Current Practice

Non invasive respiratory support in the neonate: Continuous positive airway pressure (CPAP)

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Introduction

Continuous positive airway pressure (CPAP) refers to the application of positive pressure on a spontaneously breathing neonate. This has become a popular and effective therapy in management of idiopathic respiratory distress syndrome (IRDS) in the premature neonate. Being technically simple, non-invasive, less damaging to the neonatal lung and low cost, CPAP has rapidly gained popularity over ventilators both in the developing and developed countries. At present CPAP appears to be the ideal solution for management of mild to moderate degrees of IRDS in the newborn.

Background

The first clinical use of CPAP was reported in 1971[1]. Though initially described with endotracheal application, the use of nasal prongs to deliver CPAP successfully soon followed. After almost a decade of enthusiastic clinical use, CPAP fell out of favour in early 1980s with the advent of newer modes of mechanical ventilation. After 15 years of ventilator predominance in the management of IRDS, the efficacy and protective value of CPAP was brought to light with the reports from Columbia University unit. Since then CPAP has retained its popularity as the treatment of choice for mild to moderate IRDS.

Components of a CPAP system

Components of a CPAP system essentially consist of:

1. Gas source: Provides warm humidified and oxygen blended gas.
2. Pressure generator: Creates positive pressure in the circuit.
3. Patient interface: Connects CPAP circuit to patient's airway.

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Devices used for CPAP delivery (Patient interface)

Patient interfaces available for CPAP delivery are:

1. Nasal prongs (single/binasal)
2. Nasopharyngeal prongs
3. Nasal cannulae
4. Nasal masks

Nasal prongs & nasopharyngeal prongs are popularly used[2]. Nasal cannulae fail to deliver optimum CPAP, due to leakage around nostrils, inadequate humidity, inability to monitor the pressures delivered and inability to control oxygen independently. Nasal masks are not successful due to difficulty in maintaining an adequate seal and its tendency to obstruct the airway[3]. Meta analyses have shown that binasal prongs are the most effective[4]. Endotracheal tube, face mask and head box are no longer considered as suitable for delivery of CPAP[5].

Effects of CPAP on the neonate

Physiological benefits on the lung

CPAP predominantly helps by splinting the airways, thus preventing atelectasis and collapse. This allows better recruitment of alveoli, thereby increasing the functional residual capacity (FRC). Additionally, there is improved compliance, decreased airway resistance, conservation of surfactant and stabilization of chest and diaphragm in the extremely premature baby[6].

Effect on arterial blood gases (ABGs)

CPAP improves oxygen by increasing the FRC. With moderate CPAP of 4-6 cm water, arterial carbon dioxide (CO_2) improves due to recruitment of alveoli creating a larger surface area for gas exchange. With further increase in CPAP pressure, over-distension of alveoli with incomplete gas emptying causes retention of CO_2.

Indications for CPAP application

Clinical situations
CPAP is the treatment of choice for mild to moderate degrees of IRDS and apnoea of prematurity. It is strongly indicated in extubation from IPPV. Its other uses are congenital pneumonia, TTN/Delayed adaptation and meconium aspiration syndrome (MAS).

Assessment criteria
Respiratory distress with a Silverman score of 4-6, tachypnoea >60 per minute or needing >55% FiO_2 to maintain satisfactory pulse oxymetry are considered as clinical indicators to initiate CPAP.

Biochemical criteria
Unsatisfactory ABGs with pCO_2>55mmHg and/or pO_2 <60 mmHg while on 3L/min of oxygen (O_2) via head box (approximately 60% FiO_2) are considered biochemical indicators to initiate CPAP.

Contraindications for CPAP

CPAP is contraindicated in neonates with congenital diaphragmatic hernia, tracheo-oesophageal fistula, choanal atresia, cleft palate, poor respiratory efforts and severe cardiovascular instability[7].

Guidelines for CPAP therapy

Timing of CPAP application
CPAP mainly helps by splinting the airways thus preventing atelectasis and alveolar collapse. To be of optimal benefit CPAP should be started as early as possible when indicated.

