Non-Invasive Ventilation in Pediatric Respiratory Failure

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Respiratory balance
Acute Respiratory Failure

Chronic Respiratory Failure
Respiratory Support

- Oxygen supplement
- Chest physiotherapy
- Non-invasive positive pressure ventilation (NIPPV) support:
  - BiPAP, CPAP, HFNC
  - Facial mask, nasal mask, nasal prong, nasal tube, nasal pillow, mouthpiece
- Invasive ventilator support:
  - IMV (PC, VC), BiPAP, CPAP,
  - Endotracheal intubation, Tracheostomy
  - ECMO
Introduction

Invasive ventilation
Delivered to patient through artificial airway positioned in patient’s trachea

Noninvasive ventilation
Delivered to patient’s upper respiratory tract by interface (mask or mouthpiece)
Less interfere with speech or swallowing
Creating a transpulmonary pressure gradient without an indwelling artificial airway
Comparison of Noninvasive mechanical ventilators with standard critical care ventilators

- NIMV offers a more portable technology due to the reduced size of the air compressor.
- Because of this reduction in size, these noninvasive ventilators do not develop pressures as high as their critical care ventilator counterparts. (>30 cm H20)
- Noninvasive ventilators have a single-limb tubing circuit that delivers oxygen to the patient and allows for exhalation.
- Lack oxygen blenders or sophisticated alarm or battery backup systems
Physiologic Effect of NIV

- Decreasing the patient's work of breathing
- Maintaining the airway patency, from the upper airways to the smaller lower airways, which can facilitate expiratory flow and reduce obstructive apnea
- Recruiting alveoli, resulting in increased functional residual capacity (FRC) and decreased ventilation-perfusion (V-Q) mismatch

Curr Opin Anaesthesiol. 2010 Jun;23(3):368-74
Pediatr Emerg Care. 2008 May;24(5):331-8
Why NIV Support in Children?

- Decrease work of breathing, decreases total oxygen consumption.
- Decrease atelectasis formation by increasing the difference between FRC and closure volume.
- Maintain upper airway patency
- Decreases the symptoms of respiratory insufficiency, by normalizing respiratory rate and decreasing dyspnea, improve the patient’s comfort
- Can stay awake and sedation is not necessary.
- Avoids the complications associated with endotracheal intubation
More usage of NIV

- The number of patients receiving this treatment is steadily increasing
- Growing number of indications in which the effectiveness of NIV has been proved
- The technique of application greatly refined
- Development of interfaces able to deal with different facial morphologies
- Availability of built-in monitoring systems
- Developments in terms of ventilatory modes and features.
Non-Invasion Ventilation

NPAV: negative pressure-assisted ventilation
NPPV: Noninvasive positive pressure ventilation
CPAP: continuous positive airway pressure
BiPAP: bi-level positive airway pressure
HFNC: high-flow nasal cannula
NPPV Indication

Acute care setting
Primarily obstructive pulmonary diseases: Bronchiolitis, Asthmatic Crises, Cystic Fibrosis
Primarily restrictive pulmonary diseases: Neuromuscular disease relapses, Obesity-Hypoventilation syndrome, Worsening of scoliosis, Thoracic trauma
Pulmonary Parenchyma Diseases: Mild or moderate pneumonia, Acute lung injury, Lung acute edema, Acute exacerbations of chronic pulmonary pathologies (pulmonary fibrosis, bronchopulmonary dysplasia)
Perioperative respiratory insufficiency: Complications in adenotonsillectomy, Post-operative weaning for severe scoliosis, Endotracheal weaning for Home-NIV patients, Endotracheal weaning with chronic pulmonary pathology

Do-not-intubate orders

https://www.draeger.com/library/content/00.%20niv-in-pediatric-patients_book_garcia.pdf
NPPV Goals

Acute care setting

- Avoid intubation
- Relieve symptoms
- Decrease heart rate and improve hemodynamic status
- Enhance gas exchange
- Improve patient-ventilator synchronization
- Maximize patient comfort
- Decrease length of stay
NPPV Indication

