NIV for acute respiratory distress in children

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In children, it is not uncommon that the rapid progression of respiratory failure with decompensation of the gas exchange may lead to a life-threatening situation. If applied early enough, noninvasive ventilation (NIV) can help stop this progression and thus avoid intubation with invasive mechanical ventilation and the complications that come with it.

Takeaway messages

- NIV is well established in clinical practice for children with respiratory failure.
- The aim of NIV is to support the patient in the early stages of respiratory failure and thus avoid invasive mechanical ventilation.
- Children undergoing NIV require careful monitoring and support in the first few hours to ensure the therapy is effective and to recognize failure early.
- Therapies such as HFNC and CPAP are effective in the early stages of respiratory failure, particularly for obstructive diseases.
- In PARDS, NIV should only be applied in mild to moderate cases by an experienced team.

A recent survey showed NIV to be a widespread technique in European pediatric intensive care units (PICUs). Of the 101 participating units from 23 countries, almost all PICUs considered applying NIV for the initial respiratory support (99.1%), after extubation (95.5% prophylactically; 99.1% therapeutically), and as part of palliative care (77.5%). Overall, the use of NIV outside the PICUs was 15.5% on the ward, 20% in the emergency department, and 36.4% during transport. In terms of the cause of respiratory failure, NIV was delivered in cases of pneumonia (97.3%), bronchiolitis (94.6%), bronchospasm (75.2%), acute pulmonary edema (84.1%), upper airway obstruction (76.1%), and in acute respiratory distress syndrome (91% if mild, 53.1% if moderate, and 5.3% if severe). The use of NIV in asthma patients was less frequent in Northern European units than in Central and Southern European PICUs (P = 0.007). Only 47.7% of the participants had a written protocol for NIV use. Bilevel NIV was applied mostly through an oronasal mask (44.4%), and continuous positive airway pressure through nasal cannulae (39.8%). If bilevel NIV was required, 62.3% reported choosing pressure support (as opposed to assisted pressure-controlled ventilation) in infants and 74.5% in older children [1].

In contrast to invasive ventilation, NIV is defined to provide the necessary respiratory support without endotracheal intubation or tracheostomy. However, the aim of NIV is the same as that of invasive ventilation; namely, to improve the alveolar ventilation and oxygenation, as well as lower the patient’s work of breathing. Complications such as laryngeal or subglottic damage, ventilator-associated pneumonia, ventilator-induced lung injuries and problems arising from sedation (e.g., delirium) and muscle relaxation should
thus be avoided, or their incidence at least reduced in comparison to invasive ventilation [2].

Most of the studies examining the effectiveness of NIV therapy for the individual indications are observational. To date, only a small number of randomized controlled trials (RCTs) have been carried out, meaning that the level of evidence is not classed as high. It is therefore the case that instead of being based on evidence, the strategies presented here have been taken from the first observational studies and since proven themselves in everyday clinical practice. A comprehensive account of this clinical consensus was published in 2015 [3].

**Bronchiolitis**

In small, randomized controlled trials (RCTs) and several observational studies, high flow nasal cannula (HFNC) and CPAP have been shown to improve the oxygen saturation, lower CO2, and reduce the respiratory rate and intubation rate [4, 5]. In addition, CPAP improves severe dyspnea and, according to a randomized controlled trial published in 2017, lowers the respiratory rate, heart rate and FiO2 more effectively and faster than HFNC [6]. Bronchiolitis in infancy is the most frequently examined and most common indication for NIV [4, 5].

**Bronchial asthma**

In two RCTs it was shown that NIV (CPAP ± NIPPV without HFNC) improves the work of breathing, dyspnea, respiratory rate, heart rate and FiO2 requirement, as well as lowering the number of admissions to the intensive care unit. Furthermore, deposition in the case of inhalation therapy with bronchodilators is improved. The only experience documented on the use of HFNC for bronchial asthma comes from an observational study [8, 9].

**Upper airway obstruction**

In small observational studies, CPAP therapy has been shown to lower the work of breathing, the respiratory rate and the heart rate. There is no data available on the effectiveness of HFNC, but the success rate in everyday clinical practice is very high [10].

**Pneumonia**

In observational studies, NIPPV in the case of pneumonia improves the oxygenation and ventilation, together with both the respiratory and heart rate [4].

**PARDS (Pediatric Acute Respiratory Distress Syndrome)**

The highest failure rate with NIV has been observed in PARDS patients. At the Pediatric Acute Lung Injury Consensus Conference in 2015, the recommendation was made to try NIV in the case of PARDS, but only mild PARDS in the early stages. NIV therapy should not be used in moderate or severe cases of PARDS [11].

