Continuous Positive Airway Pressure: The Light that Really does Keep Monster from Baby Away

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ABSTRACT
Continuous positive airway pressure (CPAP) is a simple, inexpensive and gentle mode of respiratory support in preterm very low birth weight infants. Various devices have been used for CPAP generation and delivery. In resource limited settings, bubble CPAP is an effective and inexpensive way to provide respiratory support that appears to be at least as good as the respiratory support generated by the far more expensive equipment. The simplicity and low cost makes it an attractive option in resource poor setups. Simple intervention can result in a significant decline in neonatal mortality in hospitals with limited resources.

Keywords: Continuous positive airway pressure, indigenous continuous positive airway pressure, respiratory support, preterm

INTRODUCTION
Continuous positive airway pressure (CPAP) is the application of positive airway pressure throughout the respiratory cycle during spontaneous respiration. CPAP is a non-invasive form of respiratory assistance that has been used to support spontaneously breathing infants with lung disease for nearly 40 years. Following reports that mechanical ventilation contributes to pulmonary growth arrest and the development of chronic lung disease, there is a renewed interest in using CPAP as the prevailing method of supporting newborn infants. CPAP, often thought to be “missing link” between supplemental oxygen and mechanical ventilation is gaining popularity as the prime mode of respiratory support in preterm very low birth weight (VLBW). It is a simple, low-cost and effective method of ventilating a sick newborn, could well be a boon for babies born in resource restricted countries.

HISTORY
In 1914, Von Reuss recognized Von-Tiegel’s “over-pressure apparatus”, in the classic German text, the diseases of the newborn. In this report, spontaneously breathing newborn infants were successfully managed using a simple system consisting of hoses, an oxygen gas source, a tight-fitting face mask, and a water-filled receptacle. A metal tube attached to the expiratory hose allowed gas to exhaust below the water surface, and the pressure was varied by adjusting the tube depth, according to a centimeter scale on the receptacle. In the later part of the 1960s and early 1970s, ventilators designed for use in adults were applied experimentally, and often unsuccessfully, to treat infants with severe respiratory failure. The first clinical use of CPAP was reported by Gregory et al., in Landmark report in 1971. They described the use of CPAP through endotracheal tube or a head box in preterm infants with respiratory distress syndrome (RDS). Later Kattwinkel reported the successful use of nasal prongs. Subsequently, Jen-Tien Wung at children’s hospital of New York developed bubble CPAP. Following the introduction of CPAP, the mortality of RDS decreased from 55-35% to 20-15%, an improvement which is comparable with the effect obtained by the introduction of surfactant 20 years later. These developments led to the more widespread and routine use of CPAP, as well as investigations...
into improving the application of CPAP in infants. It has been documented that atelecto-trauma, bio-trauma and volu-trauma is less with CPAP. With the advent of Insure technique of surfactant the scenario of ventilation is shifting from invasive mechanical ventilation toward CPAP.

**PRINCIPLE**

Grunting in a baby with respiratory distress is an attempt to generate pressure against closed glottis that keeps the airway open during expiration. CPAP works on the same principle. The exact mechanism is still unclear.

In a baby with hyaline membrane disease, forced residual capacity (functional residual capacity [FRC] - the volume of air that is remaining in lungs after tidal volume) is reduced below closing volume (volume below which the terminal bronchioles get closed). CPAP generates continuous pressure throughout the respiratory cycle to a point that FRC reaches above the closing volume, and terminal bronchioles remain patent throughout the respiratory cycle.

According to Laplace law, the pressure generated depends on surface tension, and inversely to the radius of the substance. In RDS, the lack of surfactant allows the water molecules (lung fluid) to coalesce and reducing the radius of the alveoli. Thereby, more pressure is required to open the collapsed alveoli. CPAP splints open the upper airway thus reduces the airway resistance and keeping the airway open by negotiating the surface tension.

CPAP by generating the pressure also stimulates the “Hering–Bruer’s” reflex. It states that stretching of pleura during the end of expiration stimulates the respiratory center (in the brain stem). By this the next cycle of respiration is initiated.

