Continuous Positive Airways Pressure
and Other Non-invasive Respiratory Techniques in Newborns

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Abstract

Continuous positive airways pressure (CPAP) is a method of assisted respiration that consists of the application of continuous positive pressure to a spontaneously breathing patient’s airways throughout the entire respiratory cycle. The first use of a CPAP was in the 1930s (Poulton EP, Oxon DM, Lancet 228:981–983, 1936; Bullowa JGH, The management of the Pneumonias. Oxford University Press, New York, 1937; Barach AL, Martin J, Eckman M, Proc Am Soc Clin Invest 16:664–680, 1937), but its first notable application in the neonatal field was in 1971 when CPAP was used in the treatment of RDS (respiratory distress syndrome) in spontaneously breathing newborns undergoing tracheal intubation (Gregory GA, Kittermann JA, Phibbs RH et al. N Engl J Med 284:1333–1340, 1971). Nowadays, nasal CPAP (N-CPAP) is considered a valid approach in the management of respiratory failure of the preterm infant from birth reducing occurrence of bronchopulmonary dysplasia (BPD) and death, without increasing risk of neurological damage.

Contents

Salient Points ............................................. 2
Background ............................................. 2
Physiopathology ........................................ 2
Respiratory System ...................................... 2
Cardiocirculatory System ............................. 6
Renal Function ........................................... 6
Intracranial Pressure .................................... 6
Technical Aspect ........................................ 6
Continuous Flow Systems ............................ 7
Variable Flow Systems ............................... 7
Methods of Administering CPAP ................. 7
Clinical Applications .................................... 9
Respiratory Distress Syndrome (RDS) .......... 9
Neonatal Apnea ......................................... 13
Weaning the Patient from Mechanical Ventilation (Post-extubation Phase) ......................... 13
Other Clinical Applications ....................... 14
Side Effects ............................................. 15
Suggestions for N-CPAP Use in the Clinical Practice .............................................. 15
Pressure Level .......................................... 15
Salient Points

- CPAP is a valid approach in the management of respiratory failure of the newborn infant.
- Nasal CPAP (N-CPAP), which is CPAP delivered with nasal prongs, is the most used and effective system for the administration of CPAP in the newborn.
- N-CPAP stabilizes airways, prevents alveoli collapse, and allows spontaneously breathing patient to achieve a functional residual capacity.
- N-CPAP can be delivered by continuous or variable flow systems.
- N-CPAP is considered a valid alternative to tracheal intubation and mechanical ventilation in the acute phase of RDS by reducing occurrence of bronchopulmonary dysplasia and death.
- Surfactant replacement and caffeine prophylaxis can reduce N-CPAP failure in preterm infants with RDS.
- N-CPAP after mechanical ventilation can prevent extubation failure.
- Nasal intermittent ventilation (NIV) especially if synchronized could be a promising approach in case of N-CPAP failure before tracheal intubation.
- Nursing care is determinant to reduce N-CPAP failure.

Background

The premature lung is prone to collapse due to low presence of endogenous surfactant and reduced capacity of the preterm baby to generate an adequate positive pressure to maintain open the alveoli. Therefore, many premature infants at birth (especially when born before 32 weeks’ GA) show signs of respiratory failure and need to be managed with respiratory support and surfactant therapy.

Continuous positive airways pressure (CPAP) is a method of assisted respiration that consists of the application of continuous positive pressure to a spontaneously breathing patient’s airways throughout the entire respiratory cycle. The first use of a CPAP dates back to 1930s (Poulton and Oxon 1936; Bullowa 1937; Barach et al. 1937), but its first notable application in the neonatal field was in 1971 when CPAP was used in the treatment of RDS (respiratory distress syndrome) in spontaneously breathing newborns undergoing tracheal intubation (Gregory et al. 1971).

There is a distinction between CPAP and PEEP (positive end expiratory pressure). CPAP maintains a constant pressure of a level above ambient air pressure, thus providing a continuous transpulmonary pressure gradient during the various phases of the respiratory cycle. Another term for CPAP is continuous distending pressure (Morley 1999). Administered through the nose, (N-CPAP, a technique first proposed by Italian authors in the early 1970s (Agostino et al. 1973; Caliumi-Pellegrini et al. 1974)) CPAP became a cornerstone of respiratory support in the 1990s. When PEEP is used, positive pressure is applied to the airways of a patient undergoing mechanical ventilation in the phases between artificial breaths.

Physiopathology

Respiratory System

The main purpose of CPAP in the newborn is to reduce the work of breathing (WOB). Work is expressed as the function of force × distance and specifically, in the case of respiratory work, as pressure × volume (P × V). It is necessary to create a pressure gradient between the atmosphere and the alveoli so that a volume of air comes into contact with the alveolar-capillary membrane during each inspiration. The pressure generated must be capable of overcoming the elastic properties and resistance of the respiratory system, thus
\[ P_{\text{tot}} = P_{\text{el}} + P_{\text{res}} = \frac{V}{C} + FR \]

where \( P_{\text{tot}} \) is the total pressure, \( P_{\text{el}} \) is the pressure necessary to overcome the elastic forces, \( P_{\text{res}} \) is the pressure required to overcome the resistance, \( C \) is compliance, \( R \) is resistance, \( V \) is volume, and \( F \) is flow (equation of motion of the respiratory system).

In the neonate, increased WOB is clinically manifested by the presence of tachypnea, intercostal/diaphragmatic retractions, and paradoxical breathing.

The amount of work expended in order to expand the rib cage depends principally on:

- The elasticity of the lungs (the work is inversely proportional to the compliance of the lungs)
- The resistance to airflow imposed by the airways
- The elastic and resistive properties of the rib cage

We will examine below the physiopathological characteristics of the neonatal respiratory system, with particular attention to aspects relating to premature infants, and we will analyze the effects of CPAP application with respect to neonatal respiratory physiology.

The neonate, particularly if premature, has a double disadvantage in performing respiratory work:

- There is increased pulmonary elastic resistance
- The airways provide considerable resistance
- The compliance of the rib cage is increased

**Greater Resistance of the Airways**

The premature newborn presents increased resistance above all due to the proximal airways for various reasons:

- Absence of the superficial layer of adipose tissue in the neck that helps to stabilize the airways, thus keeping them patent (Wilson et al. 1980; Cohen and Henderson-Smart 1986).
- Reduced mobility of the genioglossus muscle that normally stabilizes the pharynx (Gauda et al. 1987).
- Reduced diameter of the airways.
- Increased compliance of the airways, which creates a tendency for them to collapse during inspiration; this increased compliance also increases the ventilation of the dead space.

