International Journal of Medicine
pISSN 1468-3814 | eISSN 2667-7008
https://theinternationalmedicine.com/

Original Research Article *DOI: 10.61336/im/26-3-78*

Early Use of Bubble Continuous Positive Airway Pressure in Neonates with Respiratory Distress: A Prospective Observational Study

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Received: January 10, 2026
Revised: February 16, 2026
Accepted: February 26, 2026
Published: March 26, 2026

Abstract

Background: Respiratory distress is one of the most common causes of neonatal morbidity and mortality, particularly in resource-limited settings where access to mechanical ventilation may be limited. Bubble continuous positive airway pressure (bCPAP) is a non-invasive, cost-effective respiratory support modality that helps maintain functional residual capacity and reduce work of breathing in neonates. ***Aim:*** To observe the efficacy of bubble CPAP in respiratory distress in neonates. ***Objectives:*** To evaluate the efficacy of bubble CPAP in neonates with respiratory distress in terms of morbidity and mortality outcomes. ***Methods:*** This cross-sectional observational study was conducted in the Department of Paediatrics at MGM Medical College and LSK Hospital, Kishanganj, Bihar, over a period of two years (January 2021–December 2022). A total of 100 neonates with respiratory distress were enrolled. Bubble CPAP was initiated in neonates with Downes score 4–6 or oxygen saturation <85% despite supplemental oxygen. Clinical parameters including cyanosis, respiratory rate, grunting, chest retractions, and air entry were recorded using the Downes score. Outcomes included survival, CPAP failure, and mortality. Statistical analysis was performed using paired t-tests and logistic regression. ***Results:***Out of 100 neonates treated with bubble CPAP, 74 survived and were discharged, while 26 died. Significant improvement was observed in all respiratory parameters between day 0 and day 3 ($p<0.0001$). The mean Downes score decreased from 6 on day 0 to 2.46 on day 3. Survival was higher in neonates weighing >1.5 kg (87%) compared to those <1.5 kg. Respiratory distress syndrome had a survival rate of 84% with CPAP therapy. ***Conclusion:*** Early use of bubble CPAP significantly improves respiratory parameters and survival in neonates with respiratory distress. It represents a cost-effective and practical alternative to mechanical ventilation in resource-limited settings.

Keywords: Bubble CPAP, Neonatal respiratory distress, Non-invasive ventilation, Downes score, Neonatal mortality

INTRODUCTION

Respiratory distress is one of the most common causes of admission to neonatal intensive care units (NICUs) and contributes significantly to neonatal morbidity and mortality worldwide. The burden is particularly high in developing countries where access to advanced neonatal care and ventilatory support systems is limited. Reports from the National Neonatal Perinatal Database in India indicate that respiratory disorders account for a substantial proportion of neonatal morbidity and mortality.1

Respiratory distress in the newborn is clinically characterized by tachypnea (respiratory rate >60 breaths per minute), chest retractions, nasal flaring, grunting, cyanosis, and reduced air entry. These signs indicate impaired pulmonary gas exchange and increased work of breathing in neonates. Early recognition and appropriate respiratory support are essential to improve neonatal outcomes. Continuous positive airway pressure (CPAP) is an important modality in the management of neonatal respiratory distress syndrome (RDS). CPAP provides continuous distending pressure to the airways of spontaneously breathing neonates, thereby preventing alveolar collapse and maintaining functional residual capacity. This leads to improved oxygenation and reduced work of breathing.2

CPAP can be delivered using various interfaces such as nasal prongs, nasopharyngeal tubes, or face masks, and the pressure can be generated using ventilator-derived systems, bubble circuits, or dedicated CPAP drivers.[3] Among these techniques, bubble continuous positive airway pressure (bCPAP) has emerged as an effective non-invasive respiratory support method for neonates with respiratory distress. In bubble CPAP systems, the expiratory limb of the breathing circuit is submerged

under water to generate positive end-expiratory pressure. The bubbling produced by gas flow creates oscillatory pressure variations that may enhance alveolar recruitment and improve gas exchange. This mechanism helps maintain functional residual capacity and reduces the work of breathing in neonates with respiratory distress.[3]

