Non-invasive ventilation in Pediatrics

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Mechanical Ventilation in PCCU

• Intubations 30% (range 20 – 64%)

• For mean 5–6 days

• Complications
  ✓ Infection, tracheal injury, sedation
  ✓ Tracheostomy
  ✓ Volum trumas/ barotraumas
  ✓ BPD (Bronchopulmonary Dysplasia)

Non-invasive ventilation in PCCU

• Ventilation support without establishing airway.
  – Non-invasive ventilatory support can reduce the adverse effects.
Ventilation Perfusion Ratios

- **Low \( \dot{V}_A/Q \)**
  - \( P_{O_2} = 40 \)
  - \( P_{CO_2} = 45 \)
  - \( CO_2 = 45 \)

- **Normal \( \dot{V}_A/Q \)**
  - \( P_{O_2} = 100 \)
  - \( P_{CO_2} = 40 \)

- **High \( \dot{V}_A/Q \)**
  - \( P_{O_2} = 150 \)
  - \( P_{CO_2} = 0 \)
  - No flow

\( PO_2 = 150 \)
\( PCO_2 = 0 \)
Non-invasive ventilation in PCCU
History

• During the 1930s, Poulton reported the first usage of continuous positive airway pressure (CPAP) in patients with pulmonary edema, asthma, and pneumonia.
• In the 1960s, CPAP was found to be successful in the treatment of pediatric patients with post-cardiac and neonatal hyaline membrane disease.
• Soon after, CPAP was being used in adult patients with acute respiratory distress syndrome.
• Today, CPAP is used in all age groups in patients with chronic illnesses such as obstructive sleep apnea (OSA) and chronic obstructive pulmonary disease as well as acute illnesses such as pneumonia and pulmonary edema.
• More recently, bimodal positive airway pressure (BiPAP) provides inspiratory positive airway pressure (IPAP) and expiratory positive airway pressure (EPAP). This mode of ventilation is similar to the combination of CPAP and pressure support ventilation.
Objectives of Noninvasive Ventilation in Pediatric Patients With Respiratory Disorders

- Reduce work of breathing (Reduce oxygen consumption).
- Reverse hypoventilation (Increase TV).
- Increase FRC (improve oxygenation, lung compliance).
- Maintain and splint collapsed airways.
- Preserved defense mechanisms.
- Improve diaphragmatic activity.
- Less sedation.
Non-invasive ventilation when?

- Progressive respiratory failure in the absence of apnea or impeding cardiorespiratory collapse.
- **Early.**
- Relative cooperation.
- Adequate mask fit
Non-invasive ventilation where?

ICU  NIV  Ward

Others
Non-invasive ventilation
who?

Indication:
- AHRF, BA, PE
- Upper airway obstructions (stenting the airways)
- Atelectasis
- Neuromuscular diseases
- Weaning from invasive ventilation

Contraindication
- Apneas
- Hemodynamic instability
- Refractory hypoxemia
- Impaired mental status
- Moderate to severe bulbar weakness
- Inability to handle oral secretions
- Inability to tolerate nasal or face masks
- Upper gastrointestinal bleed
- Acute facial trauma
- Upper airway abnormalities...choana latresia...

Cleft palate
Non-invasive ventilation
who?
Non-invasive ventilation
How?

Noninvasive Mechanical Ventilation

Rani Ganesan, MD,* Kim D. Watts, MD,† Steven Lestrud, MD*‡

Patients with respiratory distress and respiratory failure presenting to the emergency department provide a diagnostic and therapeutic challenge. Developing technologies in noninvasive positive pressure ventilation (NIPPV) have improved the ability to administer significant respiratory support to these patients. Research and protocols for NIPPV are expanding in adult medicine but are only slowly increasing in pediatrics. NIPPV has successfully been used for obstructive sleep apnea, asthma, cystic fibrosis, and neuromuscular disorders in both acute and chronic settings. Early administration of this support may benefit patients presenting to emergency departments by improving oxygenation, ventilation, and muscle fatigue; avoiding short- and long-term complications of invasive mechanical ventilation; and improving patient outcomes.

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KEYWORDS mechanical ventilation, continuous positive airway pressure, obstructive sleep apnea, bimodal positive airway pressure
Non-invasive ventilation
How?