The premature newborn also presents increased resistance at the level of the peripheral airways. The reasons for this are:

- The structural composition of the lungs is insufficient to keep the smaller airways open.
- The reduction of FRC causes a reduction in diameter of the smaller airways.

Low surfactant production with consequent increase in pulmonary surface tension and reduction in pulmonary volume at the end of expiration (functional residual capacity, FRC).

Excessive quantity of pulmonary fluid: the clearance of the pulmonary fluid is slower in the premature newborn, particularly when delivered by elective cesarean section. In fact, the premature infant is often unable to generate an adequate delta pressure to move the fluid throughout the airways until the distal space of the lung where it is reabsorbed by the interstitial venous and lymphatic vessels. In addition, fluid and sodium absorption mechanisms are immature. Furthermore, the left-to-right shunt that occurs when there is a patent ductus arteriosus (PDA), especially during the recovery phase of RDS, can contribute to an increase in pulmonary fluid.
Increased Compliance of the Rib Cage

Compliance of the rib cage is inversely proportional to gestational age. The compliance of the rib cage is around five times greater than that of the lungs in premature newborns (for normal values of pulmonary compliance) and around three times greater in full-term newborns. In adults the ratio is 1:1 (Gerhardt and Bancalari 1980). As such, the newborn’s rib cage is much weaker and more flexible and is therefore incapable of maintaining adequate transpulmonary pressure at the end of expiration. This brings a reduction in FRC, ventilation at near-closing volumes, alveolar collapse, imbalance in the ratio of ventilation to perfusion, hypoxemia, and hypercapnia with acidosis (see chapter “Neonatal Pulmonary Physiology of Term and Preterm Newborns (First Edition)”).

The combined effect of reduced pulmonary compliance and increased compliance of the rib cage results in a reduced FRC (Fig. 1) with a tendency toward atelectasis and a reduction in gaseous exchange.

A mechanism enacted by the newborn to maintain an adequate FRC is the partial closure of the epiglottis during expiration (grunting): the premature newborn often cannot maintain adequate laryngeal tone and so may undergo a loss of pulmonary volume. It has been shown that the suppression of grunt caused by endotracheal intubation creates a reduction in $\text{paO}_2$ (Harrison et al. 1968).

Aside from the cry, the newborn has two further mechanisms to increase FRC: (1) maintaining the contraction of the inspiratory muscles during the first phase of expiration and (2) commencing the inspiration before expiration has finished. This strategy, which has the effect of increasing the FRC (dynamic increase of FRC), can facilitate gaseous exchange but is disadvantageous from the point of view of the amount of energy expended (Schulze et al. 1990). Fatigue or the presence of apnea in the newborn with respiratory distress syndrome can defeat the abovementioned mechanism and can encourage the development of atelectasis with consequent respiratory insufficiency (Morley 1999).

The reduction in FRC means that the newborn is working in the lower part of the compliance curve (Fig. 2, part A) and so is constrained to develop high pressures in order to gain small increases in volume. A low volume at the end of inspiration also induces closure of the small airways, followed by collapse of the alveoli. This necessitates greater pressures during inspiration in order to reopen the collapsed alveoli (critical opening pressure). Pulmonary collapse also causes epithelial damage with consequent protein exudates and surfactant consumption (see chapter “Lung Diseases: Surfactant Replacement Therapy (First Edition)”). This reduction in pulmonary volume also brings a change in the ratio of ventilation to perfusion with a consequent increase in
the alveolar-arterial gradient and CO₂ concentration.

**Respiratory Effects of CPAP**

The application of continuous positive pressure to the airways amplifies the effect of the strategies by the spontaneously breathing newborn that are aimed at maintaining an adequate volume at the end of expiration, minimizing the energy expended to stabilize the respiratory system, and carrying out the mechanical work of respiration. This prevents collapse of the airways and improves many critical situations that bring about an increase in the respiratory workload required of the newborn. In summary, CPAP acts on the respiratory system by the following mechanisms:

1. Increasing FRC (Fig. 2, Part B), eliminating dynamic elevation of FRC reducing resistance in the airways. The reduction in airway resistance is obtained by:
   - Increasing the transverse section of the pharynx (the oropharynx can account for 66% of supraglottidal resistance (Miller et al. 1990)).
   - Dilating the airways and making them more rigid, stabilizing them, and preventing their collapse. In particular, an increase from 12.5% to 47% of the ratio of the width to the length of the larynx at the moment of maximum abduction of the vocal cords has been shown following CPAP application (Gaon et al. 1999).
   - Increasing the FRC thus can favor caudal traction across the supraglottidal airways reducing their resistance (Van de Graaff 1988).

2. Reducing the R-L shunt, thanks to the improved oxygenation and the consequent vasodilation of the pulmonary circulation.

3. Stabilizing the thoracic wall, reducing its distortion and curbing paradoxical movement. Regularizing and slowing respiratory frequency (Kurz 1999).

4. Regularizing and slowing respiratory frequency (Kurz 1999).

5. Improving the capacity to generate a valid inspiratory force and thus to reopen collapsed alveoli following an obstructive event, probably through the elimination of the Hering-Breuer deflation reflex which is activated by a distortion in the inferior portion of the rib cage.
(Martin et al. 1977). In this way, it also reduces the incidence of obstructive apnea.

6. Increasing the average pressure in the airways (mean airways pressure, MAP) increasing the ventilation-perfusion ratio.

7. Preserving the surfactant on the surface of the alveoli.

8. Reducing alveolar edema.

Normalizing pulmonary volume, ventilations/minute, and the ventilation-perfusion ratio, CPAP improves oxygenation, increases the elimination of CO₂, and reduces the WOB (Poulton and Oxon 1936).

**Cardiocirculatory System**

CPAP results in a reduced preload in the right ventricle and consequently systolic output. The extent of these effects depends on how much pressure is applied by the lungs to the vascular spaces: the lower the compliance, the lower the applied pressure (Perlman and Thach 1988). In the premature newborn, in the presence of a highly compliant rib cage and often low pulmonary compliance, the pressure applied by the airways to the pleural spaces is only 5–10%, with little effect on cardiac output. In full-term newborns with normal lungs, 25% of the pressure in the airways (Paw) can be transferred to the pleural spaces, and therefore the use of high pressure in these babies can have a significant effect on cardiac output. The increased thoracic compliance of the premature newborn therefore protects the intrathoracic vascular structure from a large increase in intrapleural pressure and from a consequent reduction in central venous return (Gerhardt and Bancelari 1980). On the other hand, CPAP reduces pulmonary resistance in babies with RDS because of the vasodilatation of the pulmonary circulation resulting from improved oxygenation; this is the most important effect in newborns with respiratory pathologies treated with CPAP.

