How to initiate NIV and CPAP in children

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Initiation criteria

According to the clinical presentation of the patient and the underlying disease, continuous positive airway pressure (CPAP) /non-invasive ventilation (NIV) may be initiated in different settings and on different criteria[1, 2, 3], see Figure 1.

ACUTE

Acute respiratory failure

- Impossibility to wean from invasive ventilation or CPAP/NIV (PICU)

SUBACUTE

Abnormal overnight gas exchange

- SpO2 minimum < 90%
- PtcCO2 maximum > 50 mmHg
- ≥ 2% (or ≥ 5 consecutive min) of recording time with SpO2 < 90%
- ≥ 2% (or ≥ 5 consecutive min) of recording time with PtcCO2 > 50 mmHg
- 3% oxygenation index > 1.4 events/hour

CHRONIC (STABLE)

Abnormal P(S)G ± overnight gas exchange

- SpO2 minimum < 90%
- PtcCO2 maximum > 50 mmHg
- ≥ 2% (or ≥ 5 consecutive min) of recording time with SpO2 < 90%
- ≥ 2% (or ≥ 5 consecutive min) of recording time with PtcCO2 > 50 mmHg
- 3% oxygenation index > 1.4 events/hour
- AHI ≥ 10 events/hour

Figure 1 shows initiation criteria for the commencement of CPAP or NIV depending on where the patient is been started with treatment.

CPAP: continuous positive airway pressure, NIV: noninvasive ventilation, PICU: pediatric intensive care unit, P(S)G: poly(somno)graphy, SpO_2: pulse oximetry, $PtcCO_2$: transcutaneous carbon dioxide pressure, AHI: apnea-hypopnea index.

In 10 to 50% of children, CPAP/NIV is initiated during an acute respiratory failure due to unsuccessful weaning from invasive ventilation or CPAP/NIV in the pediatric intensive care unit (PICU)[4]. In this setting, initiation is based on clinical criteria, without the need for objective criteria such as an overnight gas exchange recording or a poly(somno)graphy (P(S)G). However, this is not an optimal situation to initiate CPAP/NIV, due to the stressful environment and the lack of preparation of the child and the caregivers. This underlines the importance of a systematic screening of children at risk of severe obstructive sleep apnea (OSA) and/or nocturnal alveolar hypoventilation[1].

An elective initiation of CPAP/NIV in a stable setting, after an abnormal overnight gas exchange recording or abnormal sleep study, is largely preferable. However, the planning of a sleep study or an overnight gas exchange recording is highly dependent on the type of underlying disease, with no validated criteria for children. There is also a lack of objective validated criteria for CPAP/NIV initiation. Depending on the underlying disease, patient characteristics, and local/regional/national experience and resources, diverse categories of criteria, alone or ± associated, are used:

- clinical symptoms: sleep-disordered breathing (SDB) symptoms, recurrent pneumonia, failure to thrive
- abnormal daytime and/or nocturnal gas exchange: nocturnal hypercapnia represents the most commonly admitted criteria to start NIV in children
- abnormal lung function: low forced vital capacity (FVC)
- echocardiographic anomalies: right heart failure, pulmonary hypertension
- elevated apnea-hypopnea index (AHI) on a P(S)G.

IN PRACTICE

For CPAP: severe persistent OSA in children with upper airway malformation, defined by an obstructive apnea hypopnea index (OAHI) > 10 events/hour associated with abnormal nocturnal gas exchange and that the criteria are the same as chronic (stable) section of Figure 1 after upper airway surgery, or as an alternative to surgical intervention, is the main indication for CPAP[5].

Respiratory criteria during sleep that have been used for continuous positive pressure or noninvasive ventilation initiation[6].	
1	Minimum SpO_2 < 90%
2	Maximal $PtcCO_2$ > 50 mmHg
3	Time spent with a SpO_2 < 90% ≥ 2% of recording time
4	Time spent with a $PtcCO_2$ > 50 mmHg ≥ 2% of recording time
5	3% oxygen desaturation index > 1.4 events/hour
6	AHI > 10 events/hour

SpO_2: pulse oximetry, $PtcCO_2$: transcutaneous carbon dioxide pressure, AHI: apnea-hypopnea index.

For NIV: severe respiratory exacerbations requiring a hospitalization, and a fortiori invasive ventilation or NIV, is the main indication for long term NIV. Nocturnal alveolar hypoventilation, defined by a transcutaneous carbon dioxide pressure ($PtcCO_2$) > 50 mmHg during ≥ 2% of recording times or ≥ 5 consecutive minutes, is a common indication in stable patients[6, 7].

In children with neuromuscular disease (NMD), NIV may also be initiated prior to elective surgery (such as arthrodesis) or to prevent or limit thoracic deformity in young infants with NMD (such as infants with spinal muscular atrophy (SMA type I))[8, 9]. However, in this last situation, the superiority of NIV as compared to daily intermittent positive pressure breathing (IPPB) has not been demonstrated.

CPAP/NIV may be difficult, impossible or not indicated in certain situations listed in Table 2. As such, the absence of the conditions listed in Table 2 should be checked before proposing or initiating CPAP or NIV[1, 10].

Table 2: Ineligibility criteria for continuous positive airway pressure (CPAP) or noninvasaive ventilation (NIV).