Chronic care setting

- **Central Nervous System Diseases**: Arnold-Chiari malformation, Central Hypoventilation syndromes, Brain tumor, Myelomeningocele, Spinal Cord traumas, Cranioencephalic trauma
- **Neuromuscular Diseases**: Myopathies (congenital, mitochondrial, metabolic, inflammatory), Muscular dystrophy (such as Duchenne’s Disease), Guillain-Barré syndrome, Myasthenia gravis, Phrenic nerve palsy, Poliomyelitis
- **Upper airway Alterations**: Pierre-Robin Syndrome, Tracheomalacia, Obstructive sleep apnea syndrome
- **Pulmonary Diseases**: Bronchopulmonary Dysplasia, Cystic Fibrosis, Bronchiectasis, Apnea of prematurity
- **Respiratory Sleep Alterations**: Obesity-Hypoventilation syndrome, Prader-Willi syndrome, Williams syndrome

https://www.draeger.com/library/content/00.%20niv-in-pediatric-patients_book_garcia.pdf
NPPV Goals

Chronic care setting

- Relieve or improve symptoms
- Enhance quality of life
- Decrease morbidity
- Increase survival
NPPV Contraindication

- Cardiopulmonary arrest
- Acutely impaired mental status, (eg, Glasgow coma score <8 or rapidly declining or patients with status epilepticus)
- High aspiration risk (eg, absence of airway protective reflexes or inability to clear secretions)
- Need for airway protection (eg, epiglottitis, progressive upper airway edema, or burns)
- Hemodynamic instability requiring high or escalating levels of vasopressor support
- Upper gastrointestinal bleed
- Facial injuries (eg, large lacerations, or facial bone fractures) or facial or airway anomalies (eg, micrognathia, Apert syndrome, Crouzon syndrome).
- Untreated pneumothorax
Algorithm for NIV in acute respiratory failure in children

**Acute Respiratory Failure (ARF)**

**Only hypercapnic ARF**

- **Mild or moderate ARF:**
  - pH < 7.35 and > 7.2
  - PCO₂ > 45 and < 90 mmHg

- **Severe ARF:**
  - pH < 7.2
  - PCO₂ > 90 mmHg

- Good Training and equipment.
- No other organ failures.
- Patient cooperation.

**First option NIV**

- **Yes**
  - After first hour of NIV: arterial blood gas improvement.
  - Success of NIV
  - Intubation & Invasive Ventilation

- **No**
  - Failure

**Hypoxemic ARF with or without hypercapnia**

- Adequate training and equipment.
- No other organ failures.
- Patient cooperation.
- Hypercapnia associated.
- Quick resolution of lung pathology expected.

- **Yes**
  - Success of NIV
  - Intubation & Invasive Ventilation

- **No**
  - Failure
  - Intubation & Invasive Ventilation

https://www.draeger.com/library/content/00.%20niv-in-pediatric-patients_book_garcia.pdf
NPPV Initial Patient Selection

- Moderate to severe dyspnea not responsive to supplemental oxygen or other therapies (e.g., bronchodilators for status asthmaticus)
- Persistent tachypnea caused by respiratory illness
- Hypoxemia (specifically, fraction of inspired oxygen \([\text{FiO}_2]\) >0.5 to maintain \(\text{SaO}_2 >94\) percent)
- Respiratory acidosis (arterial pH <7.35 or venous pH <7.30)

Where to use NPPV?

- ICU
- Respiratory care center
- Chronic respiratory care ward
- General ward
- Home care
- Depends on local factors
  - Training & experience of staff
  - Available resources (beds, staff, equipment)
  - Monitoring capacity
NPPV

- **Patient Interfaces**
  - Nasal mask, facial mask, full face mask, helmet
  - Nasal prong, pillow
  - Mouthpiece
  - Straps and headgear

- **Ventilators**
  - Critical care ventilators
  - Noninvasive ventilators
  - Home care or portable ventilators
## Children Interfaces

<table>
<thead>
<tr>
<th></th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Side-effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nasal mask</td>
<td>Small internal volume; large choice of different industrial models</td>
<td>Not usable in case of mouth leaks</td>
<td>Pressure sores, eye irritation if leaks, facial deformity</td>
</tr>
<tr>
<td>Nasobuccal mask</td>
<td>Prevents mouth leaks</td>
<td>Large volume; risk of inhalation of gastric content in case of gastro-oesophageal reflux; impairs communication and vocalisation; increased aerophagia</td>
<td>Pressure sores, eye irritation if leaks, facial deformity</td>
</tr>
<tr>
<td>Total face mask</td>
<td>Prevents mouth leaks</td>
<td>Larger volume than nasobuccal mask; risk of inhalation of gastric content in case of gastro-oesophageal reflux; impairs communication and vocalisation; increased aerophagia</td>
<td>Pressure sores, facial deformity</td>
</tr>
<tr>
<td>Nasal pillows</td>
<td>Small and light; no pressure sores</td>
<td>Not usable in case of mouth leaks</td>
<td>Nasal irritation</td>
</tr>
<tr>
<td>Mouthpiece</td>
<td>Small and light; no pressure sores; can be used intermittently</td>
<td>Not usable during sleep</td>
<td>None</td>
</tr>
</tbody>
</table>