**Renal Function**

Renal function depends largely on the hemodynamic situation of the patient (Ahumada and Goldsmith 1996). In cases of low pulmonary compliance, the application of CPAP brings an improvement in oxygenation, and renal function can only be positively affected. In the presence of restricted water intake for the treatment or prevention of a PDA – a common situation in cases which require the application of CPAP – the administration of dopamine at renal doses may be useful (approx. 3 μ/kg/min).

**Intracranial Pressure**

A reduction in cerebral perfusion has been reported in the course of the application of PEEP. This is related to the level of the PEEP.

An increase in intracranial pressure was found during the application of CPAP by a box around the head, due to compression of the veins in the neck. It does not appear that CPAP applied by endotracheal or nasal tube results in an increase of intracranial pressure (Ahumada and Goldsmith 1996).

**Technical Aspect**

CPAP can be delivered by a variety of devices and interfaces. There are two main types of CPAP devices, categorized on the basis of the flow characteristics: continuous and variable flow systems.

An important prerequisite for success in the use of CPAP is a circuit that allows the pressure to remain at the desired level throughout the respiratory cycle. Excessive inspiratory or expiratory fluctuations directly increase WOB and offset any benefits in pulmonary mechanics produced by CPAP (Gherini et al. 1979).

Substantial differences were found in the fluctuations of Paw in different respiratory circuits hooked up to a mechanical lung model (Rasanen and Leijala 1991).
Continuous Flow Systems

These systems use a resistance to flow at the end of the respiratory circuit to produce pressure above that of atmospheric pressure. These CPAP systems include bubble CPAP. This device uses a fixed gas flow, and the column of water in the expiratory limb generates CPAP equal to the length of the tube that is immersed under water, which creates chest vibrations through bubbling. All these devices are also fitted with systems to humidify and heat the air. Continuous-flow mechanical ventilators can also be used to produce CPAP by the means of the PEEP valve to maintain continuous positive pressure throughout the entire respiratory cycle.

Variable Flow Systems

Benveniste System

The positive pressure is generated by a jet of gas directed toward an opening into a small chamber from which the mixture for the newborn comes out. Flow rates of 4–20 L/min serve to generate pressures in the chamber from 0 to 13 cmH₂O. These pressures are comparable to those measured at the oropharynx in the course of CPAP administered via one or two nasal prongs (this is indifferent, as long as the mouth is kept closed by the use of a pacifier) (Pedersen and Nielsen 1994).

Infant Flow System

A generator is connected to a circuit composed of a three-channel tube (Figs. 3 and 4): one channel (inspiratory limb) provides gas flow and is connected to the nasal cavity via nasal prongs or mask, one (expiratory limb) is open to ambient pressure, and one is used to measure the level of pressure created at the generator level. The flow provided by the infant flow driver is accelerated in the twin injector nozzles of the N-CPAP generator. This causes the flow to flip round and leave the generator via the expiratory limb. CPAP is maintained at the nasal connection throughout. When the expiratory breathing effort stops, the flow instantly flips back to the inspiratory position. The operating principle is that the high-pressure jet flows in different directions in response to the pressure generated at the level of the nasal cavities and the respiratory effort of the patient. During inspiration, the drop in pressure in the nasal cavities creates a pressure gradient that directs the flow toward the nasal cavities, thus assisting inspiration. During expiration, there is an inversion of the direction of the jet that helps the expiration (Coanda effect). The kinetic energy of this high-velocity flow is transformed into pressure in the area of the nasal cavities, thus generating CPAP. Flow rates between 5 and 11 L/min generate pressures between 2 and 10 cmH₂O. As such, the system does not require an expiratory valve. Tests on mechanical lung models have demonstrated that a CPAP circuit achieves greater stability in Paw and a reduction in WOB of around one quarter compared to traditional circuits (Moa et al. 1988; Moa and Nilsson 1993; Klausner et al. 1996). Available clinical studies have, on the other hand, reported conflicting results. Two studies did not show any difference between this system and traditional ones in terms of improving pulmonary compliance, reducing oxygen requirements and improving respiratory frequency (Ahluwalia et al. 1998; Kavvadia et al. 2000).

A recent study comparing three circuits (infant flow system, double nasal prongs, and single nasal prong fed by mechanical ventilators) for the application of NCPAP in newborns weighing less than 1800 g with light respiratory distress or apnea demonstrated better pulmonary recruitment using the infant flow circuit (Courtney et al. 2001).

Methods of Administering CPAP

Endotracheal Tube This method entails a notable resistance (directly proportional to its length and inversely proportional to its radius) and as such involves a significant increase in WOB. At this time, it is no longer recommended as a system for
the administration of CPAP. Furthermore, by bypassing the nasal and pharyngeal mucosa, it creates an alteration in the humidification and heating of the inhaled gases. Also the potential trauma applied to the vocal cords and the respiratory mucosa makes its use inadvisable for newborns who do not need mechanical ventilation.

**Head-Box (Helmet CPAP)** This system is of low efficacy below 1500 g bodyweight and extremely noisy and cumbersome and does not allow access to the newborn’s head. Furthermore, it has been associated with an increased incidence of cerebral hemorrhage due to compression of the neck (Vert et al. 1973). Aspiration pneumonia has also been reported during feeding.

**Face Mask** This system too is rarely used, particularly for premature infants. The mask should cover the nose and mouth and should always be used with an orogastric feeding tube to avoid excessive abdominal distension. In the premature newborn, apart from the problem of keeping the mask in place and the consequent difficulty of generating a sufficient level of CPAP with adequate flow, there are also problems of excessive dead space that can be two or three times greater than in a full-term newborn. Cases of
cerebral hemorrhaging have been reported in very low birth weight newborns undergoing this therapy due to the forces applied to the back of the head by the mask’s attachments (Pape et al. 1976).

Facial Chamber The entire face protrudes into a chamber held in place by a latex ring filled with styrene particles. This system too is now not used as it does not permit access to the newborn’s face for alimentation or aspiration.

Nasopharyngeal Tube (Mono-nasal CPAP) The same type of tube used for tracheal intubation is inserted through the nostril as far as the pharynx. This is a simple technique, which is widely used during the transport of the baby from the delivery room to the NICU or yet in the NICU, in case of mild forms of respiratory distress or apnea in the premature. The disadvantages lie in the fact that this tube provides elevated resistance, particularly if it is of small diameter, and that the tube also totally bypasses the humidifying-heating action provided by the nasopharyngeal mucous. In addition, it can give more nasal trauma than nasal prongs.