Bubble CPAP is considered a gentle mode of respiratory support and can be used to manage a variety of neonatal respiratory conditions including respiratory distress syndrome, transient tachypnea of the newborn, meconium aspiration syndrome, and congenital pneumonia. Early use of CPAP has been shown to reduce the need for invasive mechanical ventilation and improve neonatal outcomes.[4,5]Mechanical ventilation, although lifesaving in severe cases of respiratory distress, is associated with several disadvantages including higher cost, need for specialized equipment and trained personnel, and complications such as bronchopulmonary dysplasia and ventilator-induced lung injury. Consequently, non-invasive ventilation strategies have gained increasing importance in neonatal care.[1]

Bubble CPAP offers several advantages in resource-limited settings. It is relatively simple, cost-effective, and easier to implement compared with conventional mechanical ventilation. Studies from developing countries have demonstrated that low-cost bubble CPAP systems can significantly improve neonatal survival and reduce the need for invasive ventilation.6,7

Furthermore, CPAP therapy has been shown to improve oxygenation and clinical outcomes in neonates with respiratory distress when implemented appropriately in neonatal units.8 Given its effectiveness and affordability, bubble CPAP has become an important component of neonatal respiratory care, particularly in low- and middle-income countries. Therefore, the present prospective study was undertaken to evaluate the efficacy of bubble CPAP in neonates with respiratory distress and to assess its impact on morbidity and mortality outcomes.

MATERIALS AND METHODS

Study Design

This study was a hospital-based cross-sectional observational study conducted to evaluate the efficacy of bubble continuous positive airway pressure (bCPAP) in neonates presenting with respiratory distress.

Study Setting

The study was carried out in the Department of Paediatrics at M.G.M. Medical College and L.S.K. Hospital, Kishanganj, Bihar.

Study Duration

The study was conducted over a period of two years, from January 2021 to December 2022.

Study Population

Neonates admitted to the neonatal ward with respiratory distress during the study period were considered for inclusion in the study.

Sample Size

A total of 100 consecutive neonates presenting with respiratory distress were enrolled in the study.

Inclusion Criteria

Neonates meeting the following criteria were included in the study:

- All neonates admitted with clinical features of respiratory distress
- Neonates with respiratory distress due to conditions such as:
- Respiratory distress syndrome (RDS)
- Transient tachypnea of the newborn (TTN)
- Apnea of prematurity
- Birth asphyxia
- Meconium aspiration syndrome (MAS)
- Congenital pneumonia or sepsis
- Neonates without significant cardiovascular instability and with normal electrocardiographic findings

Exclusion Criteria

Neonates with the following conditions were excluded from the study:

- Recurrent apneic episodes not responding to bubble CPAP
- Upper airway abnormalities such as cleft palate, choanal atresia, or tracheoesophageal fistula
- Congenital diaphragmatic hernia
- Severe cardiovascular instability
- Severe ventilatory impairment (pH <7.25 and $PaCO_2$ >60 mmHg)

Data Collection

After obtaining approval from the Institutional Ethics Committee and informed consent from parents or guardians, eligible neonates were enrolled in the study. Baseline demographic and clinical data including birth history, maternal risk factors, type of delivery, gestational age, birth weight, and need for resuscitation were recorded. All neonates were examined clinically and assessed for respiratory distress using the Downes score, which includes evaluation of cyanosis, chest retractions, grunting, air entry, and respiratory rate.

Indications for Initiation of Bubble CPAP

Neonates were initiated on bubble CPAP under the following conditions:

- Downes score between 4 and 6
- Oxygen saturation (SpO_2 <85%) despite supplemental oxygen

Bubble CPAP Administration

Bubble CPAP was delivered using a Fisher and Paykel bubble CPAP system through short nasal prongs placed in both anterior nares and secured appropriately.