**Indications of CPAP in Neonates**

1. Hyaline membrane disease
2. Apnea of prematurity
3. Post-extubation in preterm VLBW
4. Transient tachypnea of newborn
5. Meconium aspiration syndrome
6. Pneumonia
7. Pulmonary edema/pulmonary hemorrhage
8. Laryngomalacia/tracheomalacia/bronchomalacia.

**Contraindications of CPAP in Neonates**

1. Patients with poor respiratory efforts
2. Trachea-esophageal fistula
3. Congenital diaphragmatic hernia
4. Nasal obstructions - choanal atresia, cleft palate
5. When $\text{PaCO}_2 > 60 \text{ mm Hg}$, $\text{pH} < 7.2$
6. Babies with cyanotic heart diseases
7. Relatively the patients with the central cause of respiratory distress like sepsis, birth asphyxia, intracranial hemorrhages.

**BASIC ESSENTIALS IN CPAP**

Every basic CPAP machine requires the following:

- **Gas source:** Continuous supply of warm humidified and blended mixture of air and oxygen
- **Pressure generator:** Continuous positive pressure generation. The pressure generators are either continuous type (conventional stand-alone CPAP, bubble CPAP) or variable flow type (infant flow meter).
- **Patients interface and circuit:** Connect the CPAP circuit to infant’s airway. The various types of interfaces are:
  - Nasal prongs (single/binasal)
  - Nasopharyngeal prongs
  - Nasal cannula
  - Nasal masks.

**HOW THE INDIGENOUS CPAP (BUBBLE CPAP) WAS MADE?**

Bubble CPAP is a continuous flow type of CPAP pressure generator where the pressure is generated by immersing the variable length of expiratory limb in the water chamber. Bubble CPAP having its origin in 1960's but its use never gained much popularity in developing countries because of cost and maintenance. The market cost of Indian bubble CPAP is between 50,000 and 80,000 rupees. In resource limited settings, every tertiary center cannot access to this life-saving machine.

The bubble CPAP was prepared with the help of intercostal drainage bag used as a pressure generator (Figure 1). The expiratory limb from the patient's interface was attached to the intercostal tube drainage (ICTD). The space between the tip of ICTD and the bottom of bag act as dead space, and the water level of 250 ml water marked as 0 cm H$_2$O pressure. ICTD was filled with water such that the tube inside the chamber was dipped about 5 cm from below. This produces the pressure of 5 cm H$_2$O at patients interface (binasal prongs).

![Figure 1: Indigenous continuous positive airway pressure circuit (self-drawn diagram)](image)
CPAP Set-up
Before the initiation, the head end is elevated 30° via shoulder roll.
1. The flow of gases is adjusted according to clinical condition of the patient from 0 to 10 liters/min (usually kept between 5 and 8 cm L/min)
2. There are two limbs in the circuit

The inspiratory limb is the connection between flow meter (blender with flow calibration) and patient. It allows the compressed blended air – oxygen to pass through humidifier, which humidifies gases at 35-37°C.

The expiratory limb starts from the humidifier. There is bifurcation of the limb at this point. Through corrugated tubing one end attached to patients interface via nasal prongs and other end to intercostal chest drainage bag through ICTD tube. This tube is immersed in water up to required depth (determined by intended pressure).

For a pressure of 6 cm H2O, the expiratory limb is dipped about 6 cm mark of the tube. Note that with each adding or removal of water from the water chamber increases or decreases the pressures respectively. The main differences between this and other CPAP is that the pressure is changed by adding or removing the water from chamber rather than removing or inserting the tube in it (due to fixity of the limb).