*Table: Advantages, disadvantages, and side-effects of interfaces for children*
Choose the interface

Apply protective dressings

Explain treatment to patient before beginning (age permitting)
Sedate patient (if required)

Adapt patient

Position the harness of fastening system

Cooperating children should be able to maintain the interface
Do not adjust the interface too tightly (two fingers should fit underneath)
The mask should be perpendicular to the face and symmetric from top to bottom

Attach the interface (requires 2 people)

Connect the ventilator
Check level of adaptation
Check for leaks

Confirm proper functioning

Program disconnection (rest) periods

**Figure 18.** Initial protocol for starting NIV in function of the interface.
**Figure 5.** Algorithm for patient care in non-invasive ventilation (NGT: nasogastric tube; CPR: cardiopulmonary resuscitation).
Monitoring

- **Ventilator patient data and alarm**: Tidal volume, air leaks
- **Subjective responses**: bedside observation, ask about discomfort
- **Physiologic response**: in synchrony, decrease RR, HR, accessory muscle activity and abdominal paradox
- **Gas exchange**: continuous oximetry, ABG, end tidal CO2, transcutaneous CO2
Respironics V60 Ventilator User Interface
Clinical effectiveness of NIV

- Decrease in work of breathing:
  Physical examination

- Improvement of respiratory gas exchange:
  gas, pulse oximetry, end-tidal or transcutaneous CO2

- Increase in FRC:
  CXR expansion and less atelectasis

- Maintenance of upper airway patency:
  polysomnography
Weaning

Adjust Ventilator settings
Duration
Oxygen Support

Decrease settings

Regular time off periods for difficult weaners

<table>
<thead>
<tr>
<th>Day</th>
<th>Evening</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
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<tr>
<td>3 hr</td>
<td>3 hr</td>
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<tr>
<td>Whole day off</td>
<td></td>
<td>decrease</td>
</tr>
<tr>
<td>Whole day off</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
NIV failure

- Inability to stabilize progression of respiratory failure
- Subsequent placement of an artificial airway
- Rapidly worsening clinical condition
- Unstable airway
- Predictors of NIV failure:
  - evidence of multiorgan dysfunction,
  - worsening respiratory acidosis,
  - underlying diagnosis of sepsis or oncologic disease
  - higher oxygen requirement prior to the initiation of therapy.

Complications due to the interface

- Skin irritation.
- Skin abrasion: anti-sore dressings, alternating between different interfaces
- Conjunctivitis
- Airway obstruction
- Hypercapnia: CO2 rebreathing
- Accidental disconnection
- Maxillar hypoplasia: maxillar underdevelopment and secondary malocclusion
CO2 rebreathing

- Single limb
- Increases as inspiratory time increases, decreases exhalation time, and at the same time higher tidal volumes further increase the CO2 rebreathed
- Increase EPAP to decrease CO2 rebreathing. Higher pressures produce more flow through exhalation port, which purge CO2 from the circuit to prevent rebreathing.

Complications related to pressure in the airway

- **Inspiratory blockage**: glottal reflex closes vocal cords when hypocapnia due to excessive pressure; increase in resistance, leakage and patient-ventilator desynchronization; lower IPAP
- **Gastric distension**: careful when IPAP > 25 cm H2O; in NMD, can occur with IPAP < 20 cm H2O due to weakness diaphragm and lower esophageal sphincter
- Food aspiration
- Pneumothorax
- Pulmonary hyperinflation
- Hemodynamic deterioration
Complications related to humidification

- Due to lack of humidification: mucosa dryness, increase nasal resistance, diminish tidal volume, cause patient discomfort; thick mucous layers that cause airway obstruction
- Due to excess humidification: aspiration

Complications related to NIV indications

- Delayed intubation
- Contraindications
Pediatric Unique Factors about Complications