Noninvasive Mechanical Ventilation

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clinical expertise. NIPPV may be delivered via nasal or full-face mask. Both modes of administration can deliver adequate support. However, full-face masks provide more constant and reliable pressure delivery. Nasal masks are best suited for patients who are able to comfortably keep their mouths closed. These masks are considered more comfortable by patients. Infants, who are obligate nose breathers, generally benefit more from nasal prong CPAP or high-flow nasal cannula.
Use of NCPAP

• Continuous positive airway pressure (CPAP) was first used as a method of supporting the breathing of infants and Neonates in 1960s.

• In USA, Canada, Australia and New Zealand, Nasal CPAP use increased four-fold over the past decade.
Which Nasal CPAP Device Should be Used?

Devices in common use for the delivery of nasal CPAP includes:

2. Double (Bi-nasal) prongs,
   - Both short (nasal) and long (Naso-pharyngeal) forms.
3. Face Masks
4. Nasal Cannula
Types of prongs:

- Argyle
- Hudson
- Inca
Types of prongs:

- Fisher & Paykel
- EME
- Others
Acute Non-invasive ventilation
How?
How to fix CPAP
Single versus double prong devices of Nasal CPAP devices in very preterm neonates

Meta-analysis of randomized trials showed that:

1-Short Bi nasal devices are more effective at preventing re-intubation in the week post-extubation

2-Short Bi nasal device have better oxygenation, respiratory rate, and weaning success when compared with single prong nasopharyngeal CPAP.

WHY: Probably due to lower resistance, allowing greater transmission of the applied pressure to the airway.
Which short Bi Nasal prongs should be used?

- Available short Bi Nasal prongs: Argyle prong, Hudson prong, infant flow driver (IFD), and INCA prongs.

- Studies using lung models suggested that the prototype IFD: compared with Argyle prongs and Hudson prongs generates more stable pressures.
Types of CPAP

• Continuous flow CPAP:
  bubble CPAP
  ventilator generator
• Variable flow CPAP.
Work of breathing when using constant or variable flow system

• Work of breathing is decreased with variable-flow NCPAP(IFD) compared with constant-flow NCPAP.
• The increase in WOB with constant-flow NCPAP indicates the presence of appreciable imposed WOB with this device.

PareshB. Pandit, MD*‡; Sherry E. Courtney, PEDIATRICS Vol. 108 No. 3 September 2001
CPAP Pressure Generators

- Ventilator CPAP
- Flow Driver CPAP
- “Bubble Bottle” CPAP
- Others
What are the Optimal Flow Characteristics?

• The amount of gas flow through the CPAP circuit is important AND depends on the system used to generate the CPAP.

• Insufficient set flow : limits the flow available for inspiration, increasing airway pressure fluctuation, and raising the work of breathing.

• The flow required is affected by the degree of "leak" of gas from the infant’s nose and mouth.
What are the Optimal Flow Characteristics

- Flow of 6 l/min or greater. If the mouth is open
- Flow of 6 l/min or less if the mouth is tightly closed and the nasal prongs are a good fit (that is, minimal "leak")
Infant flow driver system

- The IFD needs flows in excess of 8 l/min to generate pressures around 5 cm H2O.
- The "expiratory" limb of the IFD is unusual among CPAP devices in that it is open to the atmosphere.
- Potentially, the baby can inspire with a higher flow than that delivered through the inspiratory limb. This extra gas can be drawn from the expiratory limb ("variable flow").
- This reduces the possibility of the pressure falling with large inspirations and therefore may reduce the work the baby expends to take large breaths.
Conventional ventilators for nasal CPAP, How much flow???

- usually Flow is set for 6 lit/min
  - If the flow is low the work of breathing may be increased.

- The work of breathing was found to be increased with conventional ventilator driven CPAP
  - (circuit flow limited to 6 l/min) compared with an IFD system
- A flow of 6 l/min is certainly sufficient to supply the minute volume of all but the largest, most vigorously breathing infants,
- The “amount of leak”, through the mouth, affects how much flow is required to maintain the CPAP pressure in the pharynx.
- In theory, too much flow might be better than too low a flow.
How Much Pressure Should be Applied?

