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Review Article

Synopsis on Non-invasive Ventilation in Neonatology

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Abstract

Non-invasive ventilation (NIV) is a mode of respiratory support commonly used on the neonatal unit. Since the advent of NIV, it has evolved from be- ing used as a mode of respiratory support to wean infants from mechanical ventilation (MV) to a primary mode of respiratory support. NIV improve the functional residual capacity in the newborn (at term or preterm) avoiding invasive actions such as tracheal intubation. Newer methods of NIV support such as nasal bilevel positive airway pressure (BiPAP) and humidified high flow nasal cannula oxygen therapy (HHFNC) have emerged in attempts to reduce intubation rates and subsequent MV in preterm infants. With this synopsis, we aim to discuss various available NIV modes of ventilation in Neonatology, including indications, physiological principle, practical as- pects and effects on important short and long term morbidities associated with the use of NIV.

Keywords: heated humidified high flow nasal cannula, nasal continuous positive airway pressure, nasal intermittent positive pressure ventilation, noninvasive ventilation, preterm infants

Introduction

Invasive Mechanical Ventilation (IMV) has been the primary treatment in Respiratory distress Syndrome (RDS) for Very low birth weight babies (VLBW). Although lifesaving, IMV is an important risk factor in developingBroncho pulmonary dysplasia (BPD) and its related complications [1].

Affected infants require comprehensive medical followup and treatment af- ter hospital discharge with frequent hospital readmissions, home based oxygen therapy, treatment for pulmonary hypertension, these factors thus significantly affect quality of life of affected infants [2].

Despite advances in neonatal medicine, such as improved antenatal care, antenatal corticosteroids and surfactant administration; there hasn't been significant fall in incidence of BPD in last decade [3].

IMV causes volutrauma, barotrauma, inflammatory mediated alveolar and vascular destruction resulting in progressive impaired gas exchange. To al- leviate the harmful effects of IMV on the premature lungs, nasal CPAP was introduced as a non-invasive ventilation strategy. CPAP was first used clini-cally in 1971, CPAP significantly reduced the need for IMV, but failure ratesof almost 50% have prompted for seeking more effective NIV modalities [4, 5].

There are various non-invasive ways in which respiratory support can be provided to neonates with parenchymal lung disease or apnoea viz heatedhumidified high flow nasal cannula (HHHFNC), Continuous Positive Airway Pressure (CPAP), Nasal Intermittent Positive Pressure Ventilation (NIPPV).

Heated Humidified High Flow Nasal Cannula (HHHFNC)

HHHFNC is commonly used in most NICUs throughout the world. It is a flow based non-invasive respiratory support which delivers heated and humidi-fied gas.

Oxygen delivered by "low flow" nasal cannula (LFNC) typically refers to theuse of flow rates of less than or equal to 1-2 L/minute. Usually the gas usedis unblended (i.e.100% oxygen), unheated and non-humidified. LFNC is used commonly in growing convalescent preterm infants (often with chron-ic lung disease). In contrast, "high flow" nasal cannula (HFNC) has been used to refer to the administration of oxygen or blended oxygen/air to newborn infants via nasal cannula at higher flow rates than LFNC. The useof devices providing use of humidified high flow by nasal cannula (HFNC) to these babies has increased dramatically over last few years due to rela-tive simplicity of its use and user friendly nature [6]. Most commonly it is used for babies recovering from RDS on low pressure nCPAP and FiO2 andwho would traditionally undergo a period of cycling nCPAP regimen beforediscontinuing respiratory support. Anecdotally, HFNC allows infant to be handled less, makes easier to receive kangaroo care and breast feeding than nCPAP. The clinical role of HFNC is still evolving and further controlled clinical trials are needed to identify which infants benefit most from HFNC.Despite its popularity, the use of HFNC should not be extended as a routine replacement for nCPAP until further large randomised controlled trialscomparing efficacy and safety are published and the unit gains enough ex-perience using it on stable babies [7].

Physiological Principles of HFNC (8)

1. Washout of Naso-pharangeal dead space
2. Reduces respiratory resistance and hence decreases work of breathing
3. Provides continuous distending pressure; pharyngeal pressure providedis directly related to flow but inversely related to infant size.
4. Respiratory gas conditioning; improves lung and airway mechanics byeliminating the effect of drying/cooling.