Initial CPAP Settings

- FiO_2: 0.6–0.8
- Flow rate: 5–10 L/min
- CPAP pressure: 4–6 cm H_2O initially, increased in increments of 2 cm H_2O up to a maximum of 10 cm H_2O to achieve oxygen saturation of 85–90%.

All neonates were managed under radiant warmers using servo-controlled skin mode. FiO_2 was adjusted to maintain oxygen saturation between:

- 88–94% in neonates <1.5 kg
- 92–94% in neonates ≥1.5 kg

Monitoring

Neonates receiving bubble CPAP were monitored using the following parameters:

- Continuous pulse oximetry for oxygen saturation and heart rate
- Clinical assessment of respiratory distress using Downes score
- Chest radiography for diagnosis of underlying respiratory conditions
- Laboratory investigations including complete blood count, micro-ESR, peripheral smear, blood glucose, urea, creatinine, electrolytes, and blood culture where indicated

Blood pressure was monitored using non-invasive methods. Hypotension (mean BP <30 mmHg) was managed with plasma expanders and dopamine infusion when required.

Weaning from Bubble CPAP

Weaning from CPAP was initiated when:

- Respiratory distress improved with Downes score <3
- Arterial blood gas parameters were within normal limits

FiO_2 was gradually reduced in increments of 0.05 to maintain oxygen saturation above 85%. When FiO_2 decreased to ≤0.5, CPAP pressure was reduced in increments of 2 cm H_2O. CPAP was discontinued when pressure reached <3 cm H_2O with FiO_2 <0.4.

Definition of CPAP Failure

CPAP failure was defined as:

- Persistent oxygen saturation <85% despite optimal CPAP support
- Increasing Downes score (>6)
- Recurrent apnea or poor respiratory effort

Neonates with CPAP failure were shifted to intermittent positive pressure ventilation (IPPV).

Outcome Measures

The primary outcomes assessed were:

- Successful weaning from CPAP and discharge
- CPAP failure requiring mechanical ventilation
- Mortality

Secondary outcomes included duration of CPAP therapy and complications associated with CPAP use.

Statistical Analysis

Data were analyzed using appropriate statistical methods. Continuous variables were expressed as mean ± standard deviation. Changes in respiratory parameters such as cyanosis score, respiratory rate, grunting, air entry, chest retractions, and total Downes score were evaluated using paired t-tests. Logistic regression analysis was performed to determine factors associated with mortality. A p-value <0.05 was considered statistically significant.

RESULTS

During the study period, 2812 neonates were delivered at the study hospital. Among them, 102 neonates (3.6%) developed respiratory distress and required admission to the neonatal intensive care unit (NICU). Eighteen neonates were excluded from the study due to severe respiratory distress at admission, unstable cardiovascular status, or refractory seizures. Therefore, 100 neonates fulfilling the inclusion criteria were enrolled and treated with bubble continuous positive airway pressure (bCPAP).

Baseline Characteristics

Among the 100 neonates included in the study, 39 were males and 61 were females, giving a male-to-female ratio of approximately 1:1.56. This is shown in Table 1.

Table 1: Sex Distribution of Study Population

Sex	Number (n=100)	Percentage
Male	39	39%
Female	61	61%

The mean birth weight of the neonates was 2217 g, with a range from 800 g to 4000 g. Birth weight had an important influence on survival outcomes. Neonates with birth weight ≥1.5 kg had a higher survival rate (87%) compared with those weighing <1.5 kg (72%). With respect to gestational age, 34 neonates were preterm, 51 were term appropriate for gestational age (AGA), and 15 were term small for gestational age (SGA). This is shown in Table 2.

Table 2: Birth Weight Distribution and Outcome

Birth Weight	Survived	Expired	Survival Rate
<1.5 kg	16	6	72%
≥1.5 kg	68	10	87%

Preterm neonates showed a survival rate of 79%, while survival among term AGA and SGA neonates was 72% and 66%, respectively. This is shown in Table 3.