Nasal Prongs (Bi-nasal CPAP) Currently, this is the most used and effective system for the administration of CPAP in the newborn. The baby has to breathe through the nose; the nasal prongs also allow the air to be humidified and heated by most of the nasopharyngeal mucous. The mouth in this case acts as a pop-off pressure valve. The nasal prongs are easily applied and less invasive than the endotracheal tube; first examples of nasal prongs were put into use in the early 1970s (Agostino et al. 1973; Caliumi-Pellegrini et al. 1974; Kattwinkel et al. 1973). Particular attention has been paid to the work required of the newborn in order to overcome the resistance due to the small diameter of the nasal prongs (the so-called superimposed work of breathing). A study reported an increase of 100% in WOB during CPAP administered with nasal prongs compared to CPAP with a face mask (Goldman et al. 1979). A closer evaluation of the study, however, revealed that this increase could, in part, be put down to the increased resistance caused by the catheter placed inside the prongs to relieve pressure. Recently, these prongs have been redesigned with a precise angle and structure in order to minimize resistance to the airflow (Klausner et al. 1996). Another problem with these prongs is related to the loss of flow (and hence of pressure) around the prongs themselves if they are not secured properly. Nowadays, the prongs are made from a soft silicon material that expands slightly in contact with the warmth and humidity of the nostrils, adapting to their dimensions and so favoring a good fit.

Nasal Masks These devices, which consist of silicone masks that completely cover the nose, are sometimes a useful alternative to nasal prongs, in particular in extremely low birth weight infants.

Clinical Applications

Respiratory Distress Syndrome (RDS) The main physiopathological aspects of RDS, whose principal cause is a deficit of surfactant (Avery and Mead 1959), are reduction in pulmonary compliance, reduction in FRC, and alteration in the ratio of ventilation to perfusion. The rigidity of the rib cage is also reduced with a paradoxical distortion during inspiration which is greater the larger the reduction in pulmonary compliance, with a consequent reduction in tidal volume (Morley 1999; Greenough and Roberton 1996). These alterations lead to a profound alteration in gas exchange and increase the respiratory workload; the consequences of which are the presence of hypoxemia, hypercapnia, and acidosis.

Clinical Evidence The first clinical experience of neonatal CPAP application came in 1971 with a case report of 20 patients affected by RDS (Morley 1999). This was followed by others (Bancalari and Sinclair 1991; Cordero et al. 1997; Tarnow-Mordi et al. 1986).

The rationale behind the use of early N-CPAP in the VLBW newborn lies in the facilitation of the acquisition and maintenance of an adequate pulmonary volume (FRC). As well as improved gas exchange, a normal air-liquid interface is maintained at the level of the terminal alveoli. This promotes the liberation of reserves of
pulmonary surfactant, which in turn further stabilize the air spaces preventing the formation of hyaline membranes and the following atelectasis that is typical of surfactant deficiency. This should lead to a decrease in the requirement for mechanical ventilation with a reduction in its complications, in particular bronchopulmonary dysplasia.

The main reason for the interest in adopting N-CPAP, especially in very low birth weight newborns (VLBW, i.e., <1500 g), came from the publication of two multicenter retrospective studies. They showed that the incidence of chronic lung disease, assessed as the percentage of VLBW survivors who were oxygen dependent at 28 days from birth, was significantly lower in centers that had been early adopters of N-CPAP, despite having among the highest survival rates. The early adoption of N-CPAP at these centers was part of a low-invasiveness strategy consisting of the tolerance of relatively high pCO2 values, up to 60 mmHg (permissive hypercapnia), before proceeding to intubation and mechanical ventilation, and the nonuse of paralyzing drugs (Avery et al.1987; Horbar et al.1988).

Early N-CPAP was largely used in VLBW infants with recourse to intubation and mechanical ventilation only when it was held to be essential, based on well-established criteria (Jonsson et al. 1997; Kamper and Ringsted 1990; Kamper et al. 1993; Lundstrom1996). The common denominators of these clinical experiences are:

Intubation in the delivery room only if considered essential for cardiopulmonary resuscitation
Early N-CPAP, i.e., application of N-CPAP to all newborns within the first 30 min of life or at the appearance of the first signs of respiratory distress
Intubation and, if necessary, mechanical ventilation only if one or more of the following criteria are met (criteria for failure of N-CPAP): untreatable apnea, respiratory acidosis (pCO2 > 65–70 mmHg and pH <7.20), and requirement of exogenous surfactant

In Scandinavia, where the N-CPAP is widespread and long-term used, the success of N-CPAP in treating VLBW infants avoiding mechanical ventilation, was proportional to the gestational age (76% of newborns ≤26 weeks’ GA require ventilation compared to 43% of newborns >26 weeks) regardless the use of prenatal prophylaxis with steroids (Jonsson et al. 1997).

There is a general tendency to tolerate higher pCO2 values than in the past (Avery et al. 1987; Kamper and Ringsted 1990; Kamper et al. 1993), and this has reduced the need for intubation. Even when mechanical ventilation is undertaken, it does not require the use of aggressive ventilation strategies in search of blood gas values that are obtained at the cost of high baro-volutrauma (Jonsson et al. 1997).

A study carried out on 67 newborns of <1000 g birthweight (extremely low birth weight, ELBW) who underwent early N-CPAP, if they were not intubated in the delivery room for primary resuscitation, demonstrated that it was not necessary to intubate and start mechanical ventilation in 73% of the newborns >28 weeks and in 32% of the newborns ≤28 weeks (Lindner et al. 1999). In another study, Finer et al. (Finer et al. 2004) found that all infants of 23 weeks’ gestation required intubation in the delivery room, whereas only 3 of 21 (14%) infants of 27 weeks’ GA required such intubation.

The reduction in the percentage of mechanically ventilated newborns did not cause an increase in mortality or negative side effects such as cerebral hemorrhage (Jonsson et al. 1997; Kamper et al. 1993; Lindner et al. 1999; Gittermann et al. 1997; Jacobsen et al. 1993; Sandri et al. 1999).

