Bubble nasal CPAP manual

Riyadh AL-Kharj Hospital Programme
Neonatal intensive care
2005

Amer Ammari, MB, BS
Fawaz Kashlan, MD
Faisal Ezzedeen, MD
Atyah AL-Zahrani, MD
John Kawas, RRT
M.A. Majeed-Saidan, MB. Ch.B., FRCP

Adapted from the "NCPAP Education and training manual"
By J.M. Conner, R. de Klerk and A. de Klerk.

PREFACE

Respiratory Distress Syndrome (RDS) is due to a deficiency of pulmonary surfactant. Seventy one % of very low birth weight infants had RDS, and 35% of them still required oxygen at 36 weeks adjusted age (Vermont Oxford Network 2001). Along with significant mortality, RDS is associated with significant morbidity and high costs to society.

Pulmonary surfactant lines the surface of the alveoli in the lung, thereby reducing surface tension and preventing alveolar collapse. Surfactant deficiency results in progressive atelectasis of the alveoli, decreased pulmonary compliance, increased work of breathing, respiratory failure, and lung injury. The earlier the gestational age, at which birth occurs, the higher the risk that severe respiratory distress syndrome will develop.

Historically, conventional therapy for this disorder has consisted of continuous positive airway pressure (CPAP) or mechanical ventilation, along with appropriate supportive care. In the past decade, surfactant replacement has led to significant improvements in survival, particularly for infants less than 1000 grams. However, attempts to treat RDS may lead to lung injury, and secondary complications including bronchopulmonary dysplasia (BPD) and chronic lung

disease (CLD). This lung injury is thought to result from the effect of mechanical injury due to assisted ventilation, oxygen toxicity, and lung inflammation among other factors.

The following materials comprise the bubble nasal CPAP Manual. This manual provides a training tool in the administration of nasal CPAP using a bubble bottle system, following guidelines established at The Children's Hospital of New York at New York Presbyterian Medical Center (Columbia-Presbyterian Medical Center).

CONTENTS

Introduction
Section 1: Background and Theory
Section 2: Initiation of nasal CPAP
Section 3: Maintenance of nasal CPAP
NCPAP Checklist: Maintaining the nasal CPAP System
Section 4: Complications Associated with nasal CPAP
Section 5: Removal of nasal CPAP
Section 6: Respiratory Failure on nasal CPAP
NCPAP Checklist: Respiratory Failure on nasal CPAP
Section 7: Troubleshooting the nasal CPAP Delivery System
References
Appendix A: Equipment List and Manufacturers
Section 8: Delivery room protocol for the respiratory management of preterm infants

INTRODUCTION

Purpose The purpose of the nasal CPAP Training and Education Manual is to provide a training tool in the administration of nasal continuous positive airway pressure (CPAP) using a bubble system following guidelines established at Columbia-Presbyterian Medical Center in New York.

As you work through this training manual, you will learn the skills to successfully administer nasal CPAP to premature infants using a bubble system. The sections outlined below contain information regarding the theory and the application of the nasal CPAP bubble system.

Section One: Background and Theory provides a brief review of the physiology of continuous positive airway pressure, and pertinent literature supporting CPAP use in the premature infant.

Section Two: Initiation of nasal CPAP describes the nasal CPAP delivery system and the steps necessary for stabilization and initiation of NCPAP in the delivery room. This chapter describes how to determine the appropriate size and fit of each component in the nasal CPAP delivery system.

Section Three: Maintenance on nasal CPAP describes how to evaluate and to maintain a properly functioning CPAP system, including the use of the *nasal CPAP Checklist: Maintaining the nasal CPAP System*.

Section Four: Complications Associated with nasal CPAP describes complications that may occur to infants being treated with nasal CPAP.

Section Five: Removal of nasal CPAP describes the steps involved in determining whether an infant is stable and ready to be removed from the nasal CPAP system.

Section Six: Respiratory Failure on nasal CPAP describes how to evaluate and how to troubleshoot the nasal CPAP bubble system in instances where infants have progressive respiratory failure, including the use of the *nasal CPAP Checklist: Respiratory Failure on nasal CPAP*.

Section Seven: Troubleshooting the nasal CPAP Delivery System focuses on specific common questions and issues arising when using nasal CPAP.

SECTION ONE

BACKGROUND AND THEORY

Introduction

Respiratory Distress Syndrome (RDS) is due to a deficiency or dysfunction of pulmonary surfactant. Pulmonary surfactant lines the surface of the alveoli in the lung, thereby reducing surface tension and preventing alveolar collapse. Surfactant deficiency results in progressive atelectasis of the lung, decreased pulmonary compliance, increased work of breathing, respiratory failure, and lung injury.

Since the initial discovery of the role of surfactant deficiency in the pathogenesis of respiratory distress syndrome, numerous randomized controlled trials have shown that intratracheal instillation of an exogenous surfactant preparation is effective in both the prevention and treatment of RDS. To date, over 33 randomized controlled trials of surfactant replacement therapy involving over 6,000 infants have been reported. Meta-analyses of these randomized controlled trials have shown that, when compared to conventional management without surfactant replacement, surfactant therapy results in a significant decrease in the risk of pneumothorax and mortality.

Despite the success of surfactant therapy, a significant number of infants will develop lung injury, as demonstrated by the persistent high rate of chronic lung disease seen in extremely low birth weight infants. Nasal Continuous Positive Airway Pressure (CPAP) may represent a less invasive way to maintain lung volume and improve oxygenation.

Studies that examined the variation in practice between centers have suggested that the routine use of nasal CPAP in the stabilization of very low birth weight infants may reduce the incidence of chronic lung disease.

Physiology of CPAP

Continuous positive airway pressure (CPAP) has been widely used to correct respiratory insufficiency. CPAP was used in adults as early as 1936. CPAP has been used in infants with RDS since its introduction in 1971.

CPAP is uniquely suited to address many issues in the pathogenesis of RDS. Clements and colleagues described the importance of surfactant for the stabilization of alveoli at low transpulmonary pressures. Harrison and colleagues recognized the benefit of an increased alveolar pressure during expiration in infants with respiratory distress syndrome and demonstrated that eliminating the infant's ability to grunt by use of an endotracheal tube is associated with a decrease in $Pa0_2$.

CPAP works by maintaining positive pressure in the airway during spontaneous breathing, thereby increasing functional residual capacity and improving oxygenation in infants with RDS. CPAP does this by stabilizing airspaces that have a tendency to collapse during expiration due to surfactant deficiency.

A variety of mechanisms of action of nasal CPAP have been proposed. These include:

__Increase transpulmonary pressure
__Increase functional residual capacity
__Prevent alveolar collapse
__Decrease intrapulmonary shunting
__Increase lung compliance
__Conserve surfactant
__Increase airway diameter
__Splint the airway
__Splint the diaphragm
__Stimulate lung growth
__High frequency ventilatory effect (with bubble nasal CPAP)

Clinical Research Using nasal CPAP

Interest in nasal CPAP was renewed by Avery and colleagues, when they demonstrated that within the NIH score centers, the center that aggressively utilized NCPAP had the lowest incidence of chronic lung disease. Since the report of Avery and coworkers, a variety of studies using historical controls have demonstrated improved outcomes in premature infants with the introduction of early application of nasal CPAP. Jacobsen and coworkers evaluated non-asphyxiated very low birth weight infants (VLBW) before and after institution of a policy of early treatment with nasal continuous positive airway pressure and minimal handling during stabilization. This “minitouch” regime was introduced as a routine in 1986. Jacobsen and colleagues compared infants born in 1987 after the policy was instituted, to infants born in 1985, when ventilator treatment was used initially in all infants with progressive respiratory distress. The frequency of mechanical ventilation was reduced from 76% in 1985 to 35% in 1987. Intraventricular hemorrhage (IVH) grade II-IV was reduced from 49% in 1985 to 25% in 1987.
Other clinical outcomes, including mortality rate, average duration of hospitalization, number of infants with pneumothorax, patent ductus arteriosus, need for oxygen at 28 days and number of surviving infants with handicap did not differ significantly between the two study periods.

Kamper and coworkers studied a cohort of 81 very low birthweight (VLBW) infants treated with oxygen only (n=11), with early continuous positive airway pressure (n=68), or mechanical ventilation from birth (n=2). A total of 65 infants (80%) survived to discharge, 61 of whom were supported solely with CPAP or oxygen. Nineteen infants (26%) developed IVH, but only four survivors (6%) developed IVH grade II-IV. No survivors had bronchopulmonary dysplasia.

Gittermann and coworkers evaluated the introduction of early nasal CPAP in VLBW infants admitted to a tertiary neonatal intensive care unit. All liveborn VLBW infants admitted to their neonatal intensive care unit in 1990 (historical control group) and in 1993 (early NCPAP group) were evaluated. Infants in the later group had NCPAP applied as soon as signs of respiratory distress occurred. Significantly fewer infants required intubation during the later period, after the

introduction of early NCPAP (30% vs. 53%). Neither the incidence of bronchopulmonary dysplasia (32% vs. 30%), nor the incidence of mortality prior to hospital discharge (10% vs. 7%) was significantly reduced by early application of NCPAP. Lindner and coworkers studied the effect of delivery room policies on the rate of endotracheal intubation, mechanical ventilation, and short term morbidity in extremely low birth weight infants. Until 1994, Lindner and coworkers intubated extremely low birth weight infants immediately after delivery when presenting with minimal signs of respiratory distress or asphyxia. During 1995, the guidelines for respiratory support were changed. In 1996, continuous (15 to 20 seconds) pressure controlled (20 to 25 cm H2O) inflation of the lungs using a nasal pharyngeal tube, followed by continuous positive airway pressure (CPAP 4 to 6 cm H_2O) was applied to all ELBW infants immediately after delivery to establish a functional residual capacity and to avoid intubation and mechanical ventilation. Of 123 inborn ELBW infants born in 1994 and in 1996, the rate of intubation and mechanical ventilation decreased from 84% in 1994 to 40% in 1996. Twenty-five percent of the ELBW infants were never intubated in 1996 compared to 7% in 1994.