- **Aspiration**: immaturity of airway protection reflexes
- **Reflux**: impaired GE sphincter function
- **Upper airway obstruction**: anatomical factors, difficulty clearing secretions
- **Large oral leak**: tendency to mouth breathe
- **Agitation**: anxiety, incomplete understanding, developmental disorders
NCPAP
Hudson Nasal Prongs
Bubble CPAP

Simple, Clean, Easy Observation, No pressure Alarms, No integrated FiO2 monitor, No integrated monitor
Traditional BiPAP Mode

- Spontaneous mode
  - IPAP, EPAP

- Spontaneous & time (ST) mode
  - IPAP, EPAP, Rate

- Time mode
  - IPAP, EPAP, Rate,
  - Inspiratory time
New NIV Modes

- **PCV**
- **AVAPS** (average volume assured pressure support): guarantees an average tidal volume for increased safety and efficiency
- **iVAPS** (intelligent Volume-Assured Pressure Support) maintain target alveolar ventilation by automatically adjusting pressure support

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Brands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target volume with variable pressure support</td>
<td>Automatically adjust IPAP level (in a predefined pressure range) to achieve a stable predetermined target VT</td>
</tr>
<tr>
<td>Target volume with both variable pressure support and back-up respiratory rate</td>
<td>Automatically adjust both IPAP and BURR level (in a predefined pressure range) to achieve a stable target predetermined minute ventilation</td>
</tr>
<tr>
<td>Target volume with variable pressure support, back-up respiratory rate and autoadjusted EPAP</td>
<td>Automatically adjust both IPAP (in a predefined pressure range) to achieve a stable target VT, and EPAP level (in a predefined pressure range) to maintain airway patency. Additionally, provides &quot;automatic&quot; BURR to match the awake spontaneous patient respiratory rate</td>
</tr>
<tr>
<td></td>
<td>AVAPS™ (A40™, Trilogy 100™ and 200™ Philips)</td>
</tr>
<tr>
<td></td>
<td>Target volume pressure support (Vivo™ 50 and 60, Breas; Ventilogic™, Weinmann, Monnal T50™, ALMS; Elysee™ 150, 250, 350, Resmed)</td>
</tr>
<tr>
<td></td>
<td>IVAPS™ (VPAP S9™, Stellar™ 100 and 150, Lumis™ Astral™, Resmed)</td>
</tr>
<tr>
<td></td>
<td>Avaps AE™ (A40™, Trilogy™ 100 and 200 Philips)</td>
</tr>
</tbody>
</table>

IPAP: inspiratory airway positive pressure, EPAP: expiratory airway positive pressure, BURR: backup respiratory rate. AVAPS: Average volume assured pressure support. IVAPS: Intelligent volume assured pressure support.
Automatic adjusted IPAP

Automatic adjusted backup rate

Automatic adjusted EPAP and IPAP
Adaptive Servoventilation (ASV)

- Suppress central sleep apnea
- Effectively treat periodic breathing, or Cheyne Stokes respiration
- Aim of ASV is to counter-balance this ventilatory instability by modulating the level of inspiratory support
- No published data in children

Paediatric Respiratory Reviews 2016;18:73–84
Figure 3. Screenshot of the ventilator screen during pediatric non-invasive ventilation with NAVA, displaying ventilatory pressure (yellow curve, top), flow (green curve), volume (blue curve), and diaphragmatic electrical activity (EAdi, white tracing, bottom). Note the synchronization and proportionality of pressure and EAdi signals, characteristic of the NAVA mode. NAVA, neurally adjusted ventilatory assist; NIV, non-invasive ventilation; resp, respectively; PSV, pressure-support ventilation; EAdi, electrical activity of diaphragm; nCPAP, nasal continuous positive airway pressure;
Respiratory Home Care

Oxygen therapy
- 製氧機
- 氧氣鋼瓶
- 液態氧

Bronchial hygiene therapy
- PEP
- 吸痰機
- MDI/DPI
- CPT
- 溼氣治療
- 噴霧治療

Breathing & Speaking training
- 呼吸訓練
- 發聲訓練
- 吞嚥訓練
- 氣切照護

Pulmonary recondition
- 橫膈運動
- 上肢運動
- 下肢運動
- 耐力訓練
- 離床活動

Ventilator support
- PACV
- VCV PR
- ACV
- SIMV
- PSV
- Bi-PAP
Pediatric Respiratory Integrated Care