3. Set the desired flow and pressure.
4. At the patients interface binasal prongs are attached, which are supported with the head cap made from the socks after stitching the two limbs of prongs in it. It prevents the nasal injury due to the hanging pressure of prongs. A tegaderm strip was put over the skin of septum.
5. The vitals were monitored and the pulse oximeter was attached.
6. An orogastric tube was inserted to decompress the stomach or can allow feeding of newborn on CPAP.
7. Nasal suction was regularly done, and both nostrils were moistened with normal saline at regular intervals.
8. Look for bubbling in the water chamber. If no bubbling occurs any leak in the circuit has to be looked for. If no leak found then, the flow is increased with 1 L/min.
9. The failure of CPAP is considered when with the pressure of 8 cm H2O, and the flow of oxygen is 70%. The pH of the baby is below 7.2. It is the time when mechanical ventilation is to be considered.
10. The effectiveness of CPAP is increased when the preterm babies with respiratory distress are given early rescue surfactant.

MONITORING DURING THE PROCEDURE
1. Vitals - temperature, heart rate, capillary refill time, pulse oximetry (89-94%), blood glucose
2. Respiratory distress score - Silverman for preterm or Downe’s score for term
3. Monitor blood pressure, urine output, and abdominal girth
4. Arterial blood gas analysis
5. Look for nasal trauma, monitor the dryness of the nose
6. Patient has to be repositioned every 3 hours with neck slightly extended to maintain airway
7. Humidification of the gases has to be checked regularly
8. By the pressure valve at the patients interface, the pressure delivered to the patient has to be monitored
9. The circuit has to be regularly checked for leakage
10. The tubings must be regularly cleaned and checked for blockage
11. There is no need of daily regular chest X-ray in monitoring of lung signs
12. Maintain hydration of the baby
13. Keep the resuscitation equipment cot side all the times

WEANING OFF FROM CPAP
After proper monitoring when there are no signs of respiratory distress (resolution of grunting, nasal flaring, and chest retractions) and arterial blood gas analysis is within normal limits, FiO2 is gradually decreased in steps of 5% and pressure decreased by 1 cm H2O. Make sure the baby breathes with less effort.

COMPLICATIONS OF CPAP
1. Air leaks (pneumothorax)
2. Agitation
3. CPAP belly syndrome
4. Nasal trauma
5. Hypotension
6. Increased pulmonary vascular resistance
7. Chronic lung disease.

DISCUSSION
Many innovations have taken place to improve the medical care via bubble CPAP in low-resource settings. A low-cost new design developed by the undergraduates of Rice University is saving the lives of Malawi’s preterm. They made bCPAP prototype with plastic shoebox and aquarium pumps. Later they named the device - “PUMANI-means breath.” They used consumer grade regulators and aquarium pumps and opted for analog flow meters, gravimetric flow tubes. They also added sheet metal casing the generator and patients interface. Like others submersion of one end of the tubing, the bottle of water generates pressure as ours. But they used pressure valves at
the patient interface and developed a system of increasing the length of the tube by inserting and removing it where in contrast to it we used ICTD bags with fixed tubing. Recently United Kingdom a new device consisting of its own oxygen concentrator that generates oxygen from atmospheric air, eliminating the need of expensive cylinders of compressed gases. The greatest advantage is its mobility. The way bubble CPAP developed in our settings is one of the modification of CPAP developed in AIIMS Institute, New Delhi. This kind of CPAP is effective and with slight modifications it can be better used to save lives of more newborns.

CONCLUSION

CPAP is now-a-days considered as a first line therapy for management of RDS in preterm infants. Currently, the use of CPAP is increasing exponentially due to the advantage of being less expensive, less damaging and having reduced incidence of the chronic lung disease and broncho-pulmonary dysplasia over the use of invasive mechanical ventilation. It is an extension of ventilatory support rather than replacement of mechanical ventilation. Use of indigenous CPAP according to availability of resources in the particular settings is boon to the current management of preterm with respiratory distress. Its use in non-tertiary settings can cause less referrals and can save lives of many newborns. It is to be emphasized that indigenous CPAP in itself is enlightening the darkness in many low-resource settings, but its use with surfactant will be like miracle to decrease the most worried annual statistics of infant mortality in areas where it is touching sky.

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REFERENCES