administering this application.

Positive end-distending pressure is generated by gas flow delivered via nasal cannula. The amount of pressure generated is related to gas flow, nasal cannula size, and size of the infant's nasal passages. This pressure generated is unregulated as compared to a common CPAP system. Mean pressure generated may be as much as 9.8 cm H₂O at a flow of 2 L/min.

In the thirteen infants studied, esophageal pressure was measured as an indication of end-distending pressure and thoraco-abdominal motion was measured to indicate the infant's breathing pattern. The outer prong diameter of the nasal prongs were either 0.2 cm or 0.3 cm. The flow rates used were 0.5, 1, and 2 L/min. No pressure was detected at any of the flow rates while using the 0.2 cm nasal cannula. However, the 0.3 cm nasal cannula generated pressures of 1.4 ± 0.5 cm H₂O at 0.5 L/min, 4.2 ± 0.5 cm H₂O at 1 L/min, and 9.8 ± 1.0 cm H₂O at 2 L/min. There was improvement in thoraco-abdominal motion on flow rates delivered with the 0.3 cm cannula, while no difference was seen while flow rates were delivered via the 0.2 cm cannula (an effect likely related to the delivery of positive end-distending pressure).

The application of positive end-distending pressure via nasal cannula may have mixed implications. Positive pressure generated via higher gas flows with adequate humidity may benefit infants who require nasal CPAP, while decreasing the nasal mucosal damage typically seen in some nasal CPAP systems. In addition, the labor related to nasal prong fit and patient comfort may be decreased. Delivered pressure that is unregulated and unmeasured in a clinical setting has associated hazards and complications including lung over-/under- distention and abdominal distention. Absence of alarms during malpositioning of the nasal cannula may also be significant.

Locke RG, Wolfson MR, Shaffer TH, Rubenstein SD, Greenspan JS. Inadvertent administration of positive end-distending pressure during nasal cannula flow. Pediatrics 1993;91:135-138.

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VARIABLE VERSUS CONTINUOUS FLOW NASAL CPAP COMPARISONS

Courtney SE, Pyon HP, Saslow JG, Arnold GK, Pandit, PB, Habib RH. Lung recruitment and breathing pattern during variable versus continuous flow nasal continuous positive airway pressure in premature infants: an evaluation of three devices. Pediatrics 2001;107:304- 308.

Evaluating three nasal CPAP devices to compare changes in lung volume and breathing patterns.

Three systems commonly used on premature infants were evaluated: a continuous flow nasal CPAP using nasal prongs attached to an infant ventilator set in the CPAP mode, a continuous flow nasal CPAP using a nasal cannula connected to an infant ventilator with a 2.5- mm endotracheal tube adapter set in the CPAP mode, and a variable flow nasal CPAP device. Outcome variables included lung volume and breathing patterns.

The authors report the variable flow nasal CPAP system recruited lung volume better than both continuous flow devices. Mean airway pressure delivered was more constant in the variable flow device group, which most likely explains the reason for the increased lung volume. In addition, less airway leak compared to the continuous devices may also be a contributing factor, as a better seal is formed in the nares due to the design of the nasal prongs in the variable flow device (the prongs flare out during gas inflow and have a larger internal diameter nasal prong). Coupled with the absence of flow on exhalation, there was a reduced work of breathing on the variable flow device as compared to the continuous flow nasal CPAP devices. Interestingly, breathing pattern synchrony improvement was similar on all three devices, despite better lung recruitment on the variable flow device.

Continuous flow nasal CPAP via the modified nasal cannula recruited lung volumes similar to the nasal CPAP prongs, but with significantly increased respiratory rate, asynchronous breathing, and increased FiO₂ requirement.

Courtney SE, Pyon HP, Saslow JG, Arnold GK, Pandit, PB, Habib RH. Lung recruitment and breathing pattern during variable versus continuous flow nasal continuous positive airway pressure in premature infants: an evaluation of three devices. Pediatrics 2001;107:304- 308.

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EXTUBATION MODES: COMPARING SNIPPV VS NASAL CPAP

Khalaf MN, Brodsky, N, Hurley J, Bhandari V. A prospective randomized, controlled trial comparing synchronized nasal intermittent positive pressure ventilation versus nasal continuous positive airway pressure as modes of extubation.. Pediatrics 2001;108:13-17.

