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Original Research Article

Early bubble continuous positive airway pressure as the initial mode of management of respiratory distress syndrome in preterm neonates

Nazish Tahreem*, Naushad N. Malagi, A. N. Thobbi, Raziyabanu

Department of Pediatrics, Al-Ameen Medical College and Hospital, Vijayapura, Karnataka, India

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***Correspondence:**
Dr. Nazish Tahreem,
E-mail: nnazish217@gmail.com

ABSTRACT

Background: Respiratory distress syndrome (RDS) is a common and serious condition in preterm neonates caused primarily by surfactant deficiency and immature lungs. Early application of bubble continuous positive airway pressure (bCPAP) offers a non-invasive respiratory support method that may reduce the need for mechanical ventilation and associated complications. The present study aimed to evaluate the efficacy and safety of early bubble CPAP as the initial mode of respiratory support in preterm neonates with RDS.
Methods: A prospective observational study was conducted on 100 preterm neonates between 28 and 34 weeks of gestation presenting with clinical and radiological features of RDS within 6 hours of birth. All neonates were initiated on bCPAP within 1 hour of birth or diagnosis. The primary outcome was bCPAP success, defined as avoidance of invasive mechanical ventilation within 72 hours. Secondary outcomes included the duration of bCPAP therapy, complications, incidence of bronchopulmonary dysplasia (BPD), length of stay in the neonatal intensive care unit (NICU), and survival to discharge.
Results: The mean gestational age and birth weight were 31.5±1.8 weeks and 1450±320 grams, respectively. Successful bCPAP therapy was achieved in 72% of neonates. The mean duration of bCPAP was 72.12±18.54 hours. Complications included apnea requiring intubation (12%), nasal trauma (10%), pneumothorax (5%), and BPD (8%). Neonates who failed bCPAP had significantly lower gestational ages and birth weights and higher incidences of BPD and mortality ($p<0.05$). Survival to discharge was 94%.
Conclusion: Early bubble CPAP is an effective and safe respiratory support strategy in preterm neonates with RDS, reducing the need for mechanical ventilation and associated complications.

Keywords: Respiratory distress syndrome, Preterm neonates, Bubble CPAP, Non-invasive ventilation, Bronchopulmonary dysplasia, Mechanical ventilation

INTRODUCTION

Respiratory distress syndrome (RDS) remains a leading cause of morbidity and mortality among preterm neonates worldwide.[1] Characterized primarily by surfactant deficiency and structural immaturity of the lungs, RDS leads to alveolar collapse, impaired gas exchange, and progressive respiratory failure if untreated.[2] Despite advancements in neonatal care, managing RDS effectively continues to be a critical challenge in neonatal intensive care units (NICUs), especially in resource-limited settings.[3] Continuous positive airway pressure (CPAP) has revolutionized the management of neonatal respiratory distress by providing non-invasive respiratory support.[4]

By maintaining a constant distending pressure, CPAP helps keep alveoli open, improves functional residual capacity, reduces atelectasis, and enhances oxygenation without the risks associated with invasive mechanical ventilation.[5] Among various CPAP delivery systems, bubble CPAP (bCPAP) has gained prominence due to its simplicity, cost-effectiveness, and proven efficacy.[6] It generates pressure by immersing the expiratory limb of the

circuit in water, creating characteristic bubbles that produce gentle oscillations, which may further aid in alveolar recruitment and gas exchange.[7]

Early initiation of bubble CPAP, immediately after birth or at the onset of respiratory distress, has been hypothesized to reduce the need for mechanical ventilation, decrease the incidence of bronchopulmonary dysplasia (BPD), and improve overall neonatal outcomes.[8] This approach aligns with the concept of gentle ventilation and lung protection by minimizing barotrauma and volutrauma associated with endotracheal intubation and invasive ventilation.[9] Several randomized controlled trials and observational studies have demonstrated the benefits of early bCPAP in reducing mortality and pulmonary complications in preterm infants.[10] However, the optimal timing, pressure settings, and selection criteria remain areas of ongoing research.

Furthermore, the widespread adoption of early bCPAP could be particularly advantageous in low- and middle-income countries where access to advanced ventilatory support and surfactant therapy is limited.[11] Implementing early CPAP as the primary mode of respiratory support can potentially decrease the burden of neonatal intensive care, reduce healthcare costs, and improve survival rates in preterm neonates.

This study aims to evaluate the efficacy and safety of early bubble CPAP as the initial mode of management for respiratory distress syndrome in preterm neonates. By assessing clinical outcomes, such as the need for mechanical ventilation, duration of respiratory support, incidence of complications, and survival rates, the study aims to provide evidence to support the development of protocols for early respiratory intervention in this vulnerable population.

