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Nasal intermittent positive pressure ventilation in the newborn: review of literature and evidence-based guidelines

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Various modes of nasal continuous positive airway pressure have been well established as a means of providing non-invasive respiratory support in the neonate. Recent reports suggest that nasal intermittent positive pressure ventilation may offer a better alternative, as a mode of non-invasive ventilation. This article will critically review the literature and provide some practical guidelines of the use of this technique in neonates.
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Introduction

Nasal intermittent positive pressure ventilation (NIPPV)[1–4] is a form of non-invasive ventilatory assistance using a nasal interface to deliver IPPV to provide respiratory support. This manuscript will provide evidence-based guidelines for using NIPPV in neonates, after a critical appraisal of the literature.

Nomenclature

Although a variety of other names have been used in the literature to describe this technique,[5] we prefer the term NIPPV. No studies of the frequency of NIPPV use in neonatal units in the United States have been published; however, 48% of 91 units surveyed in the United Kingdom were using it in 2006.[6]

NIPPV may be synchronized (SNIPPV) or non-synchronized to the infant's breathing efforts. The *primary mode* of (S)NIPPV refers to its use soon after birth. This may or may not include a short period ($\leqslant 2$ h) of endotracheal intubation to deliver surfactant before extubation. The *secondary mode* refers to its use after a longer period (>2 h to days to weeks) of endotracheal IPPV, usually for respiratory distress syndrome (RDS).

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Mechanism of action

Several explanations have been put forward for the effectiveness of SNIPPV. Kiciman *et al*.[7] have shown that thoraco-abdominal motion asynchrony and flow resistance through the nasal prongs is decreased in neonates on SNIPPV, with improved stability of the chest wall and pulmonary mechanics. Addition of a peak inspiratory pressure (PIP) above positive end expiratory pressure (PEEP) by using SNIPPV could be adding increased intermittent distending pressure above PEEP, with increased flow delivery in the upper airway.[8] Moretti *et al*.[9] reported that application of SNIPPV was associated with increased tidal and minute volumes when compared with nasal continuous positive airway pressure (NCPAP) in the same infant. It is also possible that SNIPPV recruits collapsed alveoli and increases functional residual capacity. Recently, Aghai *et al*.[10] have reported that infants receiving SNIPPV have decreased work of breathing.

Technique

Although a variety of nasal interfaces have been used to deliver (S)NIPPV,[5] a majority have used the short bi-nasal or naso-pharyngeal prongs.[11–14] No comparative studies have been published that assess the efficacy of various nasal interfaces to deliver (S)NIPPV. We would recommend the use of short bi-nasal prongs for its ease of placement and maintenance *in situ*.

The Infant Star ventilator with the StarSync module has been used in most of the published SNIPPV studies.[8,10–13,15,16] In the United States, the Infant Star ventilator has been phased out of production, though it is still being used at some centers. In Europe and Canada, synchronization is accomplished with the Infant Flow SiPAP Comprehensive Ventilator (Viasys Healthcare, Yorba Linda, CA, USA). In the United States, the Infant Flow SiPAP Ventilator is available, but the Comprehensive model (which provides synchronization) has not yet been approved by the FDA. The Si-PAP is a bi-level device, providing higher and lower pressures and typically the inspiratory time is much longer. The PIPs generated are typically 9–11 cm H_2O. The 840TM ventilator system (Puritan Bennett Inc., Pleasanton, CA, USA) is being modified to deliver

SNIPPV. A recent report used a nasal ventilator that detected the inspiratory effort by means of a pneumotachograph.[17] Thoraco-abdominal synchronization with SNIPPV may account, in part, for its efficacy. Therefore, the use of synchronization is an important issue that needs additional investigation.[18]

In the United Kingdom, given the widespread use of (S)NIPPV, not surprisingly, a wide variety of ventilator settings have been used.[6] One would anticipate a similar scenario in the units in USA using this technique. In terms of evidence from randomized controlled trials (RCT), the work from our group[11,13,15,16] and other independent investigators[8,12,14] have shown efficacy using fairly similar ventilator settings and guidelines. A recent study that used our SNIPPV guidelines[19] for NIPPV has also reported benefit.[20] A detailed description of the equipment and technique in providing (S)NIPPV, as practiced by our group, has been included in the Appendix.