Differences from nCPAP

HFNC should not be regarded as a form of nCPAP. Rather, it is a distinct respiratory support modality that should be assessed on its own merits in the same way as for other modalities of ventilation.

nCPAP has been shown to reduce extubation failure, treat apnoea and res-piratory distress syndrome, and may reduce chronic lung disease by min- imising duration of mechanical ventilation. Oxygen administered by nCPAPis usually blended, humidified and heated. Contrary to HFNC, the pressuredelivered by the circuit for nCPAP is measured and regulated directly. Theuse of binasal prongs to deliver nCPAP can be associated with trauma to the nasal septum and distortion of the nares. Difficulties with successful ap-plication of nCPAP are principally related to the bulky interface with the pa-tient leading to problems maintaining proper position and effectiveness. It also is less patient friendly making handling and feeding more difficult while on nCPAP [9].

In contrast, HFNC provides blended, heated, humidified oxygen at flow rates higher than the patient's inspiratory flow rate thereby reducing work of breathing and ensuring that intended oxygen concentration is delivered.If prongs are selected properly, HFNC is an open system potentially reduc-ing the risk of baro/volutrauma and reducing nasal mucosal damage. It cre-ates a flow related variable distending pressure delivered to the neonates upper airway and lungs that unlike CPAP is unmeasurable in clinical prac-tice,. Adult studies suggest it provides low PEEP, improves mucosal perfu-sion and stimulates respiratory drive. The interface is less bulky, allowing easy access for parents and nurses for handling and feeding purposes. [10, 11]

Possible Risks

Concerns that have been expressed include increased risk of infection (Vapotherm only), excessive airway pressure generation (avoid a tight fit nasal prong) and local trauma (avoid a tight fit nasal prong)

Indications for use

No formal recommendations are available for specific clinical indications published. Collectively published studies suggest a wide potential role for HFNC in respiratory care of the neonate.
Consider HFNC on:

- Stable babies recovering from RDS or with chronic lung disease
- $FiO_2 \leq 30\%$
- Ready to be cycled off on nCPAP at a pressure of 5cm H20 or lower.
- No significant apnoea, desaturations or bradycardia requiring frequent stimulation. These set of babies are likely to benefit from HFNC as weaning will be more physiological, and user friendly.

Relative Contraindications:

- Should not be used on babies where a suitable loose fit nasal cannulais not available (extremely small nares). Avoid tight fit nasal cannula at all cost
- Use judgment for babies with significant CLD. This may take some ex- perience
- Not to be considered for babies who can be taken off nCPAP to air di-rectly i.e. stable term/ near term babies.

Variables	Suggested Initial Parameters
Adequate gas heating	Maintain at 34–37 o C
Adequate gas humidification	100% Relative humidity
Allowance for gas leak from nares	Preferred cannula to nares ratio ~ 0.50
	Should be < 0.80
Maximum allowed flow = 8 l min	Per manufacturer's design/ approval
Wean FiO2 first	Consensus with limited trial data Wean to < 0.30 before weaning flow
Increase flow	For increasing FiO2 and/or WOB
Initial flow rate	Begin at 4–6 l min^{-1}
Decrease flow	When stable FiO2, RR and WOB for 12–24 h
Change to other NIV mode	If FiO2 consistently > 0.40
	If consistently increased WOB If excessive or severe apnea
Stopping nHFT	Flow 4 l min^{-1}

Table 1: *Initial Settings on HFNC*

Nasal CPAP- Nasal Continuous Positive Airway Pressure

CPAP aims to prevent alveolar collapse at end expiration. It is used for in- fants with moderate respiratory distress and for recurrent apnoeas. It is alsoused for weaning from mechanical ventilation. Use of early CPAP has signif- icantly reduced the need for invasive ventilation and surfactant administra-tion in preterms [12, 13].

Physiological principle:

1. Provides continuous distending pressure to maintain functional residual capacity (FRC) –reduction of airway collapse by decreased airway resistance and reduces work of breathing
2. Splints the pharyngeal airway to avoid obstruction
3. Keeps the surfactant on alveolar surface and thus promotes reduction ofalveolar edema
4. Improves the ventilation-perfusion ratio and decreases intrapulmonaryshunting

Indications for CPAP include (14):

- Babies weighing less than 1000 grams with respiratory distress and agood respiratory drive.
- Clinically increasing respiratory distress in any gestation (check to ruleout pneumothorax)
- Post-extubation in VLBW babies.

Use CPAP with caution in:

- Meconium aspiration syndrome, for the risk of pneumothorax in avigorous baby
- Gastrointestinal malformations for e.g. Tracheo-oesophageal fistula; for the risk of abdominal distension causing splinting of the chest leading to a further compromise of ventilation. In this situation insert an NG tube and aspirate the stomach periodically.