Ineligibility criteria	• Impossibility to correct obstructive sleep apnea and/or alveolar hypoventilation
	• Inability to protect the upper airways due to bulbar dysfunction and/or copious respiratory secretions
	• Lack of cooperation of the patient and/or the family
	• Uncontrolled gastro-oesophageal reflux or severe aerophagia
	• Anatomical facial abnormalities
	• Recent facial surgery or complications related to the interface
	• High ventilator dependence

In summary (as highlighted in Table 1) CPAP/NIV initiation is usually based on objective criteria, after having explored all other alternative therapies. In clinical practice, most patients fulfill at least 3 to 4 criteria highlighted in Table 1[11]. Nocturnal hypercapnia is a common criterion for NIV initiation.

Location of elective CPAP/NIV initiation

CPAP/NIV is most often initiated in a hospital setting, either during a hospitalization or in an outpatient setting, and more rarely at home. This depends on the underlying condition, team expertise and availability, preference and comprehension of the family, and local facilities[2, 3, 12].

Interestingly, CPAP/NIV initiated in a hospital outpatient setting, and associated with a therapeutic education program, may be as efficacious with regard to treatment adherence and efficacy, as an initiation during a hospitalization[2].

Initial settings for CPAP/NIV

INITIATION OF CPAP

Mode

Constant (or fixed) CPAP is the most common mode used for CPAP in children. Auto-CPAP, which is a CPAP mode that automatically adjusts the level of pressure to the patient's requirements, is sometimes used in children whose weight is above the minimal weight recommended by the manufacturer. There is limited experience with other "complex" CPAP algorithms (C-flex, A-Flex) in children[13]. As in adults, there is no evidence for a greater efficacy (correction of OSA), comfort, or adherence with auto-CPAP and complex CPAP algorithms as compared to constant CPAP in children.

Settings

Starting pressure is usually set at 4 cmH_2O. Airway pressure is then progressively increased (over one or several nights) to the therapeutic pressure, set either by means of a titration PSG (as recommended by the American Academy of Sleep Medicine (AASM)) or based on other criteria (symptoms, comfort, SpO_2, built-in software data) depending on local availabilities and experience. According to our national experience, mean CPAP therapeutic pressure is usually 8 ± 3 cmH_2O[4] (see Figure 2).

A ramp may be used but should not last too long (usually between 5 and 10 minutes) in order to achieve the therapeutic pressure in time. Humidification may avoid dryness of the upper airways and increase the child's comfort.

INITIATION OF NIV

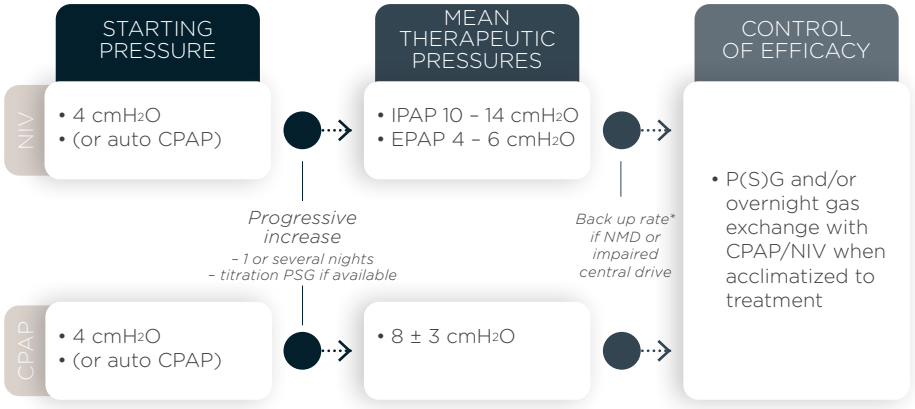
Mode

NIV is usually set with a spontaneous/timed mode, allowing the patient to trigger the ventilator. A back up rate, usually set 2 – 3 breaths below the child's physiological or spontaneous breathing rate (12 – 18 breaths/min), is commonly used for children with NMD and/or an impaired central drive. A "volume guarantee" or "minimal tidal volume" option may be available and may be used in case of alveolar hypoventilation to achieve a tidal volume of 6 – 10 ml/kg, considering the patient's ideal weight for height. Again, there is no evidence for a greater efficacy, comfort, or adherence with these more "complex" modes as compared to a "classical" mode in children.

Settings

Mean starting pressures are 4 cmH_2O for expiratory airway pressure (EPAP) and 8 cmH_2O for inspiratory airway pressure (IPAP). As for CPAP, airway pressure is then progressively increased (over one or several nights) to the therapeutic pressure, set either by means of a titration PSG (AASM recommendation) or based on other criteria (symptoms, comfort, SpO_2, built-in software data) depending on local availabilities and experience.

The usual NIV therapeutic pressures range between 4 – 6 cmH_2O for EPAP and 10 – 14 cmH_2O for IPAP, but settings may vary widely according to the underlying condition and severity.



back up rate is usually set 2 to 3 breaths below the patient's physiological or spontaneous breathing rate (12 – 18 breaths/min)

Figure 2 shows initial settings of CPAP and NIV.

CPAP: continuous positive airway pressure, auto-CPAP: autotitrated CPAP, NIV: noninvasive ventilation, NMD: neuromuscular disease, EPAP: expiratory airway pressure, IPAP: inspiratory airway pressure.

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