METHODS

This prospective observational study was conducted in the NICU of Al–Ameen Medical College and Hospital over 12 months from April 2024 to April 2025. Ethical approval was obtained from the Institutional Ethics Committee, and written informed consent was obtained from the parents or legal guardians of all enrolled neonates.

A total of 100 preterm neonates with gestational age between 28 and 34 weeks who developed clinical and radiological features of respiratory distress syndrome (RDS) within the first 6 hours of life were included in the study. The sample size of 100 was calculated based on previous studies reporting a success rate of early bubble CPAP around 70%, with a 10% margin of error and 95% confidence interval.

Inclusion criteria

Preterm neonates who were born between 28 and 34 weeks of gestational age, neonates presenting with clinical signs of respiratory distress (e.g., tachypnea, nasal flaring, grunting, and chest retractions) within the first 6 hours of life, radiological confirmation of respiratory distress syndrome (RDS) by chest X-ray, and neonates for whom bCPAP was initiated as the initial mode of respiratory support within 1 hour of birth or diagnosis of respiratory distress were included.

Exclusion criteria

Neonates with significant congenital anomalies affecting the respiratory or cardiovascular system, neonates with perinatal asphyxia, defined as an Apgar score <3 at 5 minutes, neonates requiring immediate endotracheal intubation and invasive mechanical ventilation at birth and neonates with known chromosomal abnormalities or genetic syndromes, neonates whose parents or guardians refused consent for participation.

All enrolled neonates were started on bCPAP as the initial mode of respiratory support within 1 hour of birth or immediately after diagnosis of respiratory distress. The bCPAP was delivered using the (device name/model), with an initial positive end-expiratory pressure (PEEP) set at 5 cm H_2O, and adjusted between 5 and 6 cm H_2O according to clinical response. The fraction of inspired oxygen (FiO_2) was titrated to maintain oxygen saturation levels between 90% and 95%.

Vital signs, respiratory effort, and Silverman Anderson scores were monitored at baseline and at intervals of 6, 12, 24, 48, and 72 hours. Arterial blood gases were analyzed as clinically indicated. Chest radiographs were obtained to confirm RDS and monitor lung expansion.

The primary outcome was defined as the success of early bCPAP therapy, indicated by avoidance of invasive mechanical ventilation within the first 72 hours. Secondary outcomes included duration of bCPAP therapy, incidence of complications such as nasal trauma and pneumothorax, length of NICU stay, development of BPD, and survival to discharge.

Failure of bCPAP was identified by worsening respiratory distress signs, persistent hypoxia (SpO_2 <85% despite FiO_2 >60%), recurrent apnea requiring intubation, or hemodynamic instability. Neonates meeting these criteria were transitioned to invasive mechanical ventilation in accordance with NICU protocols.

Data analysis

Data were recorded in a structured proforma and analyzed using statistical package for social science (SPSS) version XX. Continuous variables were expressed as mean ± standard deviation, and categorical variables as percentages. Comparisons were made using Student's t-test for continuous variables and the Chi-square test for categorical variables. A p value of less than 0.05 was considered statistically significant.

RESULTS

The mean gestational age of the study neonates was 31.5±1.8 weeks, with an average birth weight of 1450±320 grams. Males constituted the majority at 68%, while females accounted for 32%.

Most deliveries were cesarean sections (65%) compared to vaginal births (35%). Regarding clinical severity, 65% of neonates had mild respiratory distress (Silverman score 0-3), 30% had moderate distress (Silverman score 4-6), and 5% had severe distress (Silverman score 7-10) (Table 1).

Table 1: Demographics and clinical characteristics of the neonates.

Parameter	Value
Gestational age (weeks) mean±SD	31.5±1.8
Mean birth weight (grams) mean±SD	1450±320
Gender, N (%)	
Male	68 (68)
Female	32 (32)
Mode of delivery, N (%)	60 (60)
Vaginal	35 (35)
Caesarean section	65 (65)
Apgar score at 5 minutes <7	18 (18)
Silverman score, N (%)	65 (65)
Mild (0-3)	65 (65)
Moderate (4-6)	30 (30)
Severe (7-10)	5 (5)

The mean age at initiation of bubble CPAP (bCPAP) was 0.82±0.33 hours. The initial CPAP pressure was maintained at a median of 5 cm H_2O (range, 5–6 cm H2O). The mean duration of bCPAP therapy was 72.12±18.54 hours. At the start of treatment, the mean FiO_2 requirement was 40.82±15.76%, which decreased to 25.65±10.32% by 72 hours. Successful bCPAP therapy, defined as avoidance of mechanical ventilation, was achieved in 72% of neonates, while 28% required intubation and mechanical ventilation due to therapy failure. The results were shown in Table 2.