Practical considerations:

- The most appropriate size of hat and nasal prongs / mask should be selected.
- The fit of these should be "snug" but never tight. The fixing ties should never be over tightened in order to maintain a seal as this maycause damage to the face.
- Humidity must be used when delivering CPAP; humidified oxygen must be delivered at a temperature of 37 C at the baby's nose.
- Babies with respiratory distress and who weigh less than 1000grams, requiring non-invasive respiratory support should be nursed on nC-PAP.
- Normal CPAP pressures are 5 to 6 cm of water. The use of higher lev- els of CPAP for individual babies must be agreed by the multi -disci- plinary team (MDT) and this decision documented in the notes. As the condition of the baby improves the pressures can be carefully weaned to 4cm water.
- Some babies become agitated on CPAP. Appropriate "nesting" and removal of noxious stimuli such as light and noise can alleviate this. Occasionally sedation such as Chloral Hydrate may need to be con- sidered if these strategies are not working.

  For babies extubated onto CPAP not being able to maintain an ad-equate respiratory effort, re- intubation will be required. Signs that aid in the assessment for the need to be reintubated are:
- Significantly increased frequency and severity of apnoeas and brady-cardias
- Increasing oxygen requirements over 60%in term babies and over 40% in preterm babies
- Increased work of breathing
- Poor gases

Complications of CPAP (15):

- Gaseous distension of the stomach +/- feeding difficulties
- Nasal trauma from the pressure of the prongs / mask
- Pneumothorax

Weaning from CPAP:

- Once respiratory distress is settling, weaning from CPAP may be commenced.
- Gradually try to wean the oxygen to air and the PEEP to 5 cm water.
- When the PEEP is 5 cm water and the oxygen requirement is ≤30% consider switching over to High flow nasal cannula Oxygen (HFNC) and monitor work of breathing. See HFNC guideline.
- Babies weighing less than 1000 grams, who are being nursed on nC-PAP, should not be weaned from CPAP until the MDT decide that the baby has a consistently strong respiratory drive.
- If the baby has to work excessively to maintain respiratory status thenCPAP should be reinstated. Signs of increase in work of breathing in-clude:

Tachypnoea consistently >60 /min

Tachycardia - >160beats / min

Increasing sub and intercostal recessions

Increase in oxygen by more than 10-20%

Increase in the number of desaturations/bradycardias

Removal from CPAP without Weaning:

Term/Near term babies may require CPAP for only a short time and may notneed to wean incrementally from CPAP but may cope well in ambient oxy-gen or air.

Use of Blood Gases in babies on long term CPAP

Any baby who is placed on CPAP for worsening respiratory distress shouldhave gases taken as frequently as clinical condition dictates. As a guide –

1. For Term / near term babies
   - Take gases 4 hrs after CPAP discontinued if clinical condition remains stable in between. Earlier gases are recommended if clinical condi- tion seems unstable to assess need for escalating support.
   - If subsequent saturations are > 98% in air, gases do not need to be taken again.
   - If in oxygen, take at least one gas daily
2. Preterm/LBW Babies 1 to 14 day old
   - Gases should be taken at least daily for babies who are on CPAP in oxygen or on HFNC in oxygen
   - Gases should be taken at least 2 times a week for babies on CPAP inair.
   - Preterm/LBW Babies 14 days to 28 days
   - Gases should be taken at least 2 times a week for babies who are sta-ble on CPAP in oxygen.

- Gases should be taken once a day for babies who are on HFNC inoxygen and on alternate days in those who are on HFNC in air.

Variables	Suggested Initial Parameters
Adequate gas heating	Maintain at 34–37 C
Adequate gas humidification	100% Relative humidity
Gas flow	8–12 L/min; an high flow leads a greater stability of blood pressure during respiratory cycle and a decreasein WOB.
Initial CPAP pressures	Initial PEEP- 5-6 cm of H2O. Thereafter, the CPAP level has to be adapted according to clinical condition,oxygenation, and perfusion.
Wean FiO_2 first	Consensus with limited trial data Wean to < 0.30 be-fore weaning PEEP
Change to other NIV mode	If FiO_2 consistently > 0.40 If consistently increased WOB If excessive or severeapnea

Table 1: *Initial CPAP settings*

Non-invasive Positive pressure Ventilation

Non-invasive intermittent positive pressure ventilation has emerged as an alternative strategy to n-CPAP. It delivers time-cycled positive pressure ven- tilation above a PEEP level in the absence of ET tube [16].

NIPPV can be delivered as:

1. CMV NIPPV
2. BiPAP (Bilevel - NIPPV)

CMV-NIPPV: CMV-NIPPV uses a ventilator to provide intermittent breaths at PIP and rates similar to those used for Mechanical Ventilation.