**Criteria for initiating NIV in respiratory failure Type I or Type II**

In practice, the following general criteria (modified according to [3]) should be observed when deciding whether to initiate NIV in patients with respiratory failure Type I or Type II. In addition to demonstrating symptoms and signs of shortness of breath, the patient should
have:

- \( \text{p}a\text{CO}_2 > 45 \text{ mmHg} \)
- pH < 7.35
- \( \text{p}a\text{O}_2/\text{FiO}_2 = \text{P/F ratio} < 300 \text{ mmHg} \) (mostly not the case)
- \( \text{Sa}O_2/\text{FiO}_2 = \text{S/F ratio} < 270 \)
- HFNC. \( \text{Sp}O_2 < 92\% \) at maximum \( \text{O}_2 \) delivery without ventilatory support
- No contraindications

Depending on the expertise of the treating team, NIV should be started as early as possible. In the Intermediate Care station (= early start), the patient should have respiratory failure with \( \text{FiO}_2 < 0.4 \) and pH < 7.35.

In the Intensive Care Unit (= latest start) the patient should have respiratory failure with \( \text{FiO}_2 > 0.4 \) and pH < 7.30. These criteria also apply for transferring the patient from intermediate care to the ICU.

**NIV failure – abandonment criteria**

In a national, multicentric observational study, Wolfler et al. summarized data from 3819 children in 13 pediatric ICUs in Italy in the years 2006, 2011 and 2012. Of those, 585 were treated with NIV. The percentage of children treated unsuccessfully with NIV and subsequently intubated was: bronchiolitis 8\%, asthma attack 0\%, pneumonia 18\%, postoperative 20\%, acute exacerbation in the case of underlying disease 16\%, PARDs 44\% [12]. Mayordomo et al. found NIV failure rates of 32\% in the case of respiratory failure Type I as opposed to 8\% for Type II [13].

**Criteria for NIV failure – decision to intubate**

In practice, the following criteria should be observed when making the decision to intubate:

- Clinical worsening or no improvement of dyspnea
- Increasing apnea severity in the case of bronchiolitis
- Higher respiratory rate and greater work of breathing with the threat of exhaustion (a lowering of the respiratory rate is the most important sign of success)
- Increasing heart rate
- Increasing \( \text{FiO}_2 > 0.6 \)
- Sustained S/F ratio < 200 after optimization of NIV therapy
- Asynchrony between ventilator and patient
- Need for higher ventilation pressures (\( \text{Pip} = \text{peak pressure} > 20–22 \text{ cmH}_2\text{O}; \text{PEEP} > 12 \text{ mbar}, \text{MAP} > 11.5 \))
- Worsening of the blood gases (pH < 7.2; p\( \text{CO}_2 > 60 \text{ mmHg} \))
- Complications: e.g., too much/too thick secretion, vomiting
- Disorders of consciousness/confusion, coma
- Refusal by patient or relatives

**Contraindications for NIV**

NIV therapy should not be applied if the patient is dependent on airway management due to coma or severe gastrointestinal bleeding. NIV is also contraindicated in the case of hemodynamic instability (shock), craniofacial malformation or traumata, uncontrollable secretions, fixed obstruction of the airway (malformations, etc.) or severe hypoxemia (P/F ratio < 150; particularly important in the case of Type I failure or PARDs). Relative contraindications are excessive vomiting, confusion, agitation, circulatory instability, thermal injury to the face and airways, excessive secretions, and nosebleeds.

**Ventilators**

Most ICU ventilators have a NIV mode that allows for improved leak compensation;
however, there are limitations to effective leak compensation on devices with a compressed air connection. This frequently gives rise to problems relating to synchronization with the child’s breath cycle, in particular a delayed inspiratory trigger and autotriggering. More suitable for NIV are turbine-driven ICU ventilators, which are better able to adjust their flow. The turbine (blower) also enables the delivery of higher flows than can be generated by a high-pressure/compressed air connection. With a turbine-driven ventilator fewer synchronization problems occur, as compensation of inspiratory and expiratory leakage is better and autotriggering in particular can thus be avoided [14].

Conclusion
In pediatric intensive care, NIV for acute respiratory failure established itself primarily in clinical practice, before any evidence in the form of RCTs could be gathered. As a result, it is now more difficult to carry out RCTs for indications that have become widely accepted. In future, the aim must be the more precise determination of the role played by the individual therapies, such as HFNC, CPAP and NIPPV, for the different indications. It is particularly important to improve synchronization between the ventilator and the breath cycle in children of all ages, in order to increase the effectiveness of NIPPV. Furthermore, it is necessary to further develop and improve the interfaces for children in all age groups.

References
Milesi C, Matecki S, Jaber S et al. 6 cmH2O continuous positive airway pressure versus conventional oxygen therapy in severe viral bronchiolitis: a randomized trial. Pediatr Pulmonol 2013; 48: 45–51
Pedersen MB, Vahlkvist S. Comparison of CPAP and HFNC in management of bronchiolitis in infants and young children. Children (Basel) 2017