SNIPPV (primary mode)

Infants in a prospective, observational pilot trial of 28–34 weeks gestational age with RDS requiring surfactant with early extubation to SNIPPV had a shorter duration of intubation and decreased need for oxygen as compared with conventional ventilation (CV).[15] In this study, no infant had bronchopulmonary dysplasia (BPD); not surprisingly, as these were bigger preterm infants. Still, the decreased duration of oxygen use in infants on SNIPPV in that study raises the question of a potential impact of SNIPPV on BPD in more premature infants.

A subsequent RCT compared outcomes of more premature infants (600–1250 g birth weight) who were randomized to either immediate extubation to SNIPPV after surfactant administration or continuing on CV.[13] Infants in the SNIPPV group were extubated to SNIPPV (primary mode) within 90 min after surfactant administration. For the CV group, infants were weaned from CV and monitored by serial blood gas analyses at the discretion of the clinical team. The criteria for extubation were PIP $\leqslant$ 16 cm H_2O, PEEP $\leqslant$ 5 cm H_2O, rate 15–25 min, and fraction of inspired oxygen (FiO_2) $\leqslant$ 0.35. Infants were extubated to SNIPPV (secondary mode), standard practice at the participating sites after the earlier study.[11] There was no difference in the total duration of supplemental oxygen or PPV (duration of endotracheal tube ventilation or SNIPPV) in the two groups. More babies in the CV group, however, had the primary outcome of BPD/death, compared with the SNIPPV group (52 vs 20%, $P = 0.03$), with no difference in other common neonatal morbidities.[13]

NIPPV (primary mode)

Forty-one infants were randomized to NCPAP and 43 comparable infants to NIPPV as an initial mode of respiratory support.[14] Inclusion criteria were gestational age between 24–34 and 6/7 weeks in infants with RDS who needed nasal respiratory support. Both modes of nasal respiratory support were delivered by the SLE 2000 ventilator (Specialized Laboratory Equipment Ltd, South Croydon, UK) through INCA (Ackrad Labs, Berlin, Germany) nasal prongs. In the total cohort, infants treated initially with NIPPV needed less endotracheal ventilation than infants treated with NCPAP (25 vs 49%, $P<0.05$) with a similar trend in infants <1500 g. When controlling for weight and gestational age, NIPPV was more successful in preventing endotracheal ventilation. Importantly, infants treated with NIPPV had a decreased incidence of BPD compared with those treated with NCPAP (2 vs 17%, $P<0.05$, in the total cohort and 5 vs 33%, $P<0.05$ for infants <1500 g).[14]

In another recent RCT, 76 neonates (28–34 weeks gestation) with respiratory distress within 6 h of birth were randomized to receive NIPPV or NCPAP.[20] The failure rate (defined as the need for intubation and mechanical ventilation) at 48 h and 7 days was significantly less among infants randomized to NIPPV. The failure rate of NIPPV was significantly less in the sub-group of 28–30 weeks gestation and those who did not receive surfactant. The combination (28–30 weeks gestation and not receiving surfactant) sub-group had the most benefit, with the number needed to treat being two.[20] There were no differences in other outcomes (including BPD), comparing NIPPV to NCPAP.[20]

NIPPV has been shown to be helpful in avoiding primary intubation in a non-randomized study.[21] Using a similar study design as with SNIPPV in the primary mode,[13] an RCT (in preterm infants <30 weeks gestational age requiring intubation and surfactant soon after delivery) found that extubation to NIPPV reduced the need for endotracheal tube ventilation, and BPD, using either of the 'physiological' or 'clinical' definitions.[22] These two studies[13,22] suggest that early extubation to (S)NIPPV may be an important modifier of the outcome of BPD, even if the total duration of mechanical ventilation is similar.