De Klerk and De Klerk documented the effects of instituting a system of respiratory support based primarily on the early institution of NCPAP. Outcomes in premature infants with a birth weight of 1000-1499 grams were compared retrospectively over a 5-year period; before (period I; n = 57) and after (period II; n = 59) the introduction of an NCPAP-based approach to respiratory support. From period I to period II, there was a decline in the number of infants ventilated (65% vs. 14%) and in the number of infants receiving surfactant (40% vs. 12%). A decreased incidence of chronic lung disease (CLD) at 28 days (11% vs. 0%) and death or CLD at 28 days (16% vs. 3%) was also noted. In addition, there was a decrease in the median days of ventilation (6 vs. 2 days), and the median days on supplemental oxygen (4 vs. 2 days). Differences in the use of pressor support (34% vs. 7%), the incidence of necrotizing enterocolitis (11% vs. 0%), the time to reach full oral feeds (17.3 vs. 13.2 days), discharge weight (2569 vs. 2314 g) and average length of stay (61 vs. 52.9 days) were noted. There were no differences in other clinical outcomes.

Although early institution of nasal CPAP is promising, little evidence in support of this practice is found in randomized controlled trials. A recent Cochrane Review (Subramaniam 1999) found only one randomized controlled trial of early application of NCPAP in premature infants (Han 1987).
Han and coworkers (Han 1987) studied 82 infants less than 32 weeks gestation. Infants were randomized to nasopharyngeal CPAP or supplemental oxygen via head box. No differences in outcome were noted between the two groups. An approach that combines aspects of both early surfactant administration and early stabilization on NCPAP has been tested in the Scandinavian countries.

Verder and coworkers (1999) conducted a multicenter randomized controlled trial to determine whether early versus late treatment with porcine surfactant reduced the requirement of mechanical ventilation in very preterm infants

primarily supported by NCPAP. The study population comprised 60 infants less than 30 weeks gestation with respiratory distress syndrome who had an arterial to alveolar oxygen tension ratio (a/APO2) of 0.22 to 0.35. Although the study does not specifically evaluate the practice of delivery room stabilization, Verder and coworkers offer support for the practice of early intubation, surfactant administration, and extubation to NCPAP. Infants who received early treatment had improved oxygenation six hours after randomization (mean a/APO2 rose to 0.48 in the early-treated infants compared with 0.36 in the late-treated infants). The need for mechanical ventilation before discharge was reduced from 68% in the late-treated infants to 25% in the early-treated infants.

CPAP Delivery Systems

The CPAP delivery system consists of three components: the circuit for continuous flow of inspired gases, the interface connecting the CPAP circuit to the infant's airway, and a method of creating positive pressure in the CPAP circuit. The success involved in delivering CPAP is entirely associated with the delivery system; the system must fit properly, be lightweight and flexible, be of low resistance, be easy to apply, remove, and keep connected, and must provide a minimum of discomfort and trauma to the infant. The CPAP setup is designed to deliver pressure through a low-resistance system. The resistance in the circuit is directly proportional to the length of the circuit, and inversely proportional to the fourth power of the radius of the tubing used. This means that doubling the length of a tube doubles the resistance of the tube, and halving the radius increases the resistance (2^4 = 2x2x2x2, or 16 times). Since the pressure that is delivered and ultimately reaches the lungs is directly related to the resistance of the delivery system and patient airway, it is imperative that every effort is made to minimize this resistance.

Many techniques are available to deliver CPAP including nasal cannulae, facemask, nasopharyngeal tube, head-box with neck seal, or endotracheal tube. For the purposes of this training manual, we will focus on delivering CPAP through nasal prongs attached to a bubble bottle system.
For the NCPAP system to be effective it must have the following characteristics:
___Be a low resistance delivery system
___Large bore tubing
___Short wide connection to the infant (nasal prongs)
___Fit appropriately and prevent pressure leaks
___Snug fitting nasal prongs
___Well positioned interface
___Chinstrap in place and secure
___Flow through an optimally maintained airway
___Warmed, humidified gas
___Neck mildly extended using a neck roll
___Suctioning q 3-4 hr, and prn.
___Be maintained with meticulous and consistent technique.

The Columbia Presbyterian NCPAP Approach

Nearly thirty years ago, under the direction and leadership of Dr. Jen-Tien Wung at Columbia Presbyterian Medical Center in New York, a systematic approach to the use of the bubble CPAP system was developed. The Columbia approach with bubble CPAP has been described as a minimal, gentle ventilation approach. This approach to respiratory care focuses on meticulous attention in providing consistent and optimal CPAP delivery. At Columbia Presbyterian Medical Center, premature infants are stabilized in the delivery suite with the application of *Hudson* nasal prongs and 5cm of bubble CPAP using a water bottle system. Meticulous care of the airway including suctioning and placing appropriately fitting prongs has shown remarkable results. At Columbia Presbyterian Medical Center 76% of spontaneously-breathing very low birth weight infants < 1250 grams do not require mechanical ventilation.

SECTION TWO
INITIATION OF NCPAP

Introduction

Successful initiation of nasal CPAP involves three critical steps:
Step One: Assemble the CPAP Delivery System
Step Two: Determine the appropriate size of the NCPAP interface
Step Three: Apply the NCPAP system.

1. **Step One: Assemble the CPAP Delivery System** Follow the steps outlined below in Sections A and B to assemble the appropriate materials and set up the CPAP system in the delivery room or stabilization area (Transitional Nursery-Room 9 in the delivery room) or in the NICU. At least one bubble bottle CPAP delivery system must be set up and ready to use for all imminent deliveries of eligible infants. If a delivery system is already set up, check that the system was assembled appropriately.

Section A: Gather the following equipment:
"*Refer to Appendix A for equipment lists and manufacturers*".
Oxygen and air flow sources
Oxygen blender with flow meter
Oxygen or suction tubing to lead from the blender to humidifier
Oxygen analyzer (optional)
Humidifier filled to appropriate level with sterile water
Corrugated circuit tubing with humidifier connections
Humidifier temperature probe
Nasal prong CPAP set (Hudson nasal CPAP set)
Bottle of 0.25% Acetic acid or sterile water, 1000 cc
A 3 cc syringe
A Luer plug/prn adapter (Not required if a ventilator is being used as a flow source. The pressure tubing can be connected to the opening at the elbow of the prongs).
4 small safety pins
4 small rubber bands
Tegaderm
Gauze swabs
Soft gauze or soft cast tubing (for chin strap) / or Co-ban tape.
Paper measuring tape
Tape

Section B: Procedures to Set up the Bubble Bottle CPAP System:
Follow the steps outlined in Table 2.1 to set up the bubble bottle CPAP system.

Table 2.1
Procedure to Set Up the Bubble Bottle CPAP System

	Procedure	Rationale
1. Flow Meter	Attach the oxygen tubing to the flow meter and connect to the humidifier. Set the flow meter to 5 to 10 liters/minute (l/m).	**Flow Meter** A flow of 5 to 10 l/m will provide adequate flow to wash out carbon dioxide in the system, compensate for the normal air leakage from the tubing connections, and generate adequate CPAP pressure (verified by bubbling of the water in the outlet bottle).
2. Humidifier	Turn on the humidifier and set the temperature at 36.8-37.3° C and the chamber temp at –2. A higher temperature may be used if necessary. The humidity setting needs to be adjusted to maintain required gas humidification at or close to 100%. Attach one of the lightweight, non-kinking, corrugated tubes to the humidifier. Connect the humidifier tube temperature probe to the corrugated tubing going to the baby. Be sure the probe remains outside the incubator or away from the radiant heat source.	**Humidifier** The temperature selected should be based on the baby's size, body temperature, and thickness of secretions. Adequate humidity will prevent drying of secretions. The tubing needs to be flexible and not too heavy for a small baby's face. The probe will monitor the temperature of the inspired gas. If the temperature is too high it may damage the mucous membranes; if too low, it can cause hypothermia and dry, tenacious secretions. Other heat sources may lead to inaccurate gas temperature measurement or excessive rainout.
3. Nasal Prongs	Choose the appropriately sized nasal prongs and attach them to the tubing coming from the humidifier (refer to section 2: Determining Appropriate Interface Sizes). Attach the second corrugated tube to the other side of the prongs. Fix the Luer plug/prn adapter in place over the small opening in the elbow of the prongs (used to measure pressure).	**Nasal Prongs** Prongs should fit the nares snugly without pinching the nasal septum. If the prongs are too small, there will be an increase in airway resistance, making it harder for the baby to breathe. Small prongs also allow more air to leak from the system, making it difficult to maintain the correct pressure. If they do not fit snugly, the excess movement may cause damage to the mucosa and possible septal erosion.