- Respiratory care
- Underline disease
- Infection Control and Vaccinations
- Nutrition
- Growth and Development
- Rehabilitation (PT, OT, ST, RT)
- Psychological Support
- Education
- Palliative care
Bubble continuous positive airway pressure for children with severe pneumonia and hypoxaemia in Bangladesh: an open, randomised controlled trial

2011-2013, 225 eligible children

<table>
<thead>
<tr>
<th>Reason</th>
<th>Total (n=225)</th>
<th>Bubble CPAP therapy (n=79)</th>
<th>Low-flow oxygen therapy (n=67)</th>
<th>High-flow oxygen therapy (n=79)</th>
<th>Bubble CPAP vs low-flow oxygen therapy</th>
<th>Bubble CPAP vs high-flow oxygen therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>RR (99.7% CI)</td>
<td>p value</td>
</tr>
<tr>
<td>Total treatment failure*</td>
<td>31 (14%)</td>
<td>5 (6%)</td>
<td>16 (24%)</td>
<td>10 (13%)</td>
<td>0.27 (0.07–0.99)</td>
<td>0.0026</td>
</tr>
<tr>
<td>Clinical failure†</td>
<td>31 (14%)</td>
<td>5 (6%)</td>
<td>16 (24%)</td>
<td>10 (13%)</td>
<td>0.27 (0.07–0.99)</td>
<td>0.0026</td>
</tr>
<tr>
<td>Severe hypoxaemia (SpO₂ &lt;85%)</td>
<td>31 (14%)</td>
<td>5 (6%)</td>
<td>16 (24%)</td>
<td>10 (13%)</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>Clinical signs of severe respiratory distress</td>
<td>35 (16%)</td>
<td>7 (9%)</td>
<td>16 (24%)</td>
<td>12 (15%)</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>PCO₂ &gt;60 mm Hg and pH &lt;7.2</td>
<td>1 (0.5%)</td>
<td>0</td>
<td>1 (2%)</td>
<td>0</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>Intubation or mechanical ventilation</td>
<td>26 (12%)</td>
<td>5 (6%)</td>
<td>11 (16%)</td>
<td>10 (13%)</td>
<td>0.39 (0.08–1.77)</td>
<td>0.052</td>
</tr>
<tr>
<td>Deaths</td>
<td>23 (10%)</td>
<td>3 (4%)</td>
<td>10 (15%)</td>
<td>10 (13%)</td>
<td>0.25 (0.07–0.89)</td>
<td>0.022‡</td>
</tr>
<tr>
<td>Left hospital against medical advice</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>..</td>
<td>..</td>
</tr>
</tbody>
</table>

Data are n (%). CPAP=continuous positive airway pressure. RR=relative risk. SpO₂=arterial oxygen saturation by pulse oximetry. PCO₂=partial pressure of carbon dioxide. *At least one of: clinical failure, intubation/mechanical ventilation, died, or left hospital against medical advice. †At least two of: severe hypoxaemia, severe respiratory distress, or PCO₂ >60 mm Hg and pH <7.2. ‡For deaths we calculated 95% CI.

Table 2: Reasons for treatment failure, by treatment group
Bubble continuous positive airway pressure for children with severe pneumonia and hypoxaemia in Bangladesh: an open, randomised controlled trial

- Oxygen therapy delivered by bubble CPAP improved outcomes in Bangladeshi children with very severe pneumonia and hypoxaemia compared with standard low-flow oxygen therapy.
- Use of bubble CPAP oxygen therapy could have a large effect in hospitals in developing countries where the only respiratory support for severe childhood pneumonia and hypoxaemia is low-flow oxygen therapy.
- The trial was stopped early because of higher mortality in the low-flow oxygen group than in the bubble CPAP group.

Lancet 2015 Sep; 386 (9998):1057–1065
NIPPV versus NCPAP for preterm neonates after extubation

- Cochrane Database of Systematic Reviews 2017
- NIPPV reduces the incidence of extubation failure and the need for re-intubation within 48 hours to one week more effectively than NCPAP; however, no effect on chronic lung disease nor on mortality.
- NIPPV does not appear to be associated with increased gastrointestinal side effects

Non-invasive positive pressure ventilation for acute asthma in children

- Cochrane Database of Systematic Reviews 2016
- NPPV compared with no additional treatment, treatment as usual or placebo did not result in any benefit or harm regarding death from all causes, serious adverse events (i.e. major complications) or improvement in asthma symptoms. Five study participants did not tolerate the treatment, four because of discomfort and one because intubation was required. Current evidence cannot confirm or reject the effects of NPPV for treatment of children with acute asthma. Larger RCT are warranted.