SNIPPV (secondary mode)

It has been shown that SNIPPV is significantly better than NCPAP in preventing extubation failure within 72 h (and even after including 'late failures') in 154 enrolled infants recovering from RDS.[11] The efficacy and safety of this technique has also been reported by others.[8,12,23] It has also been shown to be effective when introduced as a practice change into a neonatal intensive care unit in which it was earlier not used.[16,24]

Of the three RCT[8,11,12] of SNIPPV vs NCPAP, one reported the intriguing observation that infants who were on SNIPPV (vs NCPAP) had decreased BPD, which was not statistically significant (35 vs 53%; $P = 0.2$).[11] The study was not designed to evaluate specifically whether SNIPPV could decrease BPD, and hence the investigators could only speculate that infants who were on SNIPPV had decreased ventilator-induced trauma and oxygen injury.[11]

A meta-analysis of the three studies identified, comparing secondary mode SNIPPV with NCPAP in the post-extubation period, showed that SNIPPV was more effective than NCPAP in preventing failure of extubation (RR 0.21 (0.10, 0.45), number needed to treat 3 (2, 5)).[23]

The study by Moretti *et al*.[17] included all infants with birth weights <1251 g and having RDS requiring mechanical ventilation at <48 h of life. Infants were randomized to SNIPPV or NCPAP, once extubation criteria were met. SNIPPV was accomplished by using a nasal-flow synchronized ventilator (Giulia, Ginevri, Rome, Italy).[17] Successful extubation (defined as not requiring re-intubation within 72 h) was accomplished in 30/32 (90%) in the SNIPPV group vs 19/31 (61%) in the NCPAP group ($P = 0.005$). There were no differences in any of the secondary outcomes. Interestingly, although statistically not significant, the duration of mechanical ventilation (median days: 6 vs 10, $P = 0.058$) and BPD (6 vs 22%, $P = 0.082$) were both lower in the SNIPPV group.[17]

In the study in which an evidence-based approach was used to introduce NIPPV in a nursery, it was routinely used for extremely low birth weight infants after extubation if apnea or respiratory insufficiency was evident.[24] NIPPV had been used in 9 (90%) of the 10 infants whose charts were randomly reviewed. Interestingly, there was also a significant decline in the number of extremely low birth weight infants discharged on supplemental oxygen (75 and 47%, pre- and post-periods, respectively; $P = 0.01$) from that nursery.[24] In a recent study, introduction of SNIPPV in a neonatal intensive care unit with no prior experience with that modality resulted in infants having significantly less need for supplemental oxygen and decreased BPD, without affecting the incidence of other short-term morbidities.[16] Furthermore, there were no differences between the two groups in nutritional intake or growth parameters.[16]

NIPPV (secondary mode)

In a recent study, intubated premature infants born at ⩽34 weeks or with birth weight ⩽1500 g, ready to be extubated before 4 weeks of age, were recruited.[25] Infants were randomized to either NIPPV or NCPAP after extubation. Although there were significant differences in the demographics in the two groups (NIPPV babies had lower birth and body weights at time of extubation, had fewer males, but more RDS and exposure to antenatal steroids), there were no differences in the primary outcome (re-intubation within 7 days) or treatment-related complications.[25] An important technical issue was that the infants on NIPPV (post-extubation) were kept on the same ventilator settings as while intubated, contrary to what has been carried out in most other studies.[11–14]

(S)NIPPV failure requiring intubation

We did not find pulmonary function parameters, measured just before extubation, very useful in predicting SNIPPV success.[11] Hence, we attempt extubation in all infants if they fulfill clinical criteria, as outlined in the Appendix. We adjust ventilatory settings in all infants on the basis of clinical examination and blood gas data, as mentioned in the Appendix. We have found three categories of infants that tend to fail (S)NIPPV.

Group 1
These infants get re-intubated, usually within a few hours of extubation. Such infants tend to be <750 g weight, and are unable to maintain ventilation and oxygenation parameters in the acceptable range, despite increasing (S)NIPPV settings. On chest X-rays, these infants show significant areas of lung collapse. After re-intubation, we minimize endotracheal ventilatory settings and attempt re-extubation usually after 7 days and/or when the infants have gained another ~100 g of body weight.

Group 2
These babies are likely to get intubated after 3 days or so of being managed with (S)NIPPV. Over the 3 days, these infants usually start developing micro-atelectasis and when a significant amount of lung is involved, fail (S)NIPPV and get re-intubated. Proper anticipation and preemptory increase in the (S)NIPPV settings may avoid the endotracheal tube in such predisposed infants.