4. Bubble CPAP Delivery System	Secure the measuring tape (0-7 cm) to the outlet bottle with the 7 cm mark at the base. Empty the fluid to the 0 mark. Place the end of the corrugated tube into the water to a depth of 5 cm to generate 5 cm/H_2O of CPAP. Slide the 3 cc syringe (plunger removed) into the top of the bottle next to the corrugated tubing, and this will fix it in place. Test the system by occluding the ends of the nasal prongs. You should see active bubbling at the end of the corrugated tubing under water. **NEVER** place the prongs in the baby's nose until you have verified that the setup is fully operational.	**Bubble CPAP Delivery System** The opening at the elbow of the nasal prongs is designed to fit a pressure tubing connection and can also be used to maintain CPAP while using the transport incubator ventilator. The depth of the tubing under the water controls the amount of pressure generated in the system. If bubbling does not occur, systematically check each connection until bubbling begins. An obstruction in the system will occlude the infant's airway; result in excessive positive pressure, cause damage to the airway and lungs, and gastric distention.

2. Step Two: Determine the Appropriate Size of NCPAP Interface

Once the CPAP bubble bottle system is set up, the next step is to determine the appropriate size of the interface pieces (nasal prongs and hat). Using Tables 2.2 determine the correct size of the nasal prongs.

Hudson Interface

For using the *Hudson* nasal prong set, the infant's birth weight determines the size of nasal prongs to be used. Refer to Table 2.2 to determine the *Hudson* nasal prong size.

Table 2.2
Hudson Interface Nasal prongs' size

Size 0	**for < 700 g**
Size 1	**for 700-1000 g**
Size 2	**for 1000-2000 g**
Size 3	**for 2000-3000 g**
Size 4	**for 3000-4000**
Size 5	**for > 4000 g**

For infants at the high end of any of the weight ranges, consider using the larger prongs appropriate

3. Step Three: Application of the NCPAP System

Correct application of the NCPAP system involves proper positioning of the infant, ensuring a patent airway, and correct application of the interface and delivery system.

Table 2.3 outlines each procedural step involved in application of the NCPAP system.

Table 2.3
Application of the nasal CPAP system.

Procedure	Rationale
1. Position Position the baby with the head of the bed elevated about 30◦. Place a small roll under the baby's neck/shoulders. The roll should be firm enough to support the baby's head in the 'sniffing' position.	**Position** The elevated bed may decrease intracranial pressure and pressure on the baby's diaphragm. Slight neck extension helps keep the airway open.
2. Saturation Probe A SaO2 probe should be placed on a pre-ductal site, e.g. right arm or wrist. Maintain this site for the duration of the oxygen therapy.	**Saturation Probe** In conditions with right-to-left shunting it is important to adjust oxygen therapy based on the pre-ductal SaO2.
3. Suctioning Gently suction the mouth, nose and pharynx. Use the largest sized catheter that can be passed into the nose without significant resistance. Pass an oro/naso-gastric tube and aspirate the stomach contents. Remove the tube after aspiration, if necessary.	**Suctioning** Secretions may block the prongs or the airway beyond, thus increasing airway resistance. This in turn may worsen the symptoms of respiratory distress and/or cause apnea and bradycardia. The positive pressure generated can cause air to enter the stomach. A recent feed or an already distended stomach may increase pressure on the diaphragm or result in reflux with aspiration.
4. Prong placement Moisten the prongs with sterile water or saline drops before placing them curve side down into the baby's nose. Adjust the angle of the prongs and the way the corrugated tubing is twisted until the correct positioning is achieved: __The nasal prongs should fill the nasal opening completely without stretching the skin or putting undue pressure on the nares (blanching around the rim of the nostrils suggests that the prongs are too large). __The corrugated tubing will not be touching the baby's skin. __There will be no lateral pressure on the septum causing it to be pinched or twisted. __There will be a small space between the tip of the septum and the bridge between the prongs. __The prongs will not be resting on the philtrum.	**Prong placement** The fluid provides a little lubrication to aid initial insertion. Do not use creams and petroleum based ointments, as these will soften the mucosa, risking breakdown of the tissues. Correct positioning reduces the risk of trauma and ensures the effective delivery of CPAP.

5. Securing the Hat (Bonnet) Use the pre-made hat or make one out of appropriate sized tube-gauze (or available soft, fine woven tube bandage). Fold the rim of the hat back approximately 1 inch. If using the tube-gauze fold the edge twice. The hat must fit firmly. Place the hat on the baby's head so that the rim is just over the top of the ears. If using tube-gauze tie the end with ribbon/tape close to the baby's head. **Do not** interrupt CPAP delivery during placement of the hat.	**Securing the Hat (Bonnet)** The hat holds the prongs and tubing in place. The rim adds strength and helps prevent stretching when connecting the tubing. The hat needs to fit snugly to minimize movement of the tubing.
6. Securing the Tubing to the Hat (Bonnet) The corrugated tubing can now be secured to the hat at the angle that provides the best prong position. Hold one of the tubes gently against the side of the baby's head and place two small safety pins, one each side of the tube, through the rim of the hat. Secure with the rubber band by threading it around one pin, over the corrugated tubing, and around the other pin. The rubber band needs to fit firmly over the tubing to prevent movement. Tie a knot in the rubber band to make it shorter if necessary. Repeat the procedure for the tubing on the other side of the head.	**Securing the Tubing to the Hat (Bonnet)** This will allow the prongs to stay in place as the baby's head moves.
7. Apply the Chin Strap To prepare the chinstrap use non-elastic tape and gauze. Cut a piece of tape that will reach from one side of the hat across under the chin and attach to the other side of the hat. The tape needs to be backed with the folded gauze to prevent the adhesive contacting the skin. Or use Coban tape. The jaw is gently pulled forward, closing the mouth. A pacifier may be used with the chinstrap in place if this will help to settle the baby.	**Apply the Chin Strap** An air leak via the mouth will reduce the effectiveness of the system by allowing a significant loss of positive pressure. Keeping the design simple is cost effective and convenient, as the chinstrap may need replacing every few hours. It will easily become soiled and the tape loses its adhesiveness each time it is detached from the hat for suctioning or feeding. The strap will not be so firm as to prevent the infant from yawning or crying.

8. Apply a Mustache (after ~ 4 hours of life) Gently clean the baby's face in the vicinity of the prongs and cheeks with water. Dry thoroughly using soft gauze.	**Apply a Mustache** This will help keep the prongs firmly in position. If applied in the first few hours of life, the mustache will not remain in place due to excessive secretions during the first few hours of CPAP.
Cut two pieces of Tegaderm to fit across the prepared area.	Tegaderm provides protection for the skin plus a surface for the Velcro to adhere.
Cut a strip of Velcro (hook side) to fit the area. It needs to be narrow in the center over the philtrum but wider over each cheek.	A single Velcro strip provides gentle splinting of the area. Two separate cheek patches may be just as effective in securing the prongs; each baby's face is different, so use whichever works best.
Cut two narrow (~8 mm) strips of soft Velcro to wrap around the area of the prongs that cover the cheeks	Avoid using the hooked Velcro to wrap around the prongs, it may scratch the skin when disconnected.
Once the mustache and skin are prepared, gently remove the prongs. Wipe away any excess secretions, and place the Tegaderm followed by the Velcro mustache in place. Wrap the soft Velcro strips around each side of the prong cannula, and place the prongs back in the nose. Gently press on the prong cannula until the soft Velcro strips adhere to the mustache. Some twisting of the prongs, the connections and corrugated tubing may be necessary to achieve the correct prong position.	This promotes a dry surface for the Velcro mustache to adhere.
During the process of applying the mustache, take the opportunity to suction the nose and mouth.	This promotes proper positioning of the prongs while securing them in place.
9. Check the NCPAP system Once the system is applied, check that the prongs are positioned appropriately and that the CPAP system is bubbling at 5 cm H_20.	**Check the NCPAP System** This ensures proper application and operation of the NCPAP delivery system.

SECTION THREE

MAINTENANCE OF NCPAP

Introduction

Continuous positive airway pressure is successful when meticulous attention is paid to both the infant and to the NCPAP delivery system. This meticulous attention involves vigilance in continuous monitoring of the infant's condition, frequent suctioning to maintain optimal airway care, constant evaluation of the performance of the delivery system, and prevention of complications which may arise from the NCPAP delivery system.

1. Monitoring the Infant's Condition

The infant's condition must be monitored frequently once the NCPAP is applied. Monitor all infants on NCPAP following our NICU's current practice guidelines for monitoring premature infants with respiratory distress.

It is recommended that monitoring the infant's status while on NCPAP should include evaluation of the following:

__Respiratory status: respiratory rate, work of breathing;
__Cardiovascular status: central and peripheral perfusion, blood pressure, and heart rate;
__Gastrointestinal status: abdominal distention, bowel sounds;
__Neurological status: tone, response to stimulation, activity;
__Thermoregulation: infant and environment temperature; and
__Monitor: pre-ductal oxygen saturations, oxygen requirements

It is recommended that the infant be observed every 2-3 hours over the first 4 days of life and every 3-4 hours thereafter while on NCPAP. Any infant that is experiencing moderate to significant respiratory distress while on NCPAP will require closer observation of change in condition.

Refer to Table 3.1 for specific guidelines and rationale for monitoring the infant while on NCPAP.

2. Maintaining Optimal Airway Care

One of the most critical aspects of NCPAP is maintaining an optimal airway through frequent suctioning of the mouth, nose, and pharynx. We suggest suctioning the infant at least every 3 hours if the infant has any symptoms of respiratory distress, or every 4-6 hours if the infant is in room air on NCPAP. Carefully follow the protocol steps outlined in Table 3.1 for recommendations regarding suctioning the airway.

3. Preventing Nasal Septal Damage

Damage to the septum arises from friction caused by grazing of the nasal prongs with the associated continuous pressure, friction or moisture. Avoiding these contributing factors will maintain an intact septum. Septal injury is preventable and is not a reason to discontinue using nasal prongs.