However, despite uncontrolled and cohort studies suggesting the efficacy of N-CPAP in avoiding MV and ventilatory-induced lung injury, there were few randomized clinical trials confirming the benefit of N-CPAP as the primary type of respiratory support in preterm newborns. Morley et al. published the COIN trial in 2008 (Morley et al. 2008). In this trial, N-CPAP was compared with intubation and ventilation on the hypothesis that the use of N-CPAP shortly after birth would reduce the rates of death and bronchopulmonary dysplasia. The main eligibility criteria were a gestational age at delivery between
and 28 weeks and an ability to breathe at 5 min after birth but needing respiratory support. Infants were ineligible if they had been intubated before randomization or if they required no respiratory support or oxygen. At 5 min after birth, the allocated treatment was started. In infants who were assigned to receive N-CPAP, this was started at a pressure of 8 cm of water with nasal prongs. They were intubated and underwent ventilation only if they had any of the following clinical signs: apnea unresponsive to stimulation and methylxanthine treatment, an arterial pH of less than 7.25 with arterial carbon dioxide (paCO₂) of more than 60 mmHg (8.0 kPa), a metabolic acidosis not responsive to treatment, or treatment with more than a 60% concentration of oxygen. Infants receiving N-CPAP were treated with surfactant only after intubation. Surfactant treatment, ventilation settings, and extubation and reintubation criteria were not mandated in either group and followed local protocols. Half the infants in the N-CPAP group were subsequently intubated. Infants in the N-CPAP group had a better outcome at 28 days than those in the intubation group. The two groups had similar outcomes at 36 weeks' gestational age, but there was an increased incidence of pneumothorax in the N-CPAP group.

In 2010, Finer et al. published the SUPPORT trial (Finer et al. 2010). In this randomized multicenter trial, inborn infants of 24.0–27.6 weeks' GA were randomly assigned to intubation and surfactant treatment (within 1 h after birth) or to N-CPAP treatment initiated in the delivery room. The primary outcome was death or BPD at 36 weeks’ postmenstrual age. A total of 1318 infants were enrolled in the study. The rates of primary outcome did not differ significantly between the two groups (47.8% and 51.0%, respectively) without any other differences in terms of adverse neonatal outcomes. The authors concluded that CPAP has to be considered as an alternative to intubation and surfactant in preterm infants.

A multicenter study carried out in Sweden compared the incidence of mechanical ventilation in two groups of newborns affected by moderate-to-severe RDS to whom early CPAP was applied (e.g., application at the first clinical signs of respiratory distress). The treatment group received the INSURE approach if their oxygen requirement exceeded 60%. The control group received treatment only with N-CPAP and surfactant was reserved for cases where mechanical ventilation was required. The criteria for application of mechanical ventilation (apnea and or oxygen requirement > 80%) were the same for both groups. Recourse to mechanical ventilation was reduced from 85% in the control group to 43% in the treatment group (Verder et al. 1994).

The same authors later carried out a multicenter study on newborns with RDS below 30 weeks' gestational age and who were undergoing early N-CPAP. They demonstrated that when the INSURE approach was adopted early in RDS, i.e., at an oxygen requirement between 40% and 60%, there was a reduction in the need for mechanical ventilation and of death in the first 7 days postpartum from 63% to 21% compared to a later approach (oxygen requirement >60%) (Verder et al. 1999).

This last work, aside from demonstrating the efficacy of the INSURE approach, permitted the establishment of a limit to the oxygen requirement in patients with RDS undergoing N-CPAP (FiO₂ about 40%) above which the administration of surfactant is indicated.

A study conducted in Italy on 155 newborns of gestational age ≥ 28 and <32 weeks treated by the INSURE approach at oxygen requirements >40% showed no difference in requirements for
surfactant and mechanical ventilation comparing two groups to which N-CPAP had been applied: in the first group, N-CPAP was applied within 30′ of birth, regardless of the clinical picture; in the second group, N-CPAP was applied only in the presence of respiratory distress with oxygen requirements >40% (Sandri et al. 2004).

A systematic review of the INSURE approach reported a reduced need for MV in the first week of life, when used early in respiratory distress syndrome (Stevens et al. 2007).

Either prophylactic surfactant or delivery room N-CPAP to maintain functional residual volume was identified as potentially beneficial practice which, if adopted in extremely preterm infants, could reduce lung injury (Burch et al. 2003).

Recently, the CURPAP study compared the administration of prophylactic surfactant followed by N-CPAP (prophylactic INSURE) with early N-CPAP followed by early selective surfactant given through a brief course of endotracheal intubation (early rescue INSURE) to preterm newborns of GA 25–28 weeks not intubated at birth (Sandri et al. 2010). In both groups, MV was started after surfactant in the absence of good respiratory drive. Infants who were extubated to N-CPAP after surfactant were eligible for MV if the following N-CPAP failure criteria occurred: FiO₂ > 0.40 on N-CPAP to maintain oxygen saturation of 85–92% for at least 30 min unless rapid clinical deterioration occurred, intractable apnea, respiratory acidosis defined as pCO₂ > 65 mmHg (8.5 kPa), and pH < 7.20. This study showed that, in spontaneously breathing preterm newborns treated with N-CPAP, prophylactic surfactant given within 30 min from birth is not superior to early selective surfactant in terms of requirement of MV in the first 5 days of life.

The main implication for clinical practice of the CURPAP study is that N-CPAP should be started soon after birth in spontaneously breathing infants of 25–28 weeks’ gestation, and early selective surfactant should be given once signs of respiratory distress have developed. Extubation after surfactant administration should be attempted as soon as possible. With this strategy, more than 50% of infants will need only N-CPAP, 49% intubation and surfactant, and nearly one third also mechanical ventilation in the first 5 days of life. Overall, the respiratory approach used in this study resulted in a very good respiratory outcome: 78–79% of infants, in both arms, survived without any supplementary oxygen or respiratory support at 36 weeks’ postmenstrual age. The incidences of moderate/severe BPD were 14.3 and 11.7%, respectively, in the prophylactic surfactant and N-CPAP groups, which is lower than the 30% incidence reported in other studies (Walsh et al. 2003; Payne et al. 2006).

Finally, Dunn MS et al. published the VON trial (Dunn et al. 2011). In this multicenter randomized trial, three approaches were compared for the initial respiratory management of preterm infants (26.0–28.6 weeks’ GA): prophylactic surfactant (PS) and mechanical ventilation, prophylactic surfactant given as INSURE procedure (ISX) followed by N-CPAP (bubble CPAP), or N-CPAP (bubble CPAP) and selective surfactant treatment. Primary outcome was the incidence of death and BPD at 36 weeks’ postmenstrual age. Six hundred forty eight infants were enrolled in 27 centers. Preterm infants initially managed with INSURE approach or N-CPAP plus selective surfactant therapy showed similar outcomes to those treated with PS and mechanical ventilation. Therefore, the authors concluded that early N-CPAP approach may be recommended as a less invasive and potentially less expensive method of management in this category of patients.