Group 3
Infants who get infected may fail (S)NIPPV fairly quickly and get re-intubated. Usually, the cardio-respiratory compromise secondary to sepsis is the inciting event leading to (S)NIPPV failure. We do not attempt to extubate such infants again to (S)NIPPV until clinical manifestations of the sepsis syndrome have resolved.

(S)NIPPV complications

The most serious complication reported with use of (S)NIPPV in neonates has been gastric perforation.[26] All recent studies, however, have not reported any association with necrotizing enterocolitis or gastric or other intestinal perforations with (S)NIPPV use.[11–14,17,22] Although there was a significant increase in the abdominal girth in the NIPPV group, there were no differences in other complications, comparing NIPPV to NCPAP.[20]

Long-term outcomes

The RCT using primary mode SNIPPV reported no differences in the Mental or Psychomotor Developmental Index scores on follow-up between the infants managed with SNIPPV or continued on CV.[13]

Clinical retrospective data from the NICHD/NRN benchmarking trial was used to evaluate the use of SNIPPV in infants ⩽1250 g birth weight.[27] The use of SNIPPV in three birth weight sub-groups (500–750, 751–1000, 1001–1250 g, decided *a priori*) was

Table 1 Selected studies of SNIPPV use in neonates

Author/year	*Type*	*Mode*	*N*	*SNIPPV group*[a]	*Control group*[a]	*Outcomes*
Friedlich *et al.*, 1999[8]	RCT	2^0	41	SNIPPV[b]: rate: 10; PIP: same as pre-extubation; PEEP: 4–6; Ti: 0.6 s; FiO_2 adjusted for SpO_2: 92–95%	NP-CPAP: clinician discretion; FiO_2 adjusted for SpO_2: 92–95%	Less failed extubation with SNIPPV
Barrington *et al.*, 2001[12]	RCT	2^0	54	SNIPPV: rate: 12; PIP: 16 (to deliver at least 12); PEEP: 6	NCPAP: 6	Less failed extubation with SNIPPV
Khalaf *et al.*, 2001[11]	RCT	2^0	64	SNIPPV: rate: same as before extubation; PIP: increased by 2–4 over pre-extubation values; PEEP: $\leqslant 5$; flow: 8–10 l min^{-1}; FiO_2 adjusted for SpO_2: 90–96%	NCPAP: 4–6; flow: 8–10 l min^{-1}; FiO_2 adjusted for SpO_2: 90–96%	Less failed extubation with SNIPPV
Santin *et al.*, 2004[15]	Obs	1^0	59	SNIPPV: rate: same as before extubation; PIP: increased by 2–4 over pre-extubation values; PEEP: $\leqslant 5$; flow: 8–10 l min^{-1}; FiO_2 adjusted for SpO_2: 90–96%	Continued on CV, till ready to extubate to SNIPPV (2^0)	SNIPPV group had shorter duration of intubation, supplemental oxygen, parenteral nutrition, and hospitalization
Kulkarni *et al.*, 2006[16]	Retrospective, case control	2^0	60	SNIPPV: rate: same as before extubation; PIP: increased by 2–4 over pre-extubation values; PEEP: $\leqslant 5$; flow: 8–10 l min^{-1}; FiO_2 adjusted for SpO_2: 90–96%	NCPAP: 4–6; flow: 8–10 l min^{-1}; FiO_2 adjusted for SpO_2: 90–96%	SNIPPV group had shorter duration of supplemental oxygen and decreased BPD
Bhandari *et al.*, 2007[13]	RCT	1^0	41	SNIPPV[b]: rate: same as before extubation; PIP: increased by 2–4 over pre-extubation values; PEEP: $\leqslant 5$; flow: 8–10 l min^{-1}; FiO_2 adjusted for SpO_2: 90–96%	Continued on CV, till ready to extubate to SNIPPV (2^0)	SNIPPV group had decreased BPD/death and BPD
Moretti *et al.*, 2008[17]	RCT	2^0	63	SNIPPV: rate: same as before extubation; PIP: 10–20; PEEP: 3–5; flow: 6–10 l min^{-1}; FiO_2 adjusted for SpO_2: 90–94%	NCPAP: 3–5; flow: 6–10 l min^{-1}; FiO_2 adjusted for SpO_2: 90–94%	Less failed extubation with SNIPPV
Bhandari *et al.*, 2009[27]	Retrospective	2^0 or for apnea	469	SNIPPV: rate: same as before extubation; PIP: increased by 2–4 over pre-extubation values; PEEP: $\leqslant 6$; flow: 8–10 l min^{-1}; FiO_2 adjusted for SpO_2: 85–96%	NCPAP: 4–6; flow: 8–10 l min^{-1}; FiO_2 adjusted for SpO_2: 85–96%	SNIPPV group (BW 500–750 g) had decreased BPD, BPD/death, NDI and NDI/death