Table 3: Survival According to Gestational Age

Category	Total	Survived	Expired	Survival Rate
Preterm	34	27	7	79%
Term AGA	51	37	14	72%
Term SGA	15	10	5	66%

Etiology of Respiratory Distress

The most common cause of respiratory distress in the study population was birth asphyxia, followed by respiratory distress syndrome (RDS). The highest survival rate was observed in neonates with respiratory distress syndrome (84%), while sepsis-associated respiratory distress showed the highest mortality.

This is shown in Table 4.

Table 4: Causes of Respiratory Distress and Outcomes

Cause	Total Cases	Survived	Expired	Survival Rate
Birth Asphyxia	53	40	13	75%
Respiratory Distress Syndrome	32	27	5	84%
Meconium Aspiration Syndrome	7	4	3	57%
Sepsis / Bronchopneumonia	6	3	3	50%
Apnea of Prematurity	2	2	0	100%

Efficacy of Bubble CPAP

The primary aim of the study was to assess the efficacy of bubble CPAP in neonates with respiratory distress. Clinical response to CPAP therapy was evaluated using the Downes score, which assesses cyanosis, respiratory rate, chest retractions, grunting, and air entry. At the initiation of CPAP therapy, the mean Downes score was 6, indicating moderate respiratory distress. Following initiation of bubble CPAP therapy, there was a marked improvement in respiratory status. By Day 3 of treatment, the mean Downes score had decreased to 2.46, indicating significant clinical improvement. All components of the Downes score demonstrated statistically significant improvement following bubble CPAP therapy ($p < 0.001$). This is shown in Table 5.

Table 5: Change in Downes Score After Bubble CPAP

Parameter	Mean Score Day 0	Mean Score Day 3	p-value
Cyanosis	0.91	0.32	<0.001
Respiratory Rate	2.00	0.71	<0.001
Grunting	0.99	0.51	<0.001
Air Entry	0.95	0.54	<0.001
Chest Retractions	1.15	0.49	<0.001
Total Downes Score	6.00	2.46	<0.001

Clinical Outcomes

Out of the 100 neonates treated with bubble CPAP, 74 neonates were successfully weaned and discharged, while 26 neonates died, giving an overall survival rate of 74%. The mean duration of CPAP therapy was 28 hours, ranging from 6 to 72 hours. Among the neonates who failed CPAP therapy, 21 deteriorated within the first 24 hours, while 9 neonates initially improved but later required mechanical ventilation after 24 hours due to worsening respiratory distress. This is shown in Table 6.

Table 6: Overall Outcome of Bubble CPAP Therapy

Outcome	Number	Percentage
Survived	74	74%
Expired	26	26%

Complications of Bubble CPAP

Complications related to bubble CPAP therapy were minimal. The most common technical difficulty encountered was displacement of nasal prongs, which required repositioning during treatment. Mild nasal mucosal ulcerations healed

without permanent sequelae. Importantly, no cases of pneumothorax or oxygen toxicity were observed. This is shown in Table 7.

Table 7: Complications Observed During CPAP Therapy

Complication	Number	Percentage
Nasal mucosal ulceration	4	4%
Gastric distension	6	6%
Transient hypotension	2	2%
Pneumothorax	0	0%

DISCUSSION

The present study evaluated bubble continuous positive airway pressure (bCPAP) in 100 neonates with respiratory distress, achieving an overall survival rate of 74% and a statistically significant reduction in all components of the Downes score by day 3 ($p < 0.001$). Respiratory distress remains one of the most common causes of neonatal NICU admission and mortality, particularly in resource-limited settings where access to mechanical ventilation is restricted.1,2 bCPAP maintains functional residual capacity by delivering continuous distending pressure to the airways of spontaneously breathing neonates, thereby preventing alveolar collapse and reducing the work of breathing.9 The oscillatory pressure variations generated by the bubbling mechanism may additionally enhance alveolar recruitment and gas mixing.3