Place of prophylactic CPAP
While CPAP should be started as early as possible when indications are evident, it has been established that there is no additional benefit of prophylactic CPAP on preterm babies without clinical or biochemical evidence of IRDS. In fact, there are concerns regarding increased adverse effects such as lung injury, air leak syndromes and intraventricular haemorrhage. Hence prophylactic CPAP is not recommended at present[8].

Initiation for CPAP and stepping up of support
CPAP should be started with a pressure of 4-6 cm water and 40-50% of FiO_2. If oxygenation is unsatisfactory, pressure should be gradually increased by 1-2 cm water at a time, up to 7-8 cm water. Then FiO_2 may be gradually increased by 5% at a time up to 60%. The aim is to achieve a comfortable baby with satisfactory pulse oxymetry and ABGs.

Monitoring during CPAP application

General & supportive
Baby should be monitored for clinical stability. Vital signs (heart rate, respiratory rate, arterial pressure, temperature, SpO_2, urine output) should be monitored. Shallow respiration, apnoeic attacks, desaturations & bradycardia should be recorded. Grunting, retractions, undue restlessness and cyanosis should be absent. Capillary refill time should be less than 4 seconds and pulse oxymetry should read between 90-95%. CPAP gas flow should be warmed and humidified. Nasal prongs should be well fitting. There should be no block in the nasal pathways. Nutrition should be maintained. Precautions for avoiding sepsis should be followed [9].

Acid base status & blood gasses
ABGs should be done before initiation of CPAP and after stabilization on CPAP. Subsequent ABGs are needed only if baby's condition so demands. ABGs should be in the acceptable range [pH 7.30–7.45, pCO_2 40-50mmHg and pO_2 60-80mmHg][9,10]. Oxygen saturation monitoring alone can be misleading in a hypo-ventilating neonate[6]. In the absence of transcutaneous CO_2 monitoring, an ABG to establish acceptable CO_2 levels and close observation for changes in the respiratory pattern is essential.

CPAP & surfactant therapy

Surfactant therapy for babies on CPAP is an established procedure in the management of IRDS. This expensive therapeutic option is most beneficial and cost effective when implemented in premature babies <30 weeks and in neonates who need higher range of oxygen and CPAP pressures. While on CPAP the baby is briefly disconnected, intubated, given the calculated amount of surfactant and extubated back on to CPAP. This is known as "INSURE" method (**In**tubation-**Sur**factant-**E**xtubation) & is widely and successfully practised[9].

CPAP in different clinical situations

IRDS
CPAP is the gold standard management in mild to moderate IRDS. Early application of CPAP reduces the need for IPPV in a significant proportion of premature neonates with IRDS. In fact, there is research to support that perinatal morbidity is less in extremely premature neonates between 24 to 27 weeks gestation when CPAP is initiated in the labour

room than when surfactant followed by IPPV is initiated within one hour of birth[9].

Recurrent apnoeic episodes
Apnoea of prematurity as well as obstructive apnoea and apnoea secondary to respiratory causes can be effectively treated by CPAP in most instances. In apnoea of prematurity methyl xanthines should be tried initially.

Post-extubation from IPPV
CPAP provided immediately after extubation from IPPV is recommended to prevent post extubation atelectasis, apnoea and respiratory acidosis.

Delayed adaptation/TTN
This condition is thought to be due to excess lung fluid. Usually the baby is term or near term and the respiratory distress is mild to moderate. If started early, CPAP helps in maintaining lung expansion. Generally CPAP can be weaned off within 72 hours.

Pneumonia
CPAP is indicated in stable neonates with mild to moderate pneumonia. It helps by maintaining lung expansion preventing any collapse due to secretions.

Meconium aspiration syndrome (MAS)
Nasal CPAP of 4-7 cm of water may be helpful, but further increase in CPAP pressure may lead to over-distension and air leak. MAS occurs in term babies and nasal prongs/cannula may make the baby very restless leading to more harm than good.