Abbreviations: N, total number of infants; SNIPPV, synchronized nasal intermittent positive pressure ventilation.

[a]Initial settings; RCT, randomized controlled trial; 2^0, secondary mode, as defined in the text.

[b]Naso-pharyngeal; rate, ventilator rate (breaths/minute); PIP, peak inspiratory pressure (cm H_2O); PEEP, positive end expiratory pressure (cm H_2O); Ti, inspiratory time (seconds); FiO_2, fraction of inspired oxygen; SpO_2, pulse oximeter oxygen saturation; NP-CPAP, naso-pharyngeal continuous positive airway pressure (cm H_2O); NCPAP, nasal continuous positive airway pressure (cm H_2O); Obs, observational study; 1^0, primary mode, as defined in the text; CV, conventional endotracheal tube ventilation; BPD, bronchopulmonary dysplasia; BW, birth weight; NDI, neurodevelopmental impairment.

examined. It is the largest data set on infants managed with SNIPPV to date. This study revealed that after logistic regression analysis, adjusting for significant covariates, infants who received SNIPPV (compared with those who received NCPAP) in the birth weight category 500−750 g were significantly less likely to have the long-term outcomes of BPD (OR (95% CI), 0.29 (0.11−0.77), $P = 0.01$)), BPD/death (0.30 (0.11−0.79), $P = 0.01$), neurodevelopmental impairment [0.29 (0.09−0.94), $P = 0.04$], and neurodevelopmental impairment/death (0.18 (0.05−0.62), $P = 0.006$).[27]

Selected studies of SNIPPV and NIPPV use in neonates have been summarized in Tables 1 and 2, respectively.

(S)NIPPV during transport

No studies have been published describing the use of (S)NIPPV during transport of the sick neonate.

SNIPPV vs NIPPV

To date, no head-to-head comparative studies have been published comparing SNIPPV vs NIPPV use in the neonate. However, the above literature suggests that both seem to be equally effective (and superior to NCPAP) in keeping infants extubated. This observation is consistent with our anecdotal experience at Yale (as use of the Infant Star ventilators was discontinued).

Strategizing (S)NIPPV

On the basis of the data described above, secondary mode (S)NIPPV would be the preferred approach, over NCPAP. The RCT studies carried out, to date, seem to be promising in terms of (S)NIPPV use in the primary mode in decreasing BPD. It is also important to point out the significant lack of major complications of using (S)NIPPV in all these recent studies,[11−14,17,22] contrary to an earlier report.[26] The caveats include the fact that most RCTs have included small numbers (especially the smallest premature infants), and there are limited data on long-term pulmonary and neurodevelopmental outcomes. Different devices used to provide (S)NIPPV might result in variable outcomes. The Cochrane Review of the use of NIPPV has suggested that future trials should enroll sufficient numbers to detect differences in important outcomes such as BPD.[28] There are at least two ongoing RCT looking at BPD and death as outcomes (NIPPV in premature infants; Clinicaltrials.gov NCT00433212; NIPPV in newborn infants with RDS; Clinicaltrials.gov NCT00780624).