Birth asphyxia was the most common aetiology (53%), followed by RDS (32%), MAS (7%), and sepsis/bronchopneumonia (6%). This pattern reflects intrapartum and peripartum risk factors characteristic of resource-limited settings and differs from high-income countries where RDS predominates as the primary indication for CPAP.1,4 RDS had the highest survival rate (84%), consistent with the established pathophysiological basis for CPAP in surfactant-deficient lung disease,9 while sepsis-associated respiratory failure had the poorest outcome (50%), attributable to haemodynamic compromise and systemic organ dysfunction that extends beyond the respiratory compartment.10 The 57% survival in MAS reflects the mechanically complex nature of airway obstruction and chemical pneumonitis, which can limit CPAP efficacy by promoting gas trapping.11

The mean total Downes score decreased from 6.00 at initiation to 2.46 by day 3 ($p < 0.001$), with significant improvement across all individual parameters — cyanosis, respiratory rate, grunting, air entry, and chest retractions. These findings are consistent with published data from similar LMIC cohorts.6,7 Early use of nasal CPAP has been shown to reduce the requirement for invasive mechanical ventilation in preterm neonates, as demonstrated by the COIN trial,12 and the SUPPORT trial, which confirmed that early CPAP was non-inferior to intubation and surfactant with a lower rate of intubation in extremely preterm infants.13 Among neonates who failed bCPAP in the present study, 21 deteriorated within the first 24 hours and were escalated to IPPV, consistent with the defined failure criteria of persistent $SpO_2 < 85\%$, Downes score > 6, or recurrent apnoea.3

Survival was significantly higher in neonates weighing ≥1.5 kg (87%) compared to those <1.5 kg (72%), reflecting the increased vulnerability of very low birth weight neonates to surfactant deficiency, thermoregulatory compromise, and limited physiological reserves.4,6 Preterm neonates showed a survival rate of 79%, while term SGA neonates had the lowest survival at 66%, likely attributable to the sequelae of chronic placental insufficiency, including compromised pulmonary reserve and haemodynamic instability. The beneficial effect of antenatal corticosteroids in accelerating fetal lung maturation and reducing RDS severity in at-risk preterm births is well established and remains a key upstream intervention.14

The complication profile of bCPAP was minimal in the present study. Gastric distension occurred in 6% of neonates and nasal mucosal ulceration in 4%, both managed conservatively. No pneumothorax was recorded. This is consistent with the established safety profile of bCPAP in low-resource environments.6,7 Rezzonico et al. demonstrated a significant reduction in the need for mechanical ventilation following systematic introduction of low-cost bubble nasal CPAP in a developing-country NICU.6 Dewez and van den Broek similarly concluded that bCPAP is effective and implementable without resource intensification in LMICs.7 The use of nasal CPAP in children with hypoxaemic pneumonia in resource-limited settings has also been reported to achieve meaningful clinical improvement.8 In the present study, the mean CPAP duration was 28 hours, and the overall low complication rate underscores the suitability of bCPAP for wider implementation in secondary-level NICUs in low- and middle-income countries, particularly where mechanical ventilation infrastructure is unavailable or prohibitively expensive.

Limitations

This study had several limitations. It was conducted at a single center with a relatively small sample size (n=100), which may limit the generalizability of the findings. The observational design without a comparison group

prevented direct comparison with other respiratory support modalities such as conventional oxygen therapy or mechanical ventilation. Additionally, advanced physiological monitoring and long-term follow-up outcomes such as neurodevelopmental status and chronic lung disease were not assessed.

Future Directions

Further multicenter prospective studies with larger sample sizes are needed to confirm the effectiveness of bubble CPAP in diverse neonatal populations. Comparative studies evaluating bubble CPAP against other non-invasive respiratory support modalities may help identify optimal treatment strategies. Future research should also assess predictors of CPAP failure and long-term neonatal outcomes, including neurodevelopmental and pulmonary status.

CONCLUSION

Early initiation of bubble continuous positive airway pressure (bCPAP) is an effective and safe non-invasive respiratory support modality for neonates with respiratory distress. It significantly improves respiratory parameters and survival while maintaining a low complication rate. Given its simplicity, affordability, and effectiveness, bubble CPAP represents a practical alternative to mechanical ventilation, particularly in resource-limited settings.

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