It is recommended that the nasal septum and prongs be evaluated every 30-60 minutes. If signs of grazing or erosion are observed, the best treatment is to remove the cause of pressure, friction, or moisture. Review Table 3.1 for details regarding interventions to prevent damage to the nasal septum.

4. Positioning while on NCPAP

Infants may be positioned side lying or prone while on NCPAP. We recommend that when the infant is placed prone a firm chest support is placed underneath the infant to allow the chin to drop slightly forward allowing for optimal positioning of the airway.

Refer to Table 3.1 for specific details regarding positioning while on NCPAP.

5. Feeding while on NCPAP

Nasal continuous positive airway pressure is not a contraindication to feeding. Infants on NCPAP are expected to have mild abdominal distention associated with swallowing air while on NCPAP. An infant on NCPAP who is being fed may require the placement of an 8 French oro-gastric tube to aspirate air prior to feeding. The oro-gastric tube should be aspirated every 3 hours or more frequently as needed. If abdominal distention persists, it may be necessary to leave an indwelling oro-gastric tube to allow for continuous removal of abdominal air. If the indwelling oro-gastric tube prevents closure of the mouth and therefore allows NCPAP pressure to escape, it should be removed and inserted as needed. Or a chinstrap may be used to maintain closure of the mouth. Review Table 3.1 for specific details regarding nasal CPAP and feeding.

Table 3.1

Procedure	Rationale
1. Monitoring: **Clinical Assessment** Perform a baseline assessment of the infant prior to commencement of NCPAP. Observe and document the condition of the infant every 2-3 hrs for the first 4 days of life. Thereafter, monitor the infant's condition every 3-4 hrs. Assessment should include: __Respiration: rate, effort, breath sounds, signs of distress. __Cardiovascular: central and peripheral perfusion, blood pressure, and auscultation. __Gastro-intestinal: bowel sounds, abdominal distention, visible bowel loops. __Neurological: tone, response to stimulation, activity. __Thermoregulation: infant and environmental temperature. Monitor: pre-ductal saturations, oxygen requirement, trends and changes in saturations and oxygen requirements.	**Monitoring:** **Clinical Assessment** Baseline observations are essential to the ongoing assessment and management of the infant. Observations are essential to the ongoing management of the infant. Decisions regarding status and ongoing treatment are made on the basis of serial assessments. Some mild abdominal distention is expected with CPAP. Careful observation will differentiate this from distention associated with gastro-intestinal disorders such as obstruction, perforation, or infection.

2. Airway Care: Suctioning Suction the mouth, nose and pharynx at least every 3 hours and prn for symptomatic infants. Use the largest size catheter able to be passed into the naso-pharynx without significant resistance. Use a few drops of sterile 0.9% saline solution instilled into the nose to help lubricate the catheter and loosen dry secretions. Always wear gloves when suctioning, in accordance with universal precaution guidelines.	**Airway Care: Suctioning** The presence of excess secretions will narrow the airway and increase the effort of breathing. It may cause increased oxygen requirement, obstructive apnea, bradycardia, or pneumothorax. Thickening of secretions indicates the need for increased inspired gas humidity and/or heat. Flecks of blood may suggest the mucosa is dry. Avoiding contact with blood and body fluids prevents the spread of infection.
3. Preventing Damage to the Nasal Septum Septal injury is absolutely preventable and is not a reason to discontinue using the nasal prongs. ___Use the correct prong size. ___Secure the prongs in place with a snug fitting hat and correctly placed tubing. ___Use a mustache if necessary. ___Do not allow the bridge of the prongs to press up against the septum. ___Avoid twisting the prongs with resultant lateral pressure against the septum. ___Do not use creams, ointments, gels, or products such as Duoderm on the septum itself. ___Frequent observation of the site and prong position every 30-60 minutes is essential. ___If signs of grazing or erosion are observed, reposition the prongs to remove the pressure, friction, or moisture.	**Preventing Damage to the Nasal Septum** The septum will become grazed and erode within a few hours if it is subjected to continuous pressure, friction, and or moisture. Avoiding these contributing factors will maintain an intact septum. The best protective cushion between the bridge of the prongs and the septum is air. Moist skin is compromised skin, so the area must be kept clean and dry.
4. Positioning with NCPAP Change the infant's position every 3-6 hours. When positioning an infant supine or side lying, always support the airway position using a neck roll. When the infant is positioned prone remove the neck roll and place a chest pad under the infant. Make a firm pad using linen, that is the same size as the length from the infant's clavicle to lower ribs and width between the shoulders. Do not use beanbags or gel pillows under the chest, as these will not provide appropriate support.	**Positioning with NCPAP** Regular position change is essential to skin care and neurological development and facilitates adequate observation of the infant by care providers. A clear well-supported airway will assist the infant's respiratory effort. Raising the chest slightly will allow the chin to fall slightly forward and thereby correctly support the airway.

5. Feeding with NCPAP Nasal CPAP is not a contraindication to enteric feeding. It may be necessary to pass an oro-gastric (OG) tube to aspirate excess air before feeds. Naso-gastric tubes are contraindicated in an infant receiving NCPAP. An 8 French oro-gastric tube may be left indwelling to allow continuous removal of air. If the indwelling OG- tube prevents closure of the mouth and allows CPAP pressure to escape, then it should be removed and inserted prn. A chinstrap may also be used to keep the mouth closed. Infants whose acute respiratory symptoms are well controlled on NCPAP may be breast-fed or nipple/bottle fed. These infants will need to be observed closely for signs of distress during feeding with NCPAP in place.	**Feeding with NCPAP** Swallowing of air while on CPAP can cause air to enter the stomach. A recent feed or an already distended stomach may increase pressure on the diaphragm or result in reflux with aspiration.
6. Phototherapy with NCPAP Phototherapy eye patches may be placed gently over the eyes and secured with soft paper tape to the corrugated CPAP tubing. Do not allow the eye patches to touch the nasal septum or prongs or obstruct your view of the nasal septum and prongs.	**Phototherapy with NCPAP** The eye patches will obstruct your view of the nasal septum and could put pressure on the prongs and septum leading to septal injury.

6. Evaluating the Performance of the nasal CPAP Delivery System

In addition to monitoring the infant's condition and maintaining an optimal airway, the CPAP system must constantly be evaluated for optimal performance. This involves checking the CPAP delivery circuit beginning with the nasal prongs and ending with the bubble bottle system. Carefully review the procedures in Table 3.2 for evaluating the CPAP delivery system.

It is recommended that the CPAP delivery system be evaluated every 2 to 3 hours for performance, in addition to the daily use of the "*Checklist for Maintaining CPAP Form*".

Table 3.2
Evaluating the CPAP delivery system

Procedure	Rationale
1. NCPAP Delivery Circuit Check the entire circuit from wall to baby to outlet every hour to ensure that it is functioning correctly. Check for leaks and/or broken connections. Change the entire CPAP circuit every week. Check the following: ___The blender is set at the appropriate percentage of inspired oxygen. ___The flow meter is set between 5 and 10 liters/minute. ___The humidifier holds the correct amount of water. ___The inspired gas temperature is appropriate. ___The corrugated tubing does not contain water. ___The oxygen analyzer reads the same as the blender setting (use of an analyzer is optional). ___The outlet bottle is bubbling. ___The tubing in the outlet bottle is fixed at 5 cm of water.	**NCPAP Delivery Circuit** Changing the circuit weekly prevents growth of bacteria. Oxygen requirement will vary as the infant's condition changes. A flow of 5 to 10 liters/minute will provide adequate pressure and prevent carbon dioxide re-breathing. An adequate water level is required to maintain inspired gas humidity. The temperature should be based on the infant's size, body temperature, and the amount and thickness of secretions. Condensation will cause water to accumulate. This needs to be removed in order to prevent water from reaching the infant. The oxygen analyzer serves as a double check for the blender and needs to be routinely calibrated. The bubbling indicates that the desired CPAP pressure is being generated. Vigorous bubbling is not necessary; consistent, gentle bubbling is adequate. Some infants with mild respiratory distress may tolerate intermittent bubbling. A CPAP of 5 cm of water will deliver 5cm of pressure to the infant. Higher than physiologic PEEP (2-3 cm H_2O) recruits more alveoli for gas exchange and increases functional residual capacity. Higher CPAP pressure will cause pressure to " pop off" from the mouth.
2. Interface (Nasal Prongs) Check the following: ___Prongs fit snuggly within the nares. ___The infant's mouth is closed.	**Interface (Nasal Prongs)** Prongs that are too small will allow air to escape, and increase resistance to breathe. Pressure will be lost through an open mouth.

Checklist for maintaining CPAP

This list may be used daily to check the performance of the nasal CPAP delivery system

Criteria	Criteria met/not met	Additional information
CIRCUIT AND BUBBLER: Blended air/oxygen gas supply		
Flow between 5-10 liters/min		
Humidifier temperature correct (36.8-37.3 °C)		
Humidifier water level correct		
Oxygen analyzer correctly set		
Corrugated tubing correctly placed		
Excess rainout (afferent tubing) drained		
Excess rainout (efferent tubing) drained		
Gas bubbling continuously		
Water level at 5 cm H_2O		
INTERFACE: Nasal prong size correct		
Nasal prongs positioned correctly		
Hat fits snugly		
Mustache suitable and effective (if > 4 hr of age)		
Chin strap correct size and position		
Septum intact		
POSITIONING: Head position correct (if prone)		
Neck roll correct size and position if supine or side lying		
MONITORING/SUCTIONING: Pre-ductal oxygen saturation probe		
Documentation in nurse's record of q3-6 hourly nasal/oral suction as appropriate		

Notes: ----------

SECTION FOUR

COMPLICATIONS ASSOCIATED WITH NCPAP

Although the risks associated with NCPAP administration are minimal, there may be complications that arise during delivery of NCPAP. Careful attention to detail in management of the NCPAP delivery system and the infant while on NCPAP may minimize the risk of adverse events.