Investigating Synchronized Nasal Intermittent Positive Pressure Ventilation versus Nasal Continuous Positive Airway Pressure in extubation.

As more very low birth weight (VLBW) infants survive, clinicians often see an increased duration of mechanical ventilation. Ventilator management of these infants is aimed at minimizing the need for prolonged mechanical ventilation so that ventilator-induced lung injury and oxygen toxicity may also be minimized. Non-invasive means of CPAP are commonly used to wean these infants from mechanical ventilation. Common reasons for extubation failure are upper-airway instability, inadequate respiratory drive, and atelectasis.

During the one year time period discussed in this study, infants who were ≤ 34 weeks GA with RDS were enrolled in a randomized controlled trial to determine whether Synchronized Nasal Intermittent Positive Pressure Ventilation (SNIPPV) would decrease extubation failure as compared with nasal CPAP. Infants were randomly assigned to either SNIPPV or nasal CPAP using sealed envelopes broken into 3 birth weight categories: 500-749 g, 750-999 g, and >1000 g. Infants randomized to nasal CPAP were placed on CPAP of 4 to 6 cm H₂O. Infants randomized to SNIPPV were placed on synchronized IMV at the same rate as they received before extubation; in addition, PIP was increased by 2 to 4 cm H₂O, and PEEP was kept at ≤ 5 cm H₂O. FiO₂ was adjusted to maintain oxygen saturations at 90% to 96% on pulse oximetry in all infants. In both modes, the flow rate was kept at 8 to 10 L/min.

This study showed that the infants extubated to SNIPPV had a higher success rate of extubation compared with the nasal CPAP group (94% vs 60%; $P < .01$) at 72 hours postextubation. In all 3 birth weight categories, more infants on SNIPPV were successfully extubated. Specifically:

- in infants with birth weight <750 g, 5 (100%) of 5 on SNIPPV versus 4 (57%) of 7 on nasal CPAP ($P = .2$);
- in infants with birth weight of 750 g - 999 g, 10 (83%) of 12 on SNIPPV versus 3 (27%) of 11 on nasal CPAP ($P = .01$);
- and those whose birth weight was >999 g, 17 (100%) of 17 on SNIPPV versus 11 (92%) of 12 on nasal CPAP ($P = .41$).

There was no difference in the incidence of apnea in both study groups during the 72 hours. Interestingly, an observation showed a decreased incidence of ROP and decreased CLD in those infants receiving SNIPPV versus nasal CPAP, a result which will require further study.

Nasal CPAP may improve thoraco-abdominal motion synchrony, which has been shown to be improved further while on nasal IMV. Nasal IMV has also been shown to decrease flow resistance through the nasal prongs and to stabilize the chest wall. Flow delivery is increased in the upper airway while on SNIPPV, which also increased tidal volumes when compared to nasal CPAP. SNIPPV may create an inadvertent PEEP which allows recruitment of collapsed alveoli and increases FRC. All of these factors probably account for the success of SNIPPV over nasal CPAP alone.

Khalaf MN, Brodsky, N, Hurley J, Bhandari V. A prospective randomized, controlled trial comparing synchronized nasal intermittent positive pressure ventilation versus nasal continuous positive airway pressure as modes of extubation.. Pediatrics 2001;108:13-17.

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Learning Objectives [back to top](#)

The Johns Hopkins University School of Medicine and The Institute for Johns Hopkins Nursing take responsibility for the content, quality, and scientific integrity of this CE activity. At the conclusion of this activity, participants should be able to:

- Develop a better understanding of the multiple CPAP applications available for neonatal use today;
- Understand the potential therapeutic value a CPAP system may provide;
- Appreciate the advantages and disadvantages associated with the clinical application of a neonatal CPAP system.

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- Dr. Nogee has indicated a financial relationship of grant/research support with Forest Laboratories and has received an honorarium from Forest Laboratories.
- Dr. Lawson has indicated a financial relationship of grant/research support from the NIH. He also receives financial/material support from Nature Publishing Group as the Editor of the Journal of Perinatology.

All other faculty have indicated that they have not received financial support for consultation, research, or evaluation, nor have financial interests relevant to this e-Newsletter.

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