To compare outcomes of children receiving noninvasive ventilation with those receiving invasive ventilation as first-line mode of mechanical ventilation following unplanned intensive care admission.

Pediatric Intensive Care Audit Network: 21/31 PICUs in the United Kingdom and Ireland

over 8 years (2007–2014)

Exclusion: Postoperative admissions, elective admissions, and emergency admissions from another hospital, tracheostomy, chronic ventilation prior to PICU admission

Crit Care Med 2017 Jun; 45:1045–1053
Outcomes for Children Receiving Noninvasive Ventilation as the First-Line Mode of Mechanical Ventilation at Intensive Care Admission: A Propensity Score-Matched Cohort Study*

- Outcome variables: PICU mortality, length of ventilation (LOV), PICU length of stay (LOS), and ventilator-free days at 28 days (VFD-28).
- Propensity Score (PS) Estimates. the probability of treatment group assignment conditional on observed baseline covariates, thus only one IV case could be matched with each NIV case, who theoretically had an equal chance of receiving NIV or IV based on key characteristics

Crit Care Med 2017 Jun; 45:1045–1053
Outcomes for Children Receiving NIV as the First-Line Mode of MV at IC Admission: A Propensity Score-Matched Cohort Study*

**TABLE 1. Patient Demographic and Clinical Characteristics of the Whole Cohort (n = 15,025) and Propensity Score-Matched Cohort (n = 6,002)**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Whole Cohort (n = 15,025)</th>
<th>Propensity Score Matching Cohort (n = 6,002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Invasive Ventilation</td>
<td>(n = 10,221)</td>
<td>(n = 3,001)</td>
</tr>
<tr>
<td>Noninvasive Ventilation</td>
<td>(n = 4,804)</td>
<td>(n = 3,001)</td>
</tr>
<tr>
<td><strong>p</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age in weeks, median (IQR)</td>
<td>66 (12–279)</td>
<td>33 (8–162)</td>
</tr>
<tr>
<td>Sex, n (%)</td>
<td>5,945 (58.1)</td>
<td>1,698 (56.6)</td>
</tr>
<tr>
<td>Male</td>
<td>2,698 (56.2)</td>
<td>1,709 (57.0)</td>
</tr>
<tr>
<td>Primary diagnostic group, n (%)</td>
<td>3,292 (32.2)</td>
<td>1,887 (61.9)</td>
</tr>
<tr>
<td>Respiratory</td>
<td>3,427 (71.3)</td>
<td>1,853 (61.8)</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>1,496 (14.6)</td>
<td>396 (13.2)</td>
</tr>
<tr>
<td>Neurologic</td>
<td>2217 (21.7)</td>
<td>141 (4.7)</td>
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<tr>
<td>Infection</td>
<td>904 (8.8)</td>
<td>211 (7.0)</td>
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<tr>
<td>Gastrointestinal</td>
<td>306 (3.0)</td>
<td>51 (1.7)</td>
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<tr>
<td>Endocrine/metabolic</td>
<td>333 (3.3)</td>
<td>56 (1.9)</td>
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<td>Trauma</td>
<td>669 (6.6)</td>
<td>2 (0.1)</td>
</tr>
<tr>
<td>Oncology</td>
<td>167 (1.6)</td>
<td>58 (1.9)</td>
</tr>
<tr>
<td>Blood/lymphatic</td>
<td>149 (1.5)</td>
<td>54 (1.8)</td>
</tr>
<tr>
<td>Other†</td>
<td>643 (6.3)</td>
<td>155 (5.2)</td>
</tr>
<tr>
<td>Not recorded</td>
<td>45 (0.4)</td>
<td>21 (0.7)</td>
</tr>
<tr>
<td><strong>Main reason for admission; n (%)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asthma</td>
<td>186 (1.8)</td>
<td>68 (2.3)</td>
</tr>
<tr>
<td>Bronchiolitis</td>
<td>935 (9.2)</td>
<td>619 (20.6)</td>
</tr>
<tr>
<td>Group</td>
<td>108 (1.1)</td>
<td>15 (0.5)</td>
</tr>
<tr>
<td>Obstructive sleep apnea</td>
<td>12 (0.1)</td>
<td>11 (0.4)</td>
</tr>
<tr>
<td>Diabetic ketoacidosis</td>
<td>13 (0.1)</td>
<td>3 (0.1)</td>
</tr>
<tr>
<td>Seizure disorder</td>
<td>78 (0.8)</td>
<td>3 (0.1)</td>
</tr>
<tr>
<td>Other (none of the above)</td>
<td>8,804 (88.1)</td>
<td>2,282 (76.0)</td>
</tr>
<tr>
<td>Not recorded</td>
<td>84 (0.8)</td>
<td>30 (0.6)</td>
</tr>
<tr>
<td><strong>Ethnicity; n (%)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>6,175 (60.4)</td>
<td>1,719 (57.3)</td>
</tr>
<tr>
<td>Mixed White</td>
<td>333 (3.3)</td>
<td>105 (3.5)</td>
</tr>
<tr>
<td>Asian</td>
<td>1,297 (12.7)</td>
<td>478 (15.9)</td>
</tr>
<tr>
<td>Black</td>
<td>550 (5.4)</td>
<td>206 (6.8)</td>
</tr>
<tr>
<td>Other†</td>
<td>1,592 (15.6)</td>
<td>422 (14.0)</td>
</tr>
<tr>
<td>Not recorded</td>
<td>272 (2.6)</td>
<td>72 (2.4)</td>
</tr>
</tbody>
</table>