1. Pneumothorax

If a pneumothorax occurs it is more likely to occur in the acute phase of respiratory distress. A pneumothorax is NOT a contraindication to continuing NCPAP therapy.

2. Nasal Obstruction

Nasal obstruction occurs from secretions or improper position of the NCPAP prongs. To avoid obstruction, the nares should be suctioned frequently and the prongs checked for proper placement.

3.Nasal Septal Erosion or Necrosis

Pressure or friction to the nasal septum will result in nasal septal erosion or necrosis. This can be avoided by maintaining a small cushion of air (2-3 mm) between the bridge of the prongs and the septum. Choosing the proper size snug-fitting nasal prongs, use of a Velcro mustache to secure the prongs in place, and avoiding pinching of the nasal septum, will minimize the risk of septal injury. Septal erosion is not a contraindication for the use of nasal prongs. If an injury has occurred due to pressure or friction, the simple solution is to strictly avoid further pressure injury. It is not necessary to apply any creams or dressings to the area. Significant nasal septal erosion may require a consult with the ENT or Plastic Surgery team.

4. Gastric Distention

Gastric distention occurs from swallowing air. Gastric distention is a benign finding and does not predispose the infant to necrotizing enterocolitis or bowel perforation. This occurs more often in the chronic phase of respiratory distress than in the acute phase. Gastric distention can be treated by intermittent aspiration of stomach contents. For severe distention an indwelling orogastric tube may be inserted. It is important to ensure patency of the orogastric tube, because secretions will block the tube and lead to distention.

SECTION FIVE

REMOVAL OF NCPAP

Introduction

When an infant has met clinical criteria to be removed from NCPAP, the NCPAP delivery system is removed completely. It is not recommend that the NCPAP system be weaned from a pressure of 5cm of H_20 to a lower pressure prior to removal.

1. Indications for removal from NCPAP are:

___Infant is > 72 hours post extubation
___Infant is stable in room air with oxygen saturations >88%
___Infant has no evidence of tachypnea or retractions
___Infant has minimal to no apnea or bradycardia events

2. Procedures for removal of NCPAP

It is recommended that the infant's nose and mouth be suctioned thoroughly prior to, and after removal of NCPAP. The infant should be carefully monitored after removal of the NCPAP for evidence of tachypnea, retractions, or increased apnea and bradycardia. The infant should be suctioned every 6 hours for the first 24 hours after the removal of NCPAP.

3. Indications for reintroducing NCPAP

If the infant develops frequent apnea and bradycardia episodes, tachypnea or retractions, the NCPAP should be reintroduced.

SECTION SIX

RESPIRATORY FAILURE ON NCPAP

Introduction

If an infant develops symptoms of respiratory failure on routine NCPAP (CPAP of 5 cm H_20), the CPAP is not sufficient and intubation and mechanical ventilation may need to be considered. Prior to intubation, you may increase the nasal CPAP pressure to 7 cm of H_20 for a trial period.

1. Symptoms of Respiratory Failure

The symptoms of respiratory failure on NCPAP include:

___ Significant apnea
___ Respiratory failure (PCO_2 >65 mm Hg or 8.5 Kpa)
___ Progressive hypoxemia
___ Severe respiratory distress

2. Procedures Prior to Intubation and Mechanical Ventilation

It is important that prior to intubation and mechanical ventilation specific procedures are followed.

The following steps should be taken PRIOR to intubation.

___Evaluate the infant's clinical condition: Is the clinical condition compatible with the blood gas evaluation?
___Check the NCPAP delivery system for proper functioning: Is the system bubbling properly? Are air leaks by mouth and nose minimized?
___Suction the infant and reposition the nasal prongs: Are the nares obstructed? Are the prongs the correct size and position?
___Increase the CPAP to 7 cm H_20: Does the infant respond to higher pressure?

If after these procedures, the infant continues to show evidence of respiratory failure, THEN the infant has met the indications for intubation.

3. Checklist for Evaluating the CPAP Delivery System during Respiratory Failure

This checklist may be used for infants receiving bubble bottle NCPAP who experience severe respiratory distress and meet criteria for intubation due to respiratory failure.

Checklist for evaluating CPAP delivery system during respiratory failure

Complete this checklist for infants receiving bubble nasal CPAP who are experiencing respiratory distress and failure. Must be completed before removing the infant from CPAP.

Criteria	Criteria met/not met	Additional information
Nasal prongs size correct		
Nasal prongs positioned correctly		
Hat fits snugly		
Corrugated tubes are correctly placed		
Mustache suitable and effective		
Neck roll of correct size and position if in the supine position or side lying.		
Chin strap correct size and position		
Head position correct (if prone)		
Gas bubbling continuously		
Airway suctioned		
CPAP increased to 7 cm H2O		
Infant's clinical condition consistent with definition of respiratory failure AFTER these measures taken		
Oxygen requirements: Blood gas values: Date/time	FiO2 ---------- PH ---------- PaO2 ---------- PaCO2 ---------- Time ----------	

Notes: ----------

SECTION SEVEN

TROUBLESHOOTING THE NCPAP DELIVERY SYSTEM

Introduction

This section focuses on specific aspects in troubleshooting problems with the nasal CPAP delivery system. These are common questions and issues that arise with staff who are new to using the bubble bottle nasal CPAP system.
If you have a question or problem that is not addressed here, please discuss it with one of the NICU consultants or the respiratory therapist on call.

Troubleshooting

1. "It's not bubbling!"

This indicates loss of airflow or a pressure leak somewhere in the system. A simple way to check if it is a 'circuit' problem or a 'baby' problem is to remove the prongs from the nose and occlude them with your fingers. If the system doesn't bubble, it means the problem is with the circuit. Systematically check the circuit, as outlined above, tightening all connections as you go.

Troubleshoot the system beginning at the wall and ending at the outlet bottle. If the system does bubble, when you occlude the prongs with your fingers, then the pressure leak is occurring within the nares or via an open mouth. Air will escape if the prongs are too small or if they are not curved down into the nose and fitting snugly. The suggested sizes are only a guide, as babies' nose sizes do vary. A firm, effective chinstrap is essential to the delivery of consistent positive pressure.

2. "The prongs won't stay in place!"

A. Are they the right size?

Nasal prongs should be the largest size that will fit snugly in the nares without allowing excessive leak around the prongs, or causing persistent blanching of the nares. Prongs that are too small are more likely to move around causing friction, trauma, and inconsistent CPAP pressure. The correct size prongs are more effective, more comfortable, and more stable than prongs that are too small. It is acceptable to create a nose seal using *duoderm* to cover the entire nose and to limit air leakage around the prongs.

B. Does the hat fit snugly?

The hat is the anchor for the prongs, so a loose hat will allow any head movement to dislodge the prongs.

C. Are the corrugated tubes fixed firmly in place on the sides of the hat and are they at the correct angle to keep the prongs in place?

If there is rotating pressure on the prongs they may twist out of the nose. If in doubt, try undoing the rubber bands and, with the prongs correctly positioned in the nose, allow the tubing to sit naturally in place. Reposition the pins and rubber bands as necessary.

D. Would a Velcro mustache help or does the existing one need replacing?

See instructions for applying a mustache under Table 2.3 Protocol Steps for Initiation of NCPAP.

3. "The baby won't settle!"

Does the baby need suctioning? This may seem a contradiction when suggesting ways to settle a baby down, but a build up of secretions can cause considerable distress to a baby whose breathing is already compromised. Aspirate any excess gastric air and/or remove the oro-gastric tube unless it is really necessary. Try positioning the baby prone, as this can help relieve abdominal distention and diaphragmatic pressure. Once you are sure the airway is clear, try the usual calming techniques of containment, linen nesting, swaddling, and pacifier. Often, just "hands off" will allow the baby to slowly settle, especially in the early hours as he/she adjusts to the CPAP.

4. "How can we avoid septal damage?"

Prevention is the key. Tissue will break down if it is subjected to continuous pressure, friction and or moisture. Avoiding these contributing factors will maintain an intact septum: Use the correct sized prongs as outlined in the application instructions.

___ Secure them in place with a snug fitting hat, correctly positioned pins and rubber bands over the corrugated tubing.

If necessary use a Velcro mustache for extra security (make sure it doesn't press up against the septum).

Don't allow the bridge of the prongs to press up against the septum.

Avoid twisting the prongs with resultant lateral pressure against the septum.

Do not use creams, ointments or gels (use saline drops to moisten the nares for initial prong insertion or during suctioning if necessary).

Frequent observation of the site and prong position is essential.

Be wary of eye pads that cover the nose on babies under phototherapy as these can obstruct your view of the septum. If an injury has occurred, reviewing the above guidelines will avoid further damage and promote healing. It is not necessary to apply creams or dressings to the injured area. Covering the septum with Duoderm or similar product may lead to further skin break down and will limit the ability to assess healing or any further damage.