Among the neonates, apnea requiring intubation was the most common complication (12%), followed by nasal trauma (10%) and bronchopulmonary dysplasia (8%). Pneumothorax occurred in 5%, and mortality was observed in 6% of cases. The results were shown in Table 3.

Neonates with successful bCPAP had a significantly higher mean gestational age (32.45±1.62 weeks) and birth weight (1500±280 grams) compared to those who failed (30.28±1.95 weeks and 1320±340 grams, respectively; p<0.01). The duration of NICU stay was significantly shorter in the successful group (15.87±4.12 days) versus the failed group (22.76±6.45 days, p<0.001). Incidence of bronchopulmonary dysplasia (BPD) (4% and 18%; p=0.02) and mortality (1.4% versus 18%; p=0.001) were also significantly lower among successful bCPAP neonates compared to failures (18% and 18%; p<0.05). The results were shown in Table 4.

Table 2: Bubble CPAP therapy parameters among the neonates.

Parameter	Value
Mean age at bCPAP initiation (hours)	0.82±0.33
Initial bCPAP pressure (cm H_2O) median (range)	5 (range 5–6)
Duration of bCPAP (hours) mean±SD	72.12±18.54
FiO_2 requirement at start (%) mean±SD	40.82±15.76
FiO_2 at 72 hours (%) mean±SD	25.65±10.32
Successful bCPAP (no mechanical ventilation), n (%)	72 (72)
bCPAP failure (needed intubation), n (%)	28 (28)

Table 3: Complications observed during bubble CPAP therapy.

Complication	Number of neonates (n)	Percentage
Nasal trauma	10	10
Pneumothorax	5	5
Apnea requiring intubation	12	12
Bronchopulmonary dysplasia	8	8
Mortality	6	6

Table 4: Comparison of outcomes between successful and failed bCPAP neonates.

Parameter	Successful bCPAP (n=72)	Failed bCPAP (n=28)	P
Gestational age (weeks) mean±SD	32.45±1.62	30.28±1.95	<0.001[a*]
Birth weight (grams) mean±SD	1500±280	1320±340	0.004[a*]
Duration of NICU Stay (days) mean±SD	15.87±4.12	22.76±6.45	<0.001[a*]
Incidence of BPD (%), N (%)	3 (4)	5 (18)	0.02[b*]
Mortality (%), N (%)	1 (1.4)	5 (18)	0.001[b*]

NICU: Neonatal intensive care unit; BPD: bronchopulmonary dysplasia; a: unpaired Student's t test; b: Chi square test; *indicates significance (p<0.05)

In this study, 94% of neonates survived to discharge, while 28% required mechanical ventilation following bCPAP failure. The average length of hospital stay was 17.45±5.12 days. A small proportion (3%) of neonates were

readmitted within 28 days after discharge. The results are shown in Table 5.

Table 5: Neonatal outcome in the present study.

Outcome	Values
Survived to discharge, N (%)	94 (94)
Required mechanical ventilation (after bCPAP failure), N (%)	28 (28)
Length of hospital stay (days, mean±SD)	17.45±5.12
Readmission within 28 days, N (%)	3 (3)

DISCUSSION

RDS continues to be a predominant cause of morbidity and mortality in preterm neonates, particularly those born before 34 weeks of gestation.[12] This condition primarily results from pulmonary surfactant deficiency and the structural immaturity of the lungs, leading to alveolar collapse and impaired gas exchange, which necessitate respiratory support. The advent of non-invasive ventilation strategies, especially bubble bCPAP, has marked a paradigm shift in managing RDS, aiming to reduce the morbidity associated with invasive mechanical ventilation.

In this prospective observational study involving 100 preterm neonates between 28 and 34 weeks of gestation, early initiation of bCPAP demonstrated a high success rate of 72%, defined by avoidance of invasive mechanical ventilation within the first 72 hours of life. This aligns well with previous studies that have reported successful outcomes ranging from 60% to 80% when bCPAP is employed early in the course of respiratory distress. In a study by Al-Lawama et al the success rate of bCPAP is 93.7%, which is comparatively higher than in our study. In another study done by Arora et al the success rate of bCPAP is 69.4%.[8,13]