NIPPV has been also advocated as a management strategy for apnea of prematurity. Two studies compared NIPPV vs NCPAP for the treatment of apnea of prematurity.[29,30] Although meta-analysis was not possible, one trial showed a reduction in apnea frequency with NIPPV and the other a trend favoring NIPPV.[23]

Table 2 Selected studies of NIPPV use in neonates

Author/year	*Type*	*Mode*	*N*	*NIPPV group*[a]	*Control group*[a]	*Outcomes*
Kugelman *et al.*, 2007[14]	RCT	1^0	84	NIPPV: rate: 12−30; PIP: 14−22; PEEP: 6−7; Ti: 0.3 s; FiO_2 adjusted for SpO_2: 88−92%	NCPAP: 6−7; FiO_2 adjusted for SpO_2: 88−92%	NIPPV group had decreased BPD
Khorana *et al.*, 2008[25]	RCT	2^0	48	NIPPV: same as pre-extubation ventilator settings	NCPAP: same as pre-extubation PEEP	No differences in outcomes; however, there were significant differences in the demographics of the two groups
Sai Sunil Kishore *et al.*, 2009[20]	RCT	1^0	76	NIPPV: rate: 50; PIP: 15−16; PEEP: 5; Ti: 0.3−0.35 s; flow: 6−7 l min^{-1}; FiO_2 adjusted for SpO_2: 88−93%	NCPAP: 5; flow: 6−7 l min^{-1}; FiO_2 adjusted for SpO_2: 88−93%	Less failed extubation with NIPPV
Ramanathan *et al.*, 2009[22]	RCT	1^0	110	NIPPV: details not reported	NCPAP: details not reported	Less failed extubation with NIPPV and decreased BPD

Abbreviations: N, total number of infants; NIPPV, nasal intermittent positive pressure ventilation.
[a]Initial settings; RCT, randomized controlled trial; 1^0, primary mode, as defined in the text; 2^0, secondary mode, as defined in the text; rate, ventilator rate (breaths per minute); PIP, peak inspiratory pressure (cm H_2O); PEEP, positive end expiratory pressure (cm H_2O); Ti, inspiratory time (seconds); FiO_2, fraction of inspired oxygen; SpO_2, pulse oximeter oxygen saturation; NCPAP, nasal continuous positive airway pressure (cm H_2O); BPD, bronchopulmonary dysplasia.

Conclusion

Although NCPAP is effective, evidence suggests that (S)NIPPV is significantly better than NCPAP in keeping infants extubated. In addition, studies suggest that NIPPV seems to be equally effective as SNIPPV. It is important to clarify that findings from trials described here might not apply to bi-level type of devices. Data is also lacking on long-term pulmonary and neurodevelopmental outcomes. More studies are required to establish the efficacy of using early (S)NIPPV, with or without surfactant administration, especially in the youngest infants at the highest risk for adverse outcome.

Conflict of interest

The authors declare no conflict of interest.

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Appendix

Indications

(S)NIPPV is indicated as follows:

1. A method of non-invasive ventilatory assistance in the spontaneously breathing infant with impending or existing ventilatory failure because of an increased work of breathing.
2. A form of weaning from invasive conventional mechanical ventilation in the spontaneously breathing patient with an increased work of breathing.

Contraindications

a. Upper airway abnormalities
   1. Choanal atresia
   2. Cleft palate
   3. Tracheoesophageal fistula
b. Severe cardiovascular instability

Potential hazards/complications

a. Obstruction of prongs because of mucus plugging
b. Feeding intolerance
c. Abdominal distension
d. Abdominal perforation
e. Ventilator-induced lung injury
f. Hypoventilation
g. Infection
h. Nose bleed/nasal irritation
i. Skin irritation and pressure necrosis

Equipment and supplies

a. Infant Star 500/950 time cycled pressure limited infant ventilator*
b. Star Sync with abdominal probe*
c. V-SIL bi-nasal airway
   1. 2.5 mm (4.0 cm length)
   2. 3.0 mm (4.0 cm length) Or
d. Argyle CPAP nasal cannula kit
   1. X-small
   2. Small
e. Neobar endotracheal tube holder
   1. Ultra
   2. Micro
   3. Small
f. Tape
g. Surgical lube
h. Orogastric tube
i. Suction catheter

*This ventilator, which provides SNIPPV, has been phased out by the manufacturer. We are currently using the Bear Cub 750 psv (Bear Medical Systems, Palm Springs, CA, USA) in our unit to provide NIPPV, using the same guidelines.