- The optimal CPAP pressure depend on the condition treated.
- Is the nasal CPAP to supporting the upper airways: apnia & low fIO2 then pressure of 4-5 cm H2O is good
- Is the nasal CPAP to support the stiff lungs & high Fio2 like HMD: 5-8cm H2O may be needed
- NB; High pressures in an infant with compliant lungs may restrict pulmonary blood flow, increase the risk of air leak, or cause over-distension leading to hypercapnia.
- If an infant disease of lungs is worsening with increasing oxygen requirements, a more opaque chest x-ray, and is recessing, we would increase the pressure in increments of 1 cm H2O, up to 10 cm H2O, and observe the effect.
Is Nasal Intermittent Positive Pressure Ventilation (NIPPV) A useful Method of Augmenting NASAL CPAP

- Some guidance on appropriate ventilator settings: PEEP: 5–7 cm H2O;
- PIP 2–4 cm H2O above pre-extubation level or 16–20 cm H2O
- ventilator rate 10–25 per min;
- flow 8–10 l/min;
- Inspiratory time 0.6 seconds.
How Do We Know An infant Is "FAILING" on Nasal CPAP and What Are The Remediable Causes?

The following are typical "failure" criteria for infants treated with nasal CPAP for early RDS:

1- Persistent serious apnoeic episodes.
2- PaCO2 of more than 60 mm Hg.
3- FiO2 need of more than 0.6 to maintain acceptable oxygen saturation.
4- Respiratory distress.
How Do We Know An infant Is "FAILING" on Nasal CPAP and What Are The Remediable Causes?

• Correctable causes for apparent failure of nasal CPAP include:
  ✓ Insufficient applied pressure.
  ✓ Insufficient circuit flow.
  ✓ Inappropriate prong size or placement.
  ✓ Airway obstruction from secretions (nose, pharynx).
  ✓ A baby’s open mouth creating a large leak and lowering the pharyngeal pressure.
How frequent to suction nasal secretion

• There are no data to help deciding the frequency of suction of nasal secretions.
• Excessive suction interferes with CPAP delivery and can traumatize the nose.
• Frequency of suctioning needs to be individualized to the infants requirement
Is Mouth Closure Important?
Is Mouth Closure Important?

- Mouth closure, with a pacifier, or by direct closure, will raise pharyngeal pressure.
- The pharyngeal pressure may fall significantly if the mouth is open even slightly.
- Chin straps have been used to avoid the fluctuations in the delivered pressure seen with intermittent mouth opening.

- The success of CPAP has been shown in most studies without actively closing babies’ mouths.
What is the Optimal Posture to nurse a baby on NCPAP?

- The evidence for the optimal position for the baby is lacking.
- The supine position is often used as it facilitates easier care of the CPAP device.
- **However studies have shown that preterm infants nursed prone are less likely to suffer central and mixed apnoea.**
- Avoiding excessive flexion, extension, or rotation of the head and neck would appear to be sensible.
How Should Infants be Weaned from NCPAP

• There are many different methods of weaning infants from nasal CPAP.
• Infants on low Fio2 and CPAP of 5 may be given a
1-Trial off CPPAP
2-Cycle ON & off CPAP before stopping !!!
3-Weaning to lower pressure settings.

There was no significant difference between different ways of weaning from CPAP in the total duration of nasal CPAP, days of ventilation after initial extubation, CLD, or IVH
BIPAB
NIPPV MANAGEMENT

Note: For initial setup you may need to use a lower IPAP to achieve a proper mask seal. Then titrate between the suggested range.

Initial Settings

** IPAP: 12-20 cmH2O **
- titrate for Work of Breathing and RR
** EPAP: 6-12 cmH2O **
- consider higher settings for pulmonary edema
- consider previous established CPAP level for OSA
- consider lower EPAP for COPD exacerbation (6-8 cmH2O)

Rate: 8-14
- patient must be spontaneously breathing
- setting too high can cause patient discomfort
Rise Time/ITime
- adjust for patient comfort
FiO2: .21-1.0
- adjust to maintain SpO2 90-95%

Initial goal is SpO2 >90% and RR < 30

30-60 min ABG and Assessment

Therapeutic Goals Reached

- RR < 25
- Return to patient baseline or normalized pH
- SpO2 > 90% with FiO2 < .50
- Baseline or no accessory muscle use
- Baseline level of consciousness and orientation

Ventilation

- Increase ΔP (IPAP-EPAP)
  - increase IPAP to a maximum of 24 cmH2O
  - decrease EPAP if safe to do so:
    - consider oxygenation
    - consider underlying OSA (if present)

Oxygenation

- Adjust FiO2
- If unable to decrease FiO2 < .50 consider increasing EPAP
- try to maintain ΔP (IPAP-EPAP) by adjusting IPAP appropriately

Yes

Trial off NIPPV **

- Wean ΔP (IPAP-EPAP)
- Wean EPAP level

No

Patient Tolerated?