5. "There is a lot of foaming at the baby's mouth."
This often occurs during the first few hours after the initiation of CPAP. It is saliva that the baby is not swallowing that is being pushed out of the mouth by the pressure of the CPAP and is actually a good sign of effective pressure generation. It can be gently wiped away with a soft gauze pad or removed with a suction catheter. Parents often comment on it, and some will find it quite distressing. A simple explanation and the opportunity to wipe their baby's mouth with the soft gauze will often relieve the associated anxiety. The amount of bubbling saliva generally diminishes over the first four to six hours of CPAP.

REFERENCES

1. Avery ME, Mead J. Surface properties in relation to atelectasis and hyaline membrane disease. *American Journal of Diseases of the Child* 1959; 97: 517-523

2. Avery ME, Tooley WH, Keller JB, et al . Is chronic lung disease in low birth weight infants preventable? A survey of eight centers. *Pediatrics* 1987; 79: 26-30.

3. Boyle MH, Torrance GW, Sinclair JC, Horwood SP. Economic evaluation of neonatal intensive care of very-low-birth-weight infants. *New Engl J Med* 1983; 308:1330-1337

4. Clements, J.A., Brown, E.S., and Johnson, R.P. Pulmonary surface tension and the mucus lining of the lungs: Some theoretical considerations. *Journal of Applied Physiology*, 1958; 12:262.

5. De Klerk AM, De Klerk RK. Nasal continuous positive airway pressure and outcomes of preterm infants. J Paediatr Child Health 2001 Apr;37(2):161-7
Farell PM and Avery ME. Hyaline membrane disease. Am Rev Resp Dis 1975; 111: 657-688

6. Gittermann MK, Fusch C, Gitterman AR, Regazzoni BM, Moessinger AC. Early nasal continuous positive airway pressure treatment reduces the need for intubation in very low weight infants. Eur J Pediatr 1997; 156: 384-388.

7. Gregory, G.A., Kitterman, J.A., Phibbs, R.H., Tooley, W.H., Hamilton, W.K. Treatment of the idiopathic respiratory-distress syndrome with continuous positive airway pressure. *New England Journal of Medicine*, 1971; 284:1333-1340.

8. Guyer B, MacDorman MF, Martin, JA, Peters KD, Strobino DM. Annual summary of vital statistics-1997. *Pediatrics* 1998; 102:1333-1349

9. Han VKM, Beverley DW, Clarson C, Sumabat WO, Shaheed WA, Brabyn DG, Chance GW. Randomized controlled trial of very early continuous distending pressure in the management of preterm infants. Early Human Dev 1987;15:21-32.

10. Harrison, V.C., Heese, HdeV, Klein, M. The significance of grunting in hyaline membrane disease. *Pediatrics*, 1968; 41:549.

11. Horbar, J.D., Carpenter, J., Kenney, M. Vermont Oxford Network 2000 Database Summary. 2001.

12. Jacobsen T, Gronvall J, Petersen S, Andersen GE. "Minitouch" treatment of very low-birth-weight infants. Acta Paediatr 1993; 82: 934-938.

13. Jobe AH. Pulmonary surfactant therapy. *New England Journal of Medicine* 1993; 328: 861-868

14. Kamper J, Wulff K, Larsen C, Lindquist S. Early treatment with nasal continuous positive airway pressure in very low birth weight infants. Acta Paediatr 1993;82:193-7.

15. Kraybill E, Runyan D, Bose C, Khan J. Risk factors for chronic lung disease in infants with birth weights of 751 to 1000 grams. J Pediatrics 1989;1115:115-20.

16. Lidner W, VoBbeck S, Hummier H, Pohlandt F. Delivery Room Management of Extremely Low Birth Weight Infants: Spontaneous Breathing or Intubation. Pediatrics 1999;103(5):961-967.

17. O'Brodovich HM, Mellins RB. Bronchopulmonary dysplasia. Unresolved neonatal acute lung injury. *Am Rev Respir Dis* 1985; 132: 694-709

17. Poulton, E.P., and Oxon, D.M. 1936. Left sided heart failure with pulmonary edema: It's treatment with the pulmonary plus pressure machine. *Lance*t, 231:981.

19. Robertson PA, Sniderman SH, Laros RK, Cowan R, Heilbron D, Goldenberg RL, Iams JD, Creasy RK. Neonatal morbidity according to gestational age and birth weight from five tertiary care centers in the United States, 1983 through 1986. *Am J Obstet Gynecol* 1992; 166:1629-1645

20. Schwartz RM, Luby AM, Scanlon JW, and Kellog RJ. Effect of surfactant on morbidity, mortality, and resource use in newborn infants weighing 500 to 1500g. *NEJM* 1994; 330(21): 1476-80.

21. Soll RF, McQueen MC. Respiratory Distress Syndrome. In Sinclair JC, Bracken MB (eds): *Effective Care of the Newborn Infant.* Oxford University Press, Oxford, UK. 1992

22. St. John EB, Nelson KG, Cliver SP, Bishnoi RR, and Goldenberg RL. Cost of neonatal care according to gestational age at birth and survival status. *Am J Obstet Gynecol* 2000 Jan; 182(1Pt1): 170-5.

23. Subramaniam P, Henderson-Smart D, and Davis PG. Prophylactic nasal continuous positive airways pressure for preventing morbidity and mortality in very preterm infants (Cochrane Review). Cochrane Library Issue 3, 1999. Update Software.

APPENDIX A:
EQUIPMENT LIST AND MANUFACTURERS

Acetic Acid Solution, 1000 ml Manufacturer: Baxter Healthcare Address: Deerfield, IL 60015 Product No: 2F 7184, NDC 0338-0656-04 (not available at RKH hospital)

Respiratory Circuit and tubing Allegiance Healthcare Corporation Address: McGaw Park, IL 60085 Product No: Customized kit (Kit, Respiratory, 20/CS) which includes: Airlife U/Connect-it Oxygen Tubing (cat. number 001350) Fisher & Paykel humidification chamber (product number MR250) Airlife Respiratory Transfer Set (cat. number 2C7103) Airlife Isothermal breathing circuit, Infant Respiratory Circuit Heated (cat. number 7431-4S2). Contents include 1 heated circuit, 2 connectors, 1 trache tie, and 1oxygen tubing connector)

Sterile Water, 1000 ml Manufacturer: Baxter Healthcare Address: Deerfield, IL 60015 Product No: 2F 7114, NDC 0338-0004-04

Stockinette (hat) Manufacturer: Alba Health, Health Products Division, Alba-Waldensian Inc. Address: 425 North Gateway Ave, Rockwood TN 37854 Product No: 081220 (2” x 25 yards (5cm x 2.9m)) Product No: 081320 (3” x 25 yards (8cm x 22.9m))

Section eight

Delivery room protocol for the respiratory management of preterm infants

A. Infants less than 1000 g or less than 28 wks gestation whether breathing spontaneously or not, need to be intubated and given exogenous surfactant in the delivery room unless judged clinically to not require intubation. They are to be evaluated within 2 hours for the possibility of extubation to bubble nasal CPAP.

Criteria for extubation:
1. Spontaneously breathing.
2. No significant apneic episodes.
2. Requiring less than 30% FiO_2 to maintain a preductal saturation of > 92%.
3. Cardiopulmonary stability (Stable BP, HR and perfusion).
4. Mild RDS on their initial CXR.

B. Infants who are 28 wks or more, 1000 g or more and spontaneously breathing are to be put on bubble nasal CPAP (5 cm H2O, with a FiO2 to maintain a preductal saturation of 92-96%).

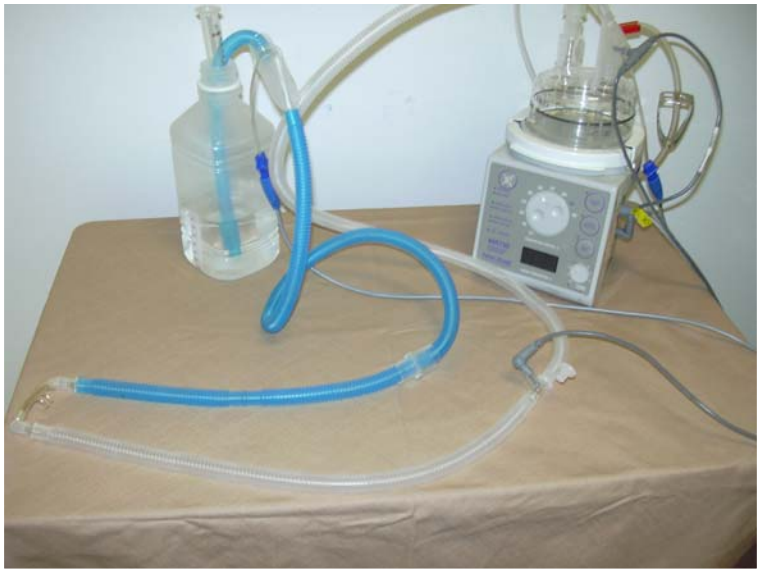
Criteria for intubation;
1. Significant apnea (requiring bag and mask ventilation or associated with bradycardia, pallor or cyanosis).
2. Requiring more than 60% FiO2 to maintain a preductal saturation of 92% or more.

3. Significant respiratory distress (Significant retractions and poor air entry).
4. PCO2 >60-65 mmHg (8KPa) and a PH <7.25

C. Infants who are more than 28 wks, more than 1000 g and not spontaneously breathing after proper stimulation and resuscitation are to be intubated (no surfactant to be given), and admitted to the NICU.
They are to be evaluated in the first 2 hrs of life.
1. They can be extubated to bubble nasal CPAP if they are spontaneously breathing, requiring less than 30% FiO2 to keep the preductal saturation 92% and above and their CXR is showing only a mild RDS picture.