In the past, doubts have been cast on the possibility of generalizing low-invasiveness treatment strategies in VLBW infants (Roberton 1993). Currently, similar doubts may be raised for ELBW infants, in whom the application of results from studies (Finer et al. 2004; Morley et al. 2008; Sandri et al. 2010) should take into account the rate of prenatal steroid use and the type of antenatal healthcare program.

Nevertheless, two meta-analysis that analyzed the results of the most recent RCTs (e.g., CURPAP, COIN, SUPPORT, etc.) demonstrated that using a non-invasive respiratory approach in the DR and beyond can lead to a small but significant reduction in the rate of BPD in very premature infants (Schmölzer et al. 2013; Fischer and
Bührer 2013). This concept is reinforced in the current neonatal resuscitation guidelines (Wylie et al. 2015).

In conclusion, the available published data suggests that:

VLBW infants, not intubated at birth for cardiopulmonary resuscitation, can be treated conservatively using NCPAP, with the administration of surfactant and mechanical ventilation only being used if precise clinical, laboratory test and instrumental criteria are met.

Prenatal steroids, higher GA, and female sex are associated with higher chances of being treated noninvasively.

A precise limit of gestational age or birth weight below which N-CPAP cannot be used with success has not yet been established.

Using NCPAP together with early selective surfactant to avoid more invasive strategies does not entail an increase in mortality rates or negative side effects.

**Neonatal Apnea**

Apnea is traditionally classified into three categories based on the presence or absence of obstruction of the upper airways: central, obstructive, and mixed (see chapter “Apnea of Prematurity and Sudden Infant Death Syndrome (First Edition)” (Kattwinkel 1977; Miller et al. 1985).

Because most apneic episodes have an obstructive component, CPAP appears to be one of the most effective strategies. It splints the upper airway with positive pressure and decreases the risk of pharyngeal or laryngeal obstruction. CPAP probably also improves apnea by increasing functional residual capacity (FRC) and so improving oxygenation status (Kattwinkel 1977; Miller et al. 1985). The positive effect of CPAP is also due to the stabilization of the rib cage, (Miller et al. 1990; Van de Graaff 1988; Kattwinkel 1977) that contributes to the airways opening and to the reduction of the Hering-Breuer reflex (Martin et al. 1977).

Given that N-CPAP does not have a direct effect on apnea of central origin, its use in association with stimulants of the respiratory centers such as methylxanthine below 32 weeks of gestational age is generally accepted (AARC (American Association for Respiratory Care) 1994; Aranda and Turmen 1979; Schmidt et al. 2006).

In case of persistent and severe apnea of prematurity, before deciding to intubate the baby, it could be useful to switch the infant from N-CPAP to other form of noninvasive respiratory approach (e.g., bi-level CPAP or NIPPV), even better if synchronized with the patient effort, as suggested from a recent randomized crossover trial (Gizzi et al. 2015).

**Weaning the Patient from Mechanical Ventilation (Post-extubation Phase)**

It is well known that after a period (long or short) of intubation and mechanical ventilation, extubation can fail, leading to the re-intubation of the newborn (Fox et al. 1981). The reasons for this failure are substantially as follows:

Apnea
An increase in oxygen requirements (this can be correlated to a loss of volume from a malfunction of the glottis after intubation or to atelectasis)
Respiratory acidosis

Various contributors have demonstrated the efficacy of N-CPAP application in the post-extubation phase following mechanical ventilation. N-CPAP compared to direct extubation reduces the need of re-intubation, both in newborns weighing <1500 g (16% failure rate vs. 52%) (So et al. 1995) and in those weighing <1000 g (24% failure rate vs. 79%) (Higgins et al. 1991). The factors that necessitate re-intubation, principally apnea but also an increase in oxygen requirement due to loss of pulmonary volume and respiratory acidosis, are counteracted by N-CPAP. A meta-analysis confirmed the efficacy of N-CPAP in weaning of patients from mechanical ventilation and thus recommended...
its adoption as an elective method for use after extubation, if necessary in combination with a methylxanthine (Davis and Henderson-Smart 2000). To achieve successful extubation to N-CPAP, it is also important to choose the most appropriate moment in terms of parameters of mechanical ventilation. This should be at a point where the respiratory problem can be considered overcome by ventilation (FiO₂ < 0.35, mean airways pressure [MAP] < 7 cmH₂O, ventilatory frequency ≤ 20/min) (So et al. 1995; Higgins et al. 1991; Davis and Henderson-Smart 2000). A recent study comparing a continuous flow with a variable flow CPAP device (bubble CPAP vs. infant flow system) concluded that both devices were effective in the post-extubation management of infants with RDS. However, in infants ventilated for ≤14 days, bubble CPAP is associated with a significantly higher rate of successful extubation and with a significantly reduced duration of CPAP support (Gupta et al. 2009). Even if previous RCTs have shown that N-CPAP is a useful method for providing respiratory support after extubation, nevertheless this approach sometimes fails and physicians use as alternative nasal intermittent positive pressure ventilation (NIPPV). A recent meta-analysis (Lemyre et al. 2017) has compared effects of management with N-CPAP versus NIPPV in preterm infants after extubation. The Cochrane review concluded that NIPPV reduces the incidence of extubation failure and the need for re-intubation within 48 h to 1 week more effectively than N-CPAP. However, nasal ventilation has no effect on BPD nor on mortality. The authors suggested that synchronization may be important in increasing the efficacy of NIPPV. Last but not least, a recent meta-analysis (Wilkinson et al. 2016) demonstrated that high-flow nasal cannulae (HFNC) have similar rates of efficacy than other forms of noninvasive respiratory support in preterm infants to prevent failure of extubation. Therefore, HFNC could be considered a valid alternative to N-CPAP in this phase of the management of preterm infants with respiratory distress.

Other Clinical Applications

**Transient Tachypnea of the Newborn (TTN)** Some doubts have been raised regarding the safety of N-CPAP in TTN (see chapter “Pulmonary Hemorrhage, Transient Tachypnea and Neonatal Pneumonia (First Edition)”) due to the theoretical risk of air trapping and pneumothorax. There are, however, no relevant published data (Greenough 1996). Authoritative guidelines include TTN in indications for N-CPAP application (AARC (American Association for Respiratory Care) 1994; Jonzon 1991), and our personal experience is that the early application of N-CPAP for TTN brings about a reduction in the clinical signs of respiratory distress without a significant increase in the incidence of pneumothorax.