Yes

Continue off NIPPV

When patient tolerates being off for 24 hours discontinue medical directive. (12 hours for CHF patients)

No

Restart NIPPV on last effective settings

Consider a reduction in settings once stabilized

Trial off NIPPV ** once ΔP (IPAP-EPAP) < 10 cmH2O with EPAP < 8 cm H2O (unless using established level for OSA)
Inclusion criteria
1 month to 15 years, RF based on Fio2 50% for 94%, and evidence of moderate to severe respiratory distress.

Exclusion criteria
FIO2 50% and Tal score 6 (slight respiratory failure), shock refractory to volume and dopamine 6 g/kg/ min, apneas, transdermal oxygen saturation 90% with FIO260% , central or peripheral neuromuscular disease obstructed upper airway, and oncologic disease.
• Up to 10 kg, conventional ventilators in spontaneous mode with pressure support and positive end-expiratory pressure (Maquet Servo-I, etc.

• > 10 kg, positive pressure ventilation was given with a flow generator (BiPAP STD 30 and VISION, Respironics, Murrysville, PA, etc.)

A prospective, randomized, controlled trial of noninvasive ventilation in pediatric acute respiratory failure*

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Outcomes: To compare the benefits of noninvasive ventilation (NIV) plus standard therapy vs. standard therapy alone in children with acute respiratory failure; assess method effectiveness in improving gas exchange and vital signs; and assess method safety.

Design: Prospective, randomized, controlled study.

Site: Two pediatric intensive care units in Santiago, Chile, at Clínica Santa María and Clínica Dávila, respectively.

Patients and Methods: Fifty patients with acute respiratory failure admitted to pediatric intensive care units were recruited; 25 patients were randomly allocated to noninvasive inspiratory positive airway pressure and expiratory positive airway pressure plus standard therapy (study group); the remaining 25 were given standard therapy (control group). Both groups were comparable in demographic terms.

Interventions and Measurements: The study group received NIV under inspiratory positive airway pressure ranging between 12 cm and 18 cm H₂O and expiratory positive airway pressure between 6 cm and 12 cm H₂O. Vital signs (cardiac and respiratory frequency), PO₂, PCO₂, pH, and PO₂/FIO₂ were recorded at the start and 1, 6, 12, 24, and 48 hrs into the study.

Results: Heart rate and respiratory rate improved significantly with NIV. Heart rate and respiratory rate were significantly lower after 1 hr of treatment compared with admission (p = 0.0009 and p = 0.004, respectively). The trend continued over time, heart rate being significantly lower than control after the first hour and heart rate after 6 hrs. With NIV, PO₂/FIO₂ improved significantly from the first hour. The endotracheal intubation was significantly lower (28%) in the NIV group than in the control group (60%, p = 0.045).

Conclusions: NIV improves hypoxemia and the signs and symptoms of acute respiratory failure. NIV seems to afford these patients protection from endotracheal intubation. (Pediatr Crit Care Med 2008; 9:484–489)

Key Words: noninvasive mechanical ventilation; bilevel positive airway pressure; respiratory failure; mask ventilation; infants; children
Predictive factors for the outcome of noninvasive ventilation in pediatric acute respiratory failure*

**Objectives:** To identify success and failure prognostic signs of noninvasive ventilation in pediatric acute respiratory failure. Non-invasive ventilation constitutes an alternative treatment for pediatric acute respiratory failure. However, tracheal intubation should not be delayed when considered necessary.

**Design:** Prospective, noncontrolled, clinical study.

**Setting:** Pediatric intensive care unit in a university hospital.

**Patients:** Children (age range, 1 month—16 yrs) with moderate-to-severe acute respiratory failure who received noninvasive ventilation during a 4-year period. Failure was defined as the need for tracheal intubation.

**Interventions:** None.

**Measurements and Main Results:** Nine (19.1%) of 47 patients needed tracheal intubation between the third and 87th hour after the start of treatment (33.6 ± 29.6 hrs). Failure was associated with the younger age group (4 ± 3.3 yrs vs. 7.7 ± 5 yrs, p < .04), acute respiratory distress syndrome (failure/acute respiratory distress syndrome: 5 of 10 vs. failure/non acute respiratory distress syndrome: 4 of 37, p = .013), and worsening radiographic images taken at 24 hrs and/or 48–72 hrs (p = .001 and p < .001, respectively). A significant reduction in heart rate was observed between the second and fourth hour after starting noninvasive ventilation (130 ± 25.8 bpm vs. 116 ± 27.7 bpm, p < .001) and $\text{Pco}_2$ (54.1 ± 19.5 torr vs. 48.6 ± 14.3 torr; 7.21 ± 2.6 vs. 6.48 ± 1.91 kPa, p < .007) in the success group. The failure group had a higher rate of breathing assistance, both initial and maximal. In the multivariate analysis, only maximum mean airway pressure and $\text{Fio}_2$ formed part of the success/failure discriminant function with a cutoff point of 11.5 and 0.57, respectively.