Other indications
CPAP is of benefit in post-surgical situations, laryngomalacia and bronchomalacia.

Adverse Effects of excessive CPAP

CPAP when cautiously used is safe and usually causes no adverse effects. When used at inappropriately high pressures it may pose several unwanted effects [6]:

Cardiovascular: Reduction in cardiac output, increased central venous pressure, increased pulmonary vascular resistance.

Pulmonary: Pulmonary air leaks are the commonest clinically significant adverse effect of CPAP[11]. Over-distension and diminished compliance are other side effects noted. Recent trials have shown an increase in the incidence of pneumothorax[12,13].

CNS: Increased intracranial pressure and decreased cerebral perfusion.

GIT: Bowel distension and decreased GI blood flow.

Renal: Diminished renal blood flow.

Local adverse effects of CPAP application: These are usually due to application of too much pressure on the nostrils or using too tight nasal prongs. They manifest as peri-nasal excoriation, scarring, pressure necrosis & septal distortion[14,15].

Failure of CPAP

CPAP may be unsuitable in certain situations in spite of application with fulfillment of the necessary criteria. In certain other situations CPAP will be successful initially but may show respiratory deterioration after a period of time. Following situations indicate necessity to initiate IPPV[10]:

1. Persistent retractions and/or grunt, worsening tachypnoea or recurrent apneoic episodes.
2. PaO_2 <55mm of Hg, while on FiO_2 >60% and/or CPAP pressure >7cm of water[7].
3. $PaCO_2$ >55-60 mmHg[7].
4. Poor perfusion, systemic hypotension.
5. Mixed or partially compensated acidosis.
6. Poor tolerance of nasal prongs.

CPAP failure is also seen in 60% of extremely low birth weight neonates less than 700g[14]**.** It is appropriate to have a low threshold to apply IPPV on extremely premature babies <27 weeks with birth weights less than 700g.

Weaning from CPAP

Weaning from CPAP should be guided by maintenance of clinical stability and satisfactory pulse oximetry. Research comparing different strategies of weaning has shown that gradual stepping down of CPAP pressure, judged by clinical stability is more effective than time controlled weaning[16]. CPAP pressure should be reduced by 1-2 cm water decrements and FiO_2 reduced by 5-10% decrements. When CPAP pressure reaches 3-4 and FiO_2 <40% baby may be changed to head box oxygen.

Common concerns regarding CPAP Application

Optimal positioning on CPAP
Any reasonable positioning is acceptable to deliver CPAP effectively, but semi-prone or prone position will minimize central and obstructive apnoea[3].

Is mouth closing important?
Although there is a theoretical benefit of mouth closure in preserving the pharyngeal pressure, successes of CPAP in most studies have been shown without any measures to keep the mouth obliterated. Hence mouth closure is not recommended[3].

Gaseous distension of stomach and CPAP
It is not a common problem with CPAP. If gaseous distension occurs, the orogastric tube end may be kept open at a level higher than the baby's head to vent the gas[3].

Successful application of CPAP and chronic lung disease (CLD)
Research has shown that there is no difference in the incidence of CLD/bronchopulmonary dysplasia (BPD) or mortality between extremely premature babies managed with early CPAP and invasive modes of ventilation. Some research even shows a better morbidity in the CPAP group[13].

Other modes of non invasive respiratory support

Several modes of non invasive ventilation (NIV), which combine nasal continuous positive airway pressure (NCPAP) effect with superimposed ventilator breaths are being used currently in many centres. Nasal intermittent positive pressure ventilation (NIPPV) which may be mandatory or synchronized and nasopharyngeal intermittent mandatory or synchronized ventilation (NPIMV/NPSIPPV) are some of the newly introduced modes. Many studies have shown that there is a benefit in NIPPV in reducing the incidence of apnoea of prematurity and extubation failures when compared with CPAP[17-20]. However, some researches indicate that early NIPPV does not decrease the need for mechanical ventilation when compared with NCPAP, in the first 72 hours of life[21].

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