Procedure

a. Using V-SIL bi-nasal airway
   1. Trim and apply neobar endotracheal tube holder to infant
   2. Estimate appropriate size airway for infant:
      <1000 g 2.5 MM/OD
      >1000 g 3.0 MM/OD
   3. Estimate depth of the airway in the nasopharynx by measuring from nose to posterior nasopharynx
   4. Lubricate airway with surgical lube
   5. Insert airway through nares to posterior nasopharynx
   6. Secure airway to tube holder with tape
   7. Insert orogastric tube, open to atmosphere
   8. Place on ventilator
b. Using Argyle CPAP nasal cannula
   1. Estimate appropriate size prongs for infant:
      <1000 g—x-small
      >1000 g—small
   2. Position the prongs in the infant's nose; the prongs should fit fully inside the infants nostrils
   3. Slip the head cap behind the infant's head and secure to the prongs with the Velcro straps
   4. Insert orogastric tube open to atmosphere
   5. Place on ventilator

Clinical management

a. (S)NIPPV (primary mode)
   1. Settings:
      - Frequency $\approx$ 40 per minute
      - PIP 4 cm H_2O > PIP required during manual ventilation (adjust PIP for effective aeration per auscultation)
      - PEEP 4–6 cm H_2O
      - Ti $\approx$ 0.45 s
      - FiO_2 adjusted to maintain SpO_2 of 85–93%
      - Flow 8–10 l m^{-1}
      - Caffeine 15–25 μgm ml or aminophylline level $\geqslant 8$ μg ml^{-1}
      - Hematocrit $\geqslant 35\%$
   2. Monitor SpO_2, HR and respirations
   3. Obtain blood gas in 15–30 min
   4. Adjust ventilator settings to maintain blood gas parameters within normal limits
   5. Suction mouth and pharynx and insert clean airway Q4, as necessary

6. Maximal support recommendations:
   $\leqslant$1000 g MAP 14 cm H_2O
   >1000 g MAP 16 cm H_2O

b. (S)NIPPV (secondary mode)

1. Extubation criteria while on CV:
   - Frequency $\approx$15–25 per minute
   - PIP $\leqslant$16 cm H_2O
   - PEEP $\leqslant$5 cm H_2O
   - FiO_2 $\leqslant$0.35
   - Caffeine 15–25 $\mu g\,ml^{-1}$ or aminophylline level $\geqslant 8\,\mu g\,ml^{-1}$
   - Hematocrit $\geqslant$35%
2. Place on (S)NIPPV
   - Frequency $\approx$15–25 per minute
   - PIP 2–4 $\uparrow$ > CV settings; adjust PIP for effective aeration per auscultation
   - PEEP $\leqslant$5 cm H_2O
   - FiO_2 adjusted to maintain SpO_2 of 85–93%
   - Flow 8–10 l m^{-1}
3. Suction mouth and pharynx and insert clean airway Q4, as necessary
4. Maximal support recommendations:
   $\leqslant$1000 g MAP 14 cm H_2O
   > 1000 g MAP 16 cm H_2O

c. Considerations for re-intubation

1. pH < 7.25; $PaCO_2$ $\geqslant$60 mm Hg
2. Episode of apnea requiring bag and mask ventilation
3. Frequent (>2–3 episodes per hour) apnea/bradycardia (cessation of respiration for >20 s associated with a heart rate <100 per minute) not responding to theophylline/caffeine therapy
4. Frequent desaturation (< 85%) $\geqslant$3 episodes per hour not responding to increased ventilatory settings

d. (S)NIPPV weaning to oxyhood/nasal cannula

1. Minimal (S)NIPPV settings
   - Frequency $\leqslant$20 per minute
   - PIP $\leqslant$14 cm H_2O
   - PEEP $\leqslant$4 cm H_2O
   - FiO_2 $\leqslant$0.3
   - Flow 8–10 l m^{-1}
   - Blood gases within normal limits
2. Wean to:
   - Oxyhood adjust FiO_2 to keep SpO_2 85–93%
   - NC adjust flow (1–2 l m^{-1}) and FiO_2 to keep SpO_2 85–93%