2. They can be given exogenous surfactant and maintained on mechanical ventilation if their oxygen requirements are above 30-40%, requiring higher ventilatory support, are still not breathing spontaneously and their CXR is showing moderate to severe RDS picture.

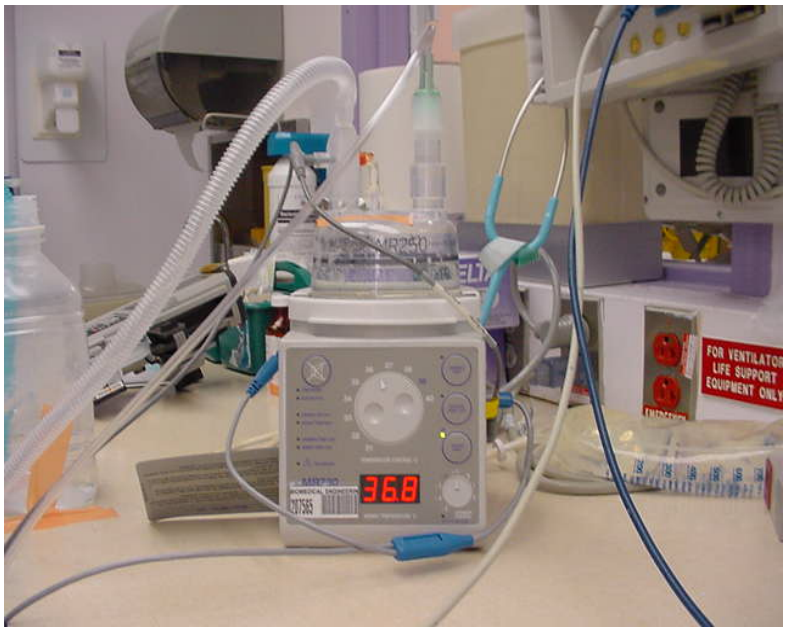
Bubble nasal CPAP circuit and interface



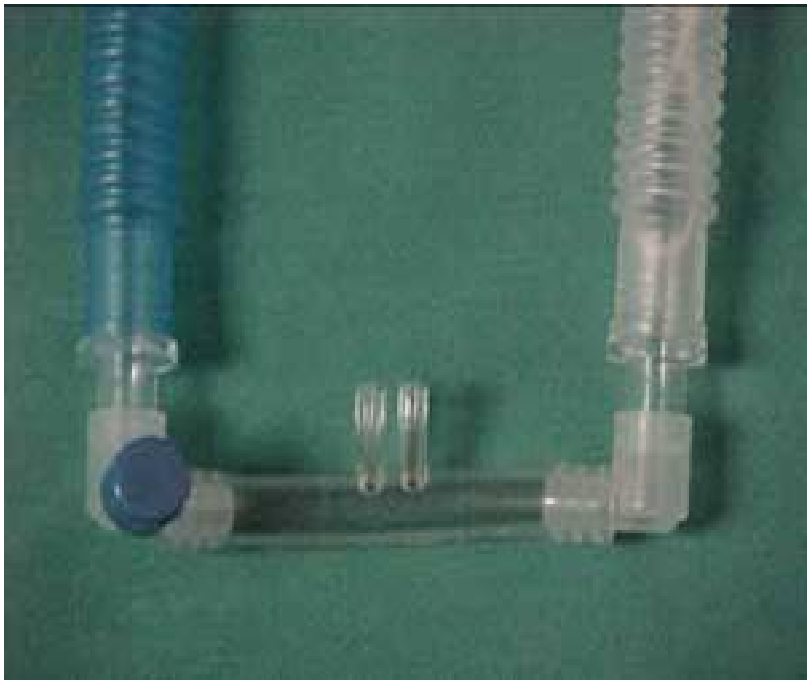
Flow meter and blender assembly

The flow should be at 5-10 L/min (Usually 7 L/min).

Humidifier
Temperature should be 36.8-37.2°C.



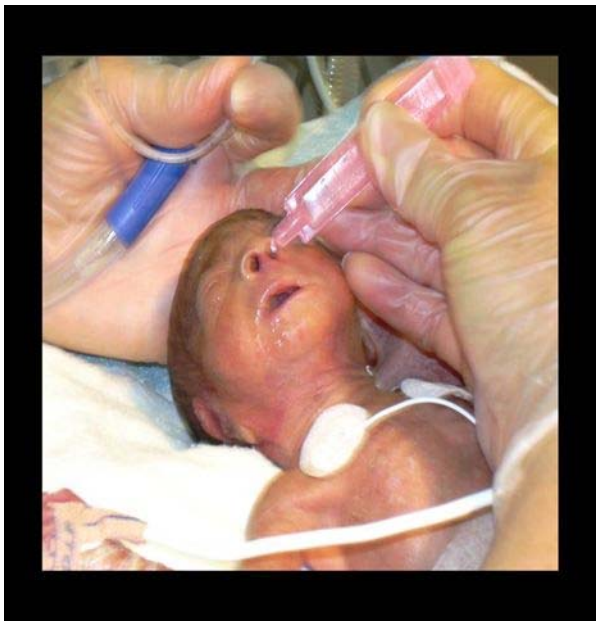
The Hudson Prongs' interface



An infant on Hudson Prongs nasal CPAP

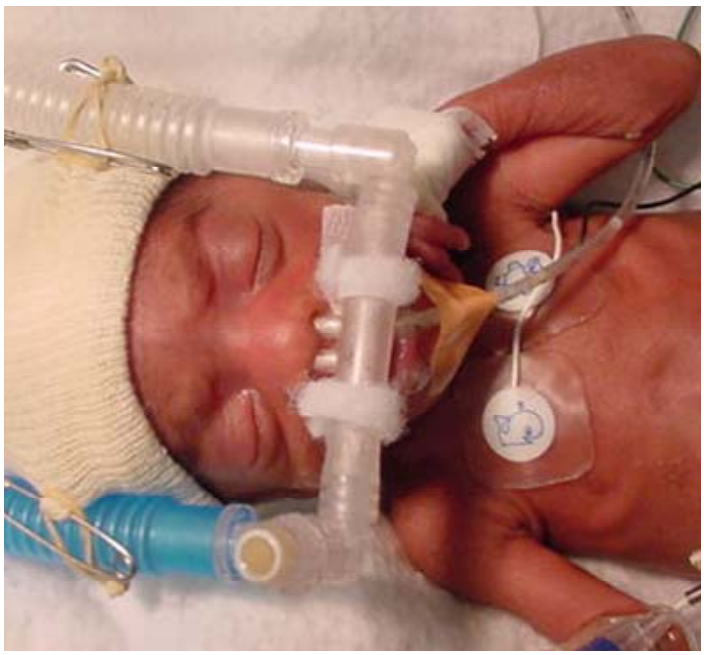
Suctioning of both nostrils with 8.0FG suction catheter as shown here.

Use normal saline prior to suctioning of both nostrils.

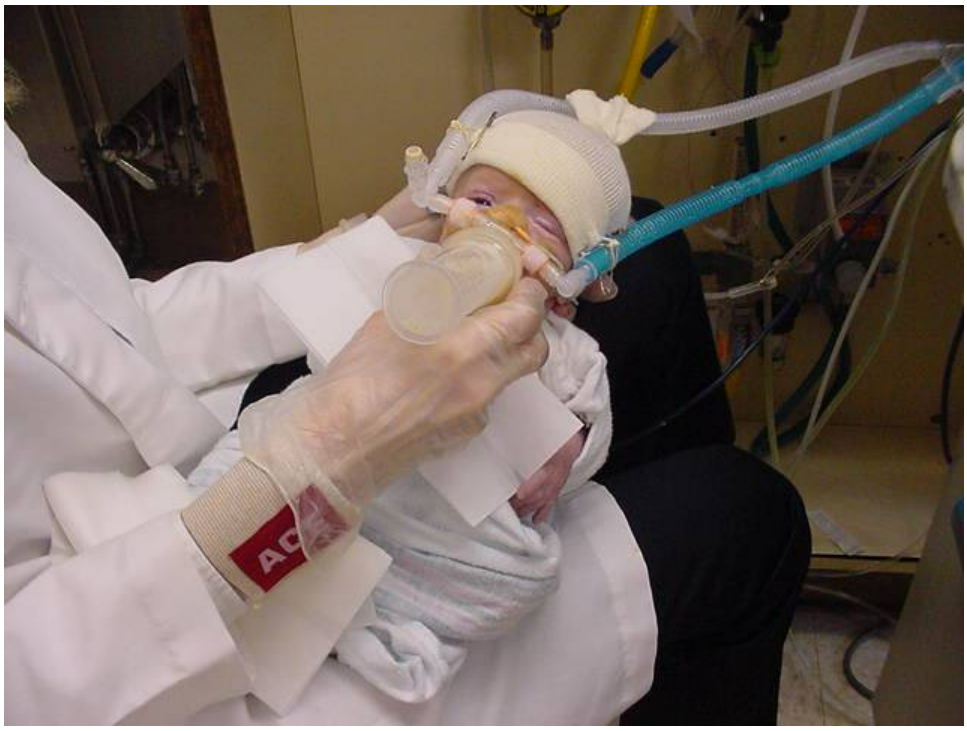


Chinstrap in place (it will keep the mouth closed to prevent pressure escape). “Co-Ban” can be used instead.