**Conclusions:** Modifications in a patient's respiratory assistance were made depending on the clinical, blood gas, and radiologic evolution of the patient. Mean airway pressure and $\text{Fio}_2$ values of >11.5 and 0.6, respectively, predict failure and possibly set the limit above the patient’s risk of delayed intubation increases. (Pediatr Crit Care Med 2010: 11:675–680)

**Key Words:** noninvasive ventilation; children; acute respiratory failure; acute respiratory distress syndrome; predictive factors; mean airway pressure.
High Flow Nasal Cannulae Therapy in Infants with Bronchiolitis

Christine McKiernan, MD, Lee Chadrick Chua, MD, Paul F. Visintainer, PhD, and Holley Allen, MD

**Objectives** To determine whether the introduction of heated humidified high-flow nasal cannulae (HFNC) therapy was associated with decreased rates of intubation for infants <24 months old with bronchiolitis admitted to a pediatric intensive care unit (PICU).

**Study design** A retrospective chart review of infants with bronchiolitis admitted before and in the season after introduction of HFNC.

**Results** In the season after the introduction of HFNC, only 9% of infants admitted to the PICU with bronchiolitis required intubation, compared with 23% in the prior season ($P=.043$). This 68% decrease in need for intubation persisted in a logistic regression model controlling for age, weight, and RSV status. HFNC therapy resulted in a greater decrease in respiratory rate compared with other forms of respiratory support, and those infants with the greatest decrease in respiratory rate were least likely to be intubated. In addition, median PICU length of stay for children with bronchiolitis decreased from 6 to 4 days after the introduction of HFNC.

**Discussion** We hypothesize that HFNC decreases rates of intubation in infants with bronchiolitis by decreasing the respiratory rate and work of breathing by providing a comfortable and well-tolerated means of noninvasive ventilatory support. *(J Pediatr 2010;156:634-8)*

In conclusion, we propose that HFNC provides a well-tolerated means of ventilatory support in infants with bronchiolitis. HFNC decreases RR and may decrease the work of breathing in infants with bronchiolitis and thereby may prevent the need for intubation and mechanical ventilation.
Negative Pressure Ventilation
In summary, NPV appears to be a promising modality to deliver NIV for a selected group of pediatric patients. The potential benefits of NPV include reduced airway complications, improved pulmonary parenchymal inflation at reduced airway pressures, improved hemodynamics thereby reduced cardiovascular compromise, decreased sedation requirements and improved enteral nutrition. Due to paucity of data, there is a need for further clinical evaluation of the use of NPV before this mode of ventilation becomes a recommended part of ICU management. Training of staff for this mode of respiratory support is possible and infants can be monitored without invasive techniques used in intensive care units. This approach could drastically reduce the cost incurred in treating patients on more invasive modes which in turn require invasive monitoring in an ICU set up which is an important aspect of medical management in developing countries.
Biphasic negative and positive external pressure ventilation
Acute Non-invasive ventilation: Monitoring

Monitoring:
- Pulse oximetry
- NIBP
- Peripheral venous access
- Arterial blood gas
- Sampling
- ECG
- Capillary gases
- Arterial lines
Non-invasive ventilation
Complications

• Air leaks
• Gastric perforation
• Aspiration
• Gastric distension if PIP >20 cm H2O
• Skin irritation / skin breakdown
• Nasal dryness
• Conjunctivitis
Training

• Physicians, nurses, and respiratory care therapists.

• Resources for monitoring, and managing complications.

• Immediate access to staff skilled in invasive airway management.
Conclusion

• NIPPV CAN HELP TO DECREASE THE NUMBER OF INTUBATED PATIENTS IN PCICU.

• Start early.

• Benefit within 3 hours of observation.
• Choose the appropriate modality for your patient.
• Close monitoring with a well trained medical staff is essential.
• Team work