Our study cohort had a mean gestational age of 31.5±1.8 weeks and a mean birth weight of 1450±320 grams, reflecting a population vulnerable to surfactant deficiency and RDS. The male predominance (68%) observed is consistent with established knowledge that male neonates have a slightly higher risk of respiratory complications due to delayed lung maturation, often referred to as the "male disadvantage" in neonatal outcomes. The predominance of cesarean deliveries (65%) may be related to obstetric indications frequently associated with preterm births and could have implications for early respiratory adaptation, although this was not specifically analyzed. In a study conducted by Kachare et al 14 60.67% of the neonates were males, and 49.33% of the neonates weighed between 1.59 and 2.49 kg.[14]

Clinical severity assessment using the Silverman Anderson score revealed that 65% of neonates presented with mild respiratory distress (scores 0–3), while 35% exhibited moderate to severe distress. Early application of bCPAP in mild to moderate cases likely contributed to the relatively high success rate observed. The mean time to initiation of bCPAP was notably prompt at 0.82±0.33 hours post-birth, emphasizing the critical role of early respiratory support before progression to severe respiratory failure. In a study conducted by Manandhar, the mean age for initiating bCPAP was 8.05±26.03 hours.[15]

Physiological parameters such as initial CPAP pressure (median 5 cm H_2O) and FiO_2 requirements (mean 40.82±15.76%) were within accepted norms for neonatal respiratory support. The reduction in FiO_2 to 25.65±10.32% by 72 hours illustrates adequate oxygenation and lung recruitment achieved through bCPAP, preventing excessive oxygen exposure and its associated risks, such as retinopathy of prematurity. The mean duration of bCPAP therapy (72.12±18.54 hours) aligns with the expected time course for surfactant production to improve and lung compliance to normalize in preterm neonates. In a study conducted by Ezenwa et al, the mean duration of bCPAP was 5±3.3 days.[16]

Complications related to bCPAP were relatively low but notable. Apnea requiring intubation was the most frequent (12%), followed by nasal trauma (10%), pneumothorax (5%), and bronchopulmonary dysplasia (BPD) (8%). These findings are consistent with other reports, reflecting the known risks associated with non-invasive ventilation in fragile neonates. The incidence of pneumothorax is particularly relevant as a potential adverse effect of positive airway pressure; however, the 5% rate observed is within acceptable limits and highlights the importance of vigilant monitoring. The 8% incidence of BPD is encouragingly low, supporting the lung-protective effects of early bCPAP by reducing ventilator-associated lung injury, a major risk factor for chronic lung disease in this population. Likewise, in a study done by Shayani et al the incidence of BPD in neonates undergoing bCPAP was 7.7%.[16]

The subgroup analysis comparing successful versus failed bCPAP therapy revealed critical insights. Neonates who failed bCPAP had significantly lower gestational age (30.28±1.95 weeks) and birth weight (1320±340 grams) compared to those who succeeded (32.45±1.62 weeks and 1500±280 grams, respectively). These findings reaffirm that lower maturity and smaller size are key risk factors for bCPAP failure, necessitating alternative or adjunctive interventions such as early surfactant therapy or invasive ventilation. The failed group also had significantly longer NICU stays (22.76±6.45 days versus 15.87±4.12 days), higher incidences of BPD (18% versus 4%), and increased mortality (18% versus 1.4%), emphasizing the vulnerability of this subgroup and the clinical importance of timely escalation of respiratory support. Likewise, in a study done by Arora et al the incidence of mortality was higher in neonates who had CPAP failure as compared to the successful bCPAP neonates (26.9% versus 0%; p=0.002).[18]

The overall mortality rate of 6% in the cohort is consistent with outcomes in similar tertiary care centers. Likewise, a study by Balaji et al found an 8% incidence of mortality in bCPAP neonates. The high survival to discharge rate of 94% highlights the effectiveness of early bCPAP in improving survival in preterm neonates with RDS. Additionally, only 3% of neonates were readmitted within 28 days, suggesting stable post-discharge respiratory status and adequate clinical follow-up.[17]

Limitations

The study's observational design and lack of a control group limit the ability to make causal inferences. The single-center setting may affect generalizability, and variations in clinical protocols between centers could influence outcomes. Additionally, long-term neuro-developmental outcomes were not assessed, which is a crucial consideration for this vulnerable population.

CONCLUSIONS

In conclusion, early initiation of bubble CPAP is an effective and safe strategy for managing RDS in preterm neonates between 28 and 34 weeks of gestation. It successfully avoids mechanical ventilation in the majority, reduces complications, and improves survival, especially in moderately preterm infants. These findings underscore the potential benefits of adopting early bCPAP protocols, particularly in resource-limited settings where access to invasive ventilation and surfactant therapy may be limited.

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