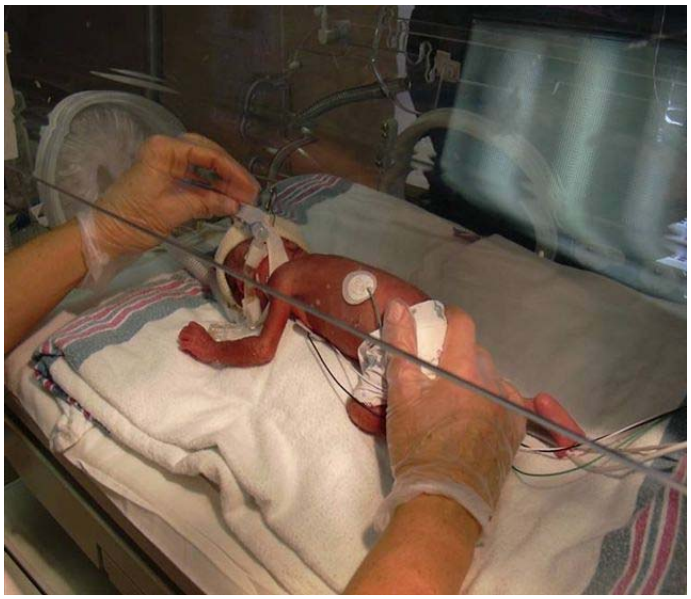
Use appropriate sized feeding tube to vent the stomach.



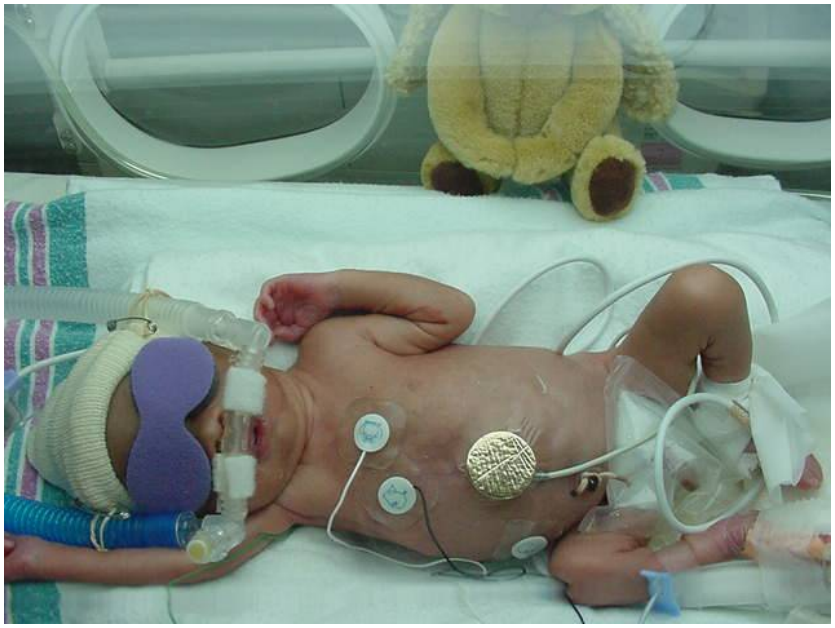
Bottle feeding an infant on bubble nasal CPAP.



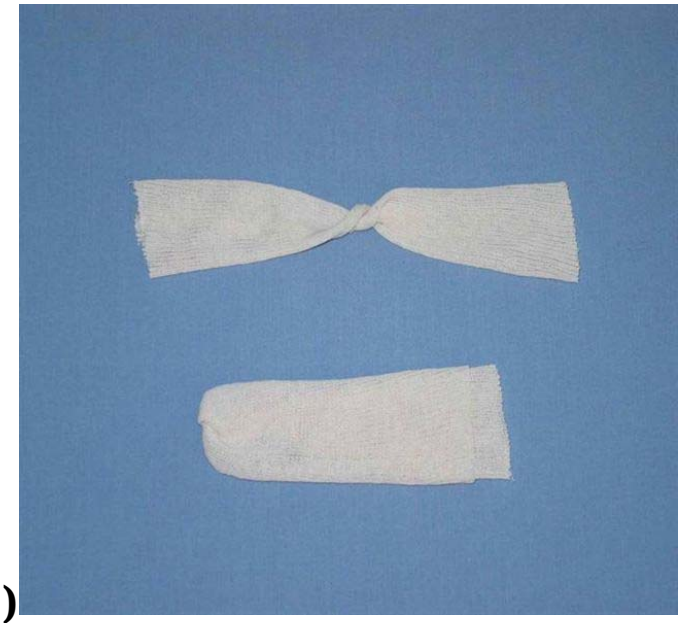
Infants can be nursed prone or side lying.



Phototherapy and eye patches



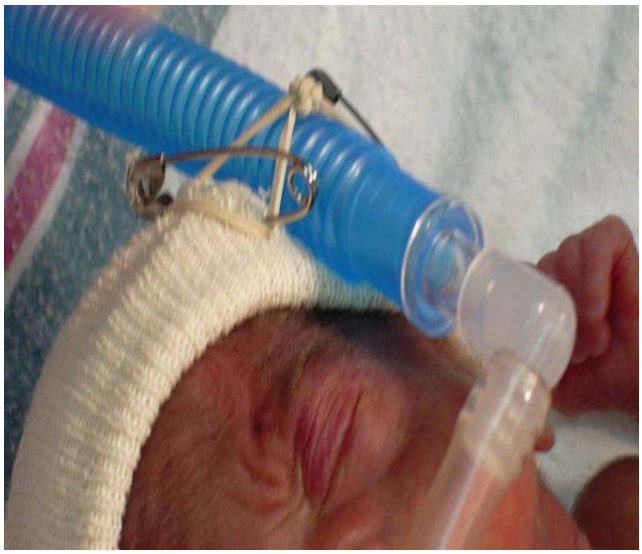
Home made hat

(1) 

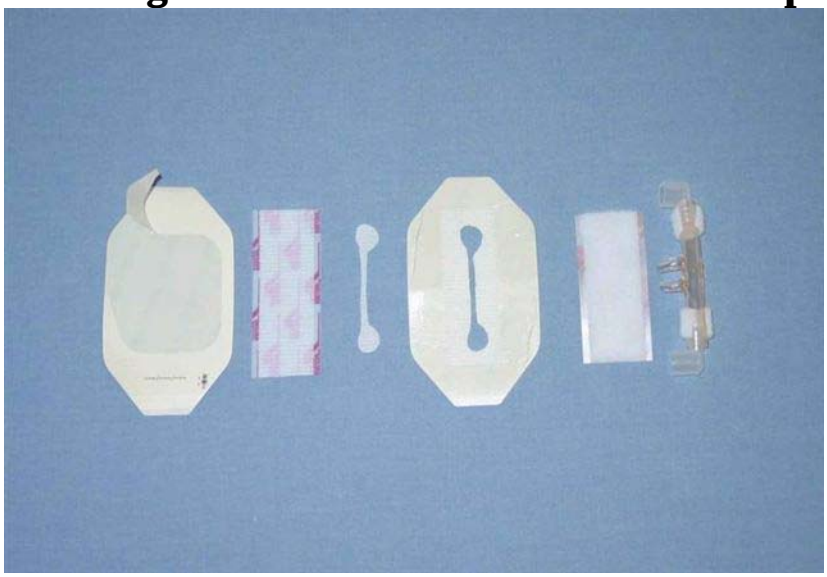
Home made hat

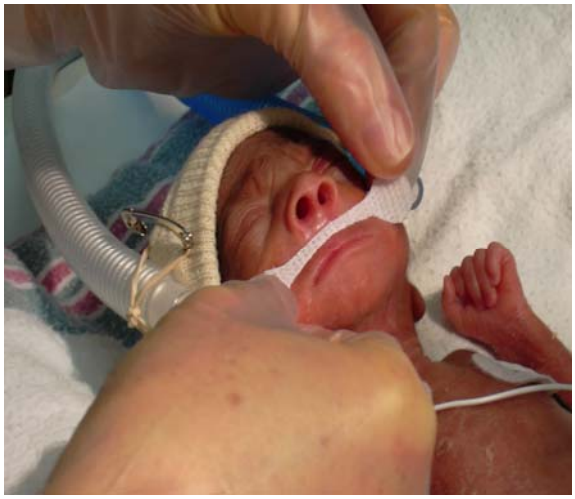
(2) 

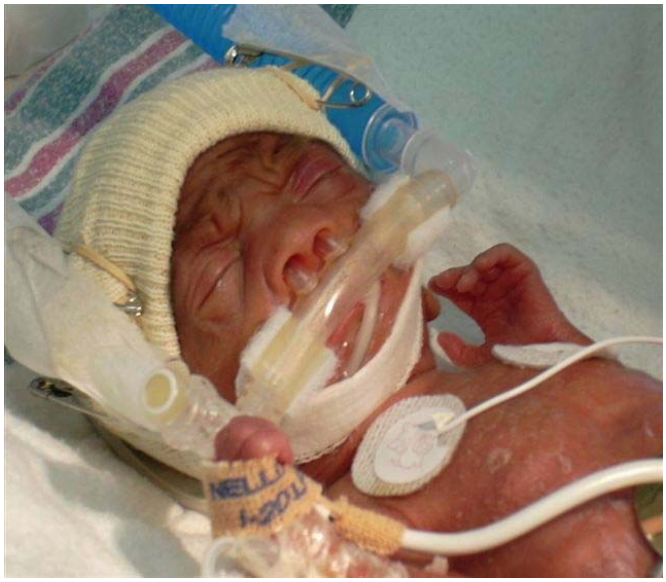
Safety pins and 2 rubber bands are used to attach the corrugated tubes to the hat, as shown.



Making of a mustache and chin strap







The chinstrap