**TABLE 1. (Continued). Patient Demographic and Clinical Characteristics of the Whole Cohort (n = 15,025) and Propensity Score-Matched Cohort (n = 6,002)**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Whole Cohort (n = 15,025)</th>
<th>Propensity Score Matching Cohort (n = 6,002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Invasive Ventilation</td>
<td>(n = 10,221)</td>
<td>(n = 3,001)</td>
</tr>
<tr>
<td>Noninvasive Ventilation</td>
<td>(n = 4,804)</td>
<td>(n = 3,001)</td>
</tr>
<tr>
<td><strong>p</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Care area admitted from, n (%)</td>
<td>4,117 (40.3)</td>
<td>2,891 (60.2)</td>
</tr>
<tr>
<td>Ward</td>
<td>261 (2.6)</td>
<td>7 (0.1)</td>
</tr>
<tr>
<td>X-ray</td>
<td>1,095 (10.7)</td>
<td>542 (11.3)</td>
</tr>
<tr>
<td>High dependency unit</td>
<td>137 (1.3)</td>
<td>96 (2.0)</td>
</tr>
<tr>
<td>Other intermediate care area</td>
<td>152 (1.5)</td>
<td>36 (0.8)</td>
</tr>
<tr>
<td>ICU/PICU/Neonatal ICU</td>
<td>4,436 (43.4)</td>
<td>1,210 (25.2)</td>
</tr>
<tr>
<td>Unknown</td>
<td>12 (0.1)</td>
<td>10 (0.2)</td>
</tr>
<tr>
<td>Not recorded</td>
<td>11 (0.1)</td>
<td>12 (0.2)</td>
</tr>
<tr>
<td>Admission year, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>433 (4.2)</td>
<td>195 (4.1)</td>
</tr>
<tr>
<td>2008</td>
<td>1,054 (10.3)</td>
<td>414 (8.6)</td>
</tr>
<tr>
<td>2009</td>
<td>1,215 (11.9)</td>
<td>411 (8.6)</td>
</tr>
<tr>
<td>2010</td>
<td>1,334 (13.0)</td>
<td>543 (11.3)</td>
</tr>
<tr>
<td>2011</td>
<td>1,372 (13.4)</td>
<td>611 (12.7)</td>
</tr>
<tr>
<td>2012</td>
<td>1,562 (15.3)</td>
<td>847 (17.6)</td>
</tr>
<tr>
<td>2013</td>
<td>1,605 (15.7)</td>
<td>942 (18.6)</td>
</tr>
<tr>
<td>2014</td>
<td>1,646 (16.1)</td>
<td>841 (17.5)</td>
</tr>
</tbody>
</table>