Physiological Principle:

1. Stablises the alveoli by providing positive airway pressure(PEEP)
2. Promotes better ventilation by delivering positive pressure breaths tothe lower airway
3. Triggers an augmented inspiratory reflex (head’s paradoxical reflex) inpreterm infants.
4. Less inflammation than Invasive Mechanical Ventilation

BiPAP:

It is a form of non-invasive ventilation that provides two alternating levels of CPAP at set intervals using nasal prongs or face mask while the baby is breathing spontaneously. Difference between high and low nCPAP pres- sure is < 4cm H2O. BiPAP is an alternative method to increase mean airway pressure (MAP) without reaching peak values typical of CMV-NIPPV.

Physiological Principle:

1. Delta P produced by the ventilator creates a switch from FRC level toanother one
2. Derived changes in FRC improves alveolar ventilation
3. Vt depends on both Delta P and lung compliance.

CMV-NIPPV and BiPAP are respiratory support modality with different mechanism to support breathing and their use should be assessed on mer-its and clinical judgement in the same way as for other modalities of ventila-tion.

CMV-NIPPV and BiPAP can be delivered either synchronised or non-syn- chronised. There are various ways of synchronising breaths while the new- born is on CMV-NIPPV/BiPAP however, it is difficult to obtain synchronisa-tion due to open ventilation and very low pressure in preterm infants. NAVA presently offers better possibility of synchronisation. Oesophageal feedingtube is used for NAVA. It signals the onset of diaphragmatic contractions. However, in preterm the combination of diaphragmatic contractions/glottis opening is out of phase in 60% cases because glottis opening doesnot fol- low immediately diaphragm contraction. Therefore, ventilation flow could find the glottis closed although diaphragm starts to move downward.There- fore, synchronisation of breaths is difficult with CMV-NIPPV or BiPAP and hence both are generally used in a non-synchronised mode.

When compared with nCPAP; CNV-NIPPV/BiPAP improves thoraco-abdom- inal synchrony, increases tidal volume and minute ventilation and thus de-creases work of breathing and improves CO2 clearance. These effects are better pronounced with synchronised than non-synchronised ventilation.

CMV-NIPPV	BiPAP
Time cycled	Time cycled
Spontaneously breathing neonate	Spontaneously breathing neonate
Uses PIP and PEEP similar to Mechanical Ventilation	Provides 2 alternating levels of CPAP at set interval Higher CPAP pressure provided for sigh breaths is much lower than PIP provided in CMV-NIPPV
Shorter inflation time	Longer inflation time(0.5-1 sec) for the higher nC-PAP pressure

Higher cycle rate(10-60/min)	Lower cycle rate(10-30/min)

Indications for NIPPV [17]:

1. Post-extubation failure: In comparison with n-CPAP, NIPPV decreases thefrequency of post extubation failure; based on clinical judgement can be considered in neonates with CPAP failure.
2. Apnea of prematurity: In preterm with recurrent apneas while on CPAP,NIPPV has shown to reduce frequency of apnea or need for intubation.

There are 3 kind of interfaces applicable for NIPPV between device and newborn.

1. Short binasal prongs
2. Hypopharangeal tube
3. Nasal mask

Short binasal prongs represent the better interface for both the comfort of the neonate (they adapt correctly and with minimal injury) and the successof the technique (lower flow resistance).

Variables	Suggested Initial Parameters
PIP	10 cm of H2O above CPAP or 2 cm of H2O abovethe set PIP which was earlier applied during Me- chanical Ventilation Maximum PIP- 22 cm of H2O
PEEP	4-6 cm of H2O
Ventilation rate	40-50/min
FiO2	Aim for SPO2 between 91-94%; MaximumFiO2-60%
Flow rate	8-12lts/min
Inflation time	0.3-0.5 sec

Table 1: Initial Settings for CMV-NIPPV

Variables	Suggested Initial Parameters
Level of lower airway pressure	4-6 cm of H2O
Level of higher airway pressure	8-10 cm of H2O
Time of higher airway pressure breaths	0.7-1 sec
Ventilation rate	20-30/min
FiO2	Aim for SPO2 between 91-94%; MaximumFiO2-60%
Flow rate	8-12lts/min

Table 2: *Initial Settings for BiPAP*

Safety of NIPPV:

1. Abdominal distension: Less likely to be clinically significant if regularOG tube aspiration is done.
2. Nasal septum erosion/nasal trauma similar to that observed with nCPAP
3. Air leak Syndrome

NIPPV Failure

Consider invasive ventilation in neonates on NIPPV with:

1. Worsening respiratory acidosis
2. Cardiorespiratory compromise
3. FiO2 requirement > 60%.

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