**Meconium Aspiration Syndrome (MAS)** The application of a continuous distending pressure could be beneficial, resolving the areas of atelectasis and reopening and stabilizing the airways (Ahumada and Goldsmith 1996; Fox et al. 1975). However, it should be reserved for the less severe forms of MAS (see chapter “Mecoonium Aspiration Syndrome (First Edition)”). More serious cases will require intubation (bronchoalveolar lavage with) surfactant, and mechanical ventilation (Lam 1999; Mosca et al. 1996).

**Congenital Cardiopathies with Hyperaflux** Pulmonary hyperaflux can lead to a reduction in pulmonary compliance and to a change in the ventilation-perfusion ratio, with consequent hypoxemia, which is potentially correctable with CPAP (Ahumada and Goldsmith 1996).

**Tracheobronchomalacia** CPAP resolves the collapse of the airways present in this condition, considerably relieving the respiratory distress correlated with it (AARC (American Association for Respiratory Care) 1994; Miller et al. 1986).

**Atelectasis** The onset of atelectasis can be due to different factors but its resolution will require the removal of the root cause in each case. However, in many situations, e.g., post-extubation atelectasis, CPAP may be used electively (AARC (American Association for Respiratory Care) 1994).
**Bronchiolitis** Early CPAP (predominantly nasal) can rapidly aid respiratory muscles and improve respiratory distress symptoms (retractions, tachypnea, agitation) and blood gas measurements (pO2, pH, pCO2). These effects have been attributed to widening of the bronchioli by positive pressure, followed by emptying of the lung and restoration of a normal FRC. This leads to a reduction in the use of mechanical ventilation (Beasley and Jones 1981; Soong et al. 1993). N-CPAP has also demonstrated its efficacy in the treatment of apnea associated with RSV infection (McNamara and Sullivan 1997).

**Paralysis of the Phrenic Nerve** Cases have been published in which paralysis of the phrenic nerve was successfully treated with N-CPAP application, which corrects the deficit in transmural pressure caused by paralysis of the diaphragm (Bucci et al. 1974).

**Nebulization of Pharmaceuticals** N-CPAP has recently been used for the respiratory administration of pharmaceuticals (beta-blockers, steroids, acetylcysteine, and adrenaline), although this does not currently seem to be of great clinical interest (Smedsaas-Lofvemberg et al. 1999).

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**Side Effects**

**System Malfunctions** The obstruction of the nasal prongs or the tube by mucous (like the obstruction of the nasal passages) is common during N-CPAP, with potentially serious consequences (sudden decrease in oxygenation) due to the lack of airflow delivered to the patient (AARC (American Association for Respiratory Care) 1994).

**Pulmonary Overdistention** Pulmonary hyperdistension is the most serious complication that can occur during N-CPAP. This condition can occur whenever the positive pressure applied is excessive with respect to the patient’s pulmonary compliance.

The presence of a hyperdistended lung leads to an increased risk of pneumothorax, a worsening of the ventilation-perfusion ratio, and an increase in CO2 retention and WOB. It is also known that the higher the pulmonary compliance, the greater the transmission of positive pressure to the posterior mediastinum, followed by an increase in central venous pressure with a decrease in venous return and cardiac output. Figure 5 shows the effects of rising CPAP values on central venous pressure, on paO2, and on paCO2, the onset of which correlates directly with hemodynamic and respiratory interferences (Fig. 2, part C) (Gregory 1986). These hemodynamic effects can have serious consequences on gastrointestinal, renal, and cerebral perfusion and can cause an increase in intracranial pressure due to the decrease in venous drainage (Ahumada and Goldsmith 1996; AARC (American Association for Respiratory Care) 1994).

**Gastric Distension** It can cause reduced ventilatory excursion due to compression of the diaphragm or even gastric perforation (CPAP belly syndrome) (Ahumada and Goldsmith 1996; AARC (American Association for Respiratory Care) 1994; Leone and Krasna 2000). It can be prevented by properly affixing the nasal prongs, by positioning a permanent orogastric tube, and by periodically checking the degree of abdominal distension.

**Nasal Lesions** Nasal-cutaneous lesions have been described during N-CPAP with possible permanent deformities (Loftus et al. 1994; Robertson et al. 1996). These lesions can be prevented by choosing silicone nasal prongs (which permit good contact without being harmful), nasal prongs of the correct dimensions with relation to the newborn’s nostrils and ensuring their correct positioning.

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**Suggestions for N-CPAP Use in the Clinical Practice**

**Pressure Level**

There have been few data published to evaluate a method that would allow the establishment of an optimum pressure for CPAP, and its clinical applicability in practice is very limited (Tanswell et al. 1980; Elgellab et al. 2001).

It is advisable to:
Start with a level of CPAP between 5 and 7 cmH2O. Individualize the CPAP level on the basis of respiratory dynamics, respiratory frequency, grunting, and thoracic retraction. The level of CPAP can be increased up to 8–10 cmH2O. Choose higher values if there is reduced pulmonary volume.

Once an improvement in the respiratory dynamics has been reached, adjust the FiO2 so as to maintain PaO2 between 60 and 80 mmHg or tcO2 saturation (measured by pulse oximetry, SpO2) at target range (e.g., 90–95% in preterm infants as suggested by the recent European RDS guidelines) (Sweet et al. 2017). Reduce the level of CPAP as long as lung compliance, lung volume, and oxygenation improve in order to avoid hyperdistension and transmission of positive pressure to the mediastinum.

### Monitoring

The use of N-CPAP therapy requires accurate monitoring to both evaluate the evolution of the illness and to identify negative side effects:

- Blood gas analysis from arterial or an arterialized capillary blood represents the gold standard for blood gas measurement. It should be carried out within 15–30 min of starting therapy and whenever clinically indicated (Ahumada and Goldsmith 1996).
- Pulse oximetry. Despite its universally known limitations, this is the method of choice for the continuous monitoring of oxygenation level, particularly when the situation has stabilized. It is advisable to target O2 saturation values according to the recent guidelines (e.g., 90–95%) (Sweet et al. 2017).
- Transcutaneous PO2 and PCO2. This type of monitoring, though potentially very useful, has in reality many limitations that require great caution in interpreting the values it obtains, which should be verified and checked frequently against the blood gas values.
- ECG and systemic arterial pressure. The potential side effects of CPAP on circulation require continuous monitoring of heart rate and periodic measurement of systemic blood pressure.
- Chest X-ray provides valuable information in evaluating the effect of CPAP on the evolution of the disease, such as improvement of the radiological picture or the development of complications such as hyperdistension or pneumothorax.