**Distribution of admissions to each PICU**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Whole Cohort (n = 15,025)</th>
<th>Propensity Score Matching Cohort (n = 6,002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Invasive Ventilation</td>
<td>(n = 10,221)</td>
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</tr>
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<td>Noninvasive Ventilation</td>
<td>(n = 4,804)</td>
<td>(n = 3,001)</td>
</tr>
<tr>
<td><strong>p</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pediatric Index of Mortality-2, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.1 (3.1–10.7)</td>
<td></td>
<td>2.8 (0.9–5.4)</td>
</tr>
<tr>
<td>Arterial or capillary blood gas taken; n (%)</td>
<td>5.1 (3.1–10.7)</td>
<td>2.8 (0.9–5.4)</td>
</tr>
<tr>
<td>Lactate, median (IQR)</td>
<td>1.9 (1.1–3.7)</td>
<td>1.6 (1.1–2.6)</td>
</tr>
<tr>
<td>Not recorded</td>
<td>6,798 (66.5)</td>
<td>3,347 (69.7)</td>
</tr>
<tr>
<td>PaO2/FiO2, median (IQR)</td>
<td>190.6 (1026–3546)</td>
<td>129.4 (85.7–200)</td>
</tr>
<tr>
<td>Not recorded</td>
<td>5,923 (57.9)</td>
<td>3,998 (83.2)</td>
</tr>
<tr>
<td>Base excess, median (IQR)</td>
<td>3.1 (−70 to 0.3)</td>
<td>1.0 (−20 to 4.8)</td>
</tr>
<tr>
<td>Not recorded</td>
<td>3,201 (31.3)</td>
<td>2,186 (45.5)</td>
</tr>
<tr>
<td>Age-standardized systolic blood pressure, z score, mean (SD)</td>
<td>−0.03 (1.18)</td>
<td>0.13 (0.98)</td>
</tr>
</tbody>
</table>

Crit Care Med 2017 Jun; 45:1045–1053
Outcomes for Children Receiving Noninvasive Ventilation as the First-Line Mode of Mechanical Ventilation at Intensive Care Admission: A Propensity Score-Matched Cohort Study*

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Whole Cohort (n = 15,025)</th>
<th>Propensity Score Matching Cohort (n = 6,002)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Invasive Ventilation</td>
<td>NIV</td>
</tr>
<tr>
<td></td>
<td>(n = 10,221)</td>
<td>(n = 4,804)</td>
</tr>
<tr>
<td>PICU mortality (%)</td>
<td>9.6</td>
<td>4.4</td>
</tr>
<tr>
<td>Length of ventilation (d), median (IQR)</td>
<td>4 (2–7)</td>
<td>4 (2–7)</td>
</tr>
<tr>
<td>Length of stay (d), median (IQR)</td>
<td>5 (2–9)</td>
<td>5 (3–8)</td>
</tr>
<tr>
<td>VFD-28—all patients, median (IQR)</td>
<td>8 (0–24)</td>
<td>12 (0–22)</td>
</tr>
<tr>
<td>VFD-28—survivors only, median (IQR)</td>
<td>12 (0–24)</td>
<td>12 (0–22)</td>
</tr>
<tr>
<td>NIV failure rate, n (%)</td>
<td>NA</td>
<td>1,237 (25.7)</td>
</tr>
</tbody>
</table>

IQR = interquartile range, NA = not applicable, NIV = noninvasive ventilation, VFD-28 = ventilation-free days at day 28.

A Wilcoxon rank-sum test was used to compare all continuous variables presented as mean (interquartile range), a two sample t test was used to compare continuous variables presented as mean (sd), and chi-square test of independence compared all categorical variables presented as n (%).
Outcomes for Children Receiving Noninvasive Ventilation as the First-Line Mode of Mechanical Ventilation at Intensive Care Admission: A Propensity Score-Matched Cohort Study*

- PSM allowed the two groups to be well matched, with better outcomes seen in patients treated with NIV-first.
- Acute NIV (rather than IV) as first-line MV therapy may be associated with a significant decrease in mortality, LOV, and LOS, an increase in the number of VFD-28.
- Variation in the use of NIV and IV between PICUs may therefore directly influence clinical outcomes.
- Prospective clinical trials conducted through international collaborative networks and research-driven clinical guidelines are urgently needed to guide future NIV practice in critically ill children.
Conclusion

- Noninvasive ventilation is a well-tolerated alternative to endotracheal intubation in the pediatric intensive care unit.
- Patients who respond to the use of noninvasive ventilation typically show improvement shortly after the initiation of therapy.
- Use of noninvasive ventilation is associated with decreased rate of endotracheal intubation, which may lead to decreased incidence of intubation related complications.
Conclusion

Key points for use of NIV in children

- NIV Patient selection and timing
- Interface
- Ventilator
- Humidification
- Appropriate Caring environment
- Good care training and skills
Thanks for your Attention

NTUCH’s scenery