### How to Try to Prevent Failure of N-CPAP?

Since the incidence of N-CPAP failure in large RCTs evaluating CPAP versus routine intubation is close to 50% (Wright et al. 2016) and CPAP failure occurs early (at about 8 h of life) above all because of increasing of oxygen requirements, it seems to be reasonable that early interventions used to establish an effective FRC may help N-CPAP a success. After delivery, the lung is fluid-filled and the reabsorption of the liquid from the lung, in the past attributed to the epithelial sodium channel, is initially related to the delta pressure.
generated by the first breaths that move the lung fluid in the airway until the alveoli, where the fluid is pumped into the interstitium and reabsorbed by the lymphatic and vein vessels in the hours following birth (Hooper et al. 2015). The term infant is able to generate this delta pressure with the first three to five initial prolonged inspiration to clear the lung fluid (Karlberg 1960). On the contrary, the preterm infants are often unable to do it. In animal experiment, it has been demonstrated that the use of sustained inflation (SI) (a deep and prolonged inflation), especially when followed by an adequate PEEP, is an intriguing approach to allow the preterm animal to create the FRC (Te Pas et al. 2009). Also in humans, the use of SI (e.g., a peak pressure of 20–25 cmH₂O maintained for 10–15 sec) seems to facilitate the respiratory transition at birth. In fact, a recent meta-analysis that compared SI versus positive pressure ventilation at birth in preterm infants at risk for RDS or with signs of respiratory failure concluded that SI improved short respiratory outcomes (reduced the need of mechanical ventilation in the first 72 h of life), even if death and BPD occurrence were not improved (Schmolzer et al. 2014). For this reason, the recent neonatal resuscitation guidelines suggest against the routine use of SI in the resuscitation of infants with signs of respiratory failure, but suggest the use only in individual clinical circumstances or in research settings (Wylie et al. 2015).

Weaning from N-CPAP

Once clinical improvement has been obtained as previously described, the improved situation is shown by the ability to progressively reduce FiO₂ (in 2–5% steps down to 21%) and the level of positive pressure (1 cmH₂O at a time down to 2–3 cmH₂O). Once minimal values have been reached for both parameters, the N-CPAP therapy can be stopped more or less gradually, taking into account the weight and gestational age of the baby monitoring an eventual increase of WOB (clinically manifested, e.g., by tachypnea and or intercostal and diaphragmatic retractions) and depending on the presence or lack of other indications for therapy, e.g., apnea of prematurity.

Nursing of the Neonate in N-CPAP

The importance of nursing is particularly important when CPAP is administered via nasal prongs. The following require particular attention (Sahni et al. 2016):

- Correct attachment (headset and nasal prongs)
- Correct positioning (circuit and infant)
- Correct temperature setting on the humidifier
- Correct aspiration of the airways and feeding

Attachment (Headset and Nasal Prongs)

The attachments for the nasal prongs always include a bonnet, which the prongs themselves are fixed to. The bonnet must be large enough to reach the level of the eyebrows and to cover the
ears completely. If it is too small, it will tend to ride up, forcing the circuit toward the neonate’s nose. The prongs generally come in three sizes (small, medium, and large): the size that is most compatible with the patient’s nostrils must be chosen. It is wrong to assume that the smallest prongs are for the most delicate neonate. If the prongs are too small, they do not give an adequate hold, which is necessary to maintain a constant level of CPAP and to avoid an increase in airways resistance. This does not allow a reduction in WOB and may cause it to increase.

The silicone nasal prongs warm up when inserted into the nostrils, and in doing so, they become softer and expand slightly, improving their hold. The use of creams or plasters around the nose is not recommended. Once the circuit has been positioned, care must be taken that the edge of the prongs does not adhere to the nasal septum: the base of the prongs must always be visible (Fig. 6) (see also section “Positioning of the Circuit”).

The prongs can increase the production of nasal secretions, and for this reason, the system for humidifying and heating the administered gas is very important (see section “Humidification and Heating”). When the infant cries, there may be a loss of pressure: therefore, correct nursing is extremely important during the administration of CPAP (see also section “Positioning the Infant”).

Silicone masks are available as an alternative to nasal prongs for very small or large infants (Fig. 7).

**Positioning of the Circuit**

The tubes should be positioned so as not to pull on the flow generator or put pressure on the neonate’s nose.

The flow generator is connected to the nasal mask by ribbons, which must not be too tight. Once the ribbons have been fixed, they should be directed downward, that is, toward the base of the ears and away from the eyes in order to avoid swelling at this level. Plasters or knots between the ribbons and the nasal mask should be avoided to facilitate the rapid adjustment of the prongs. Only the gas arrival tube should be attached to the bonnet while the others should be left free.

In the case of the infant flow generator, it is important that the outlet tube be positioned outside the incubator in order to minimize noise: if necessary use the extension tube.

**Positioning the Infant**

The infant can be placed in a prone, supine (with support), or lateral position. The neck, however, must always be slightly extended. The prone
position has been shown to be better for the premature neonate with respiratory distress (Sahni et al. 2016).

Kangaroo care is possible during N-CPAP. It is important to keep the infant’s mouth closed. This confers at least three benefits:

It avoids loss of pressure and consequent instability of CPAP, therefore reducing WOB.
It avoids drying of the mucous and the formation of dense, whitish secretions because it favours the deglutition of saliva.
It keeps the jaw in the forward position, thus avoiding the tongue falling backward and guaranteeing the patency of the airways.

The infant can be helped to keep their mouth closed. Initially, it can be of use to place a support (e.g., roll of gauze) under the neonate’s chin. The use of a pacifier favors deglutition and reduces the formation of saliva in the infant’s mouth. It also helps keep the jaw in the forward position.

**Humidification and Heating**

Adequate humidification is important in order to avoid drying of the mucous and the accumulation of dense secretions, which can block the airways. The recommended gas temperature is 37 °C: this is obtained by setting the resistance temperature of the circuit at 39 °C and that of the gas at 2 °C less. It is always important to ensure that the temperature sensor is placed outside the incubator. If the neonate is positioned under an infant warmer, the sensor should be thermally isolated.

**Airways Suction**

It is not necessary to regularly suction the infant in N-CPAP and this maneuver should be performed only when necessary. To reduce the formation of oral and nasal secretions, the following measures can be used:

Set the humidifier to a suitable temperature (see previous paragraph): if the temperature is too low, it can favor the formation of dry secretions.
Keep the infant’s mouth closed (see section “Positioning the Infant”).

**Feeding**

The use of N-CPAP does not prevent feeding. Food intake should be encouraged (via orogastric feeding tube or bottle and also nipple feeding). Additionally, fed newborns will avoid swallowing air, thus reducing abdominal distension. An orogastric tube is not always necessary.

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Continuous Positive Airways Pressure and Other Non-invasive Respiratory